ECONOMIC IMPACTS OF CLIMATE CHANGE AND ADAPTATION POLICY IN MALAYSIA

NAZNEEN JABIN

THESIS SUBMITTED IN FULFILMENT
OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

FACULTY OF ECONOMICS AND ADMINISTRATION
UNIVERSITY OF MALAYA
KUALA LUMPUR

2015

ORIGINAL LITERARY WORK DECLARATION

Name of Candidate: Nazneen Jabin (I.C/Passport No: AE7946929)

Registration/Matric No: EHA100024

Name of Degree: Doctor of Philosophy

Title of Project Paper/Research Report/Dissertation/Thesis ("this Work"):

Economic Impacts of Climate Change and Adaptation Policy in Malaysia

Field of Study: Environmental Economics

I do solemnly and sincerely declare that:

(1) I am the sole author/writer of this Work;
(2) This Work is original;
(3) Any use of any work in which copyright exists was done by way of fair dealing and for permitted purposes and any excerpt or extract from, or reference to or reproduction of any copyright work has been disclosed expressly and sufficiently and the title of the Work and its authorship have been acknowledged in this Work;
(4) I do not have any actual knowledge nor do I ought reasonably to know that the making of this work constitutes an infringement of any copyright work;
(5) I hereby assign all and every rights in the copyright to this Work to the University of Malaya ("UM"), who henceforth shall be owner of the copyright in this Work and that any reproduction or use in any form or by any means whatsoever is prohibited without the written consent of UM having been first had and obtained;
(6) I am fully aware that if in the course of making this Work I have infringed any copyright whether intentionally or otherwise, I may be subject to legal action or any other action as may be determined by UM.

Candidate's Signature Date:

Subscribed and solemnly declared before,

Witness's Signature Date:

Name:

Designation:

ABSTRACT

Malaysia is experiencing some unusual combination of droughts and extreme rainfall in recent years. As a consequence, crop production is likely to fall significantly in the years to come. There is hardly any strategy i.e. a*daptation policy* in effect to cope with this issue. The impacts and costs of adaptation measures cannot be optimally determined on a global basis as they can vary from region to region, between countries or even within a country. Moreover, due to the lack of adequate quantitative adaptive models, the economic impacts, effectiveness, and cost assessment for adaptation policies cannot be ascertained. The study of cost effectiveness for adaptation action is necessary for the government to formulate an appropriate adaptation policy. Given the absence of existing measures, this study develops a quantitative adaptive model termed the Malaysian Climate and Economy (MCE) model based on the dynamic Computable General Equilibrium (CGE) model structure to examine the climate change impacts of the adaptation policy and identify the macroeconomic influences on the overall economy. As agriculture is the most vulnerable sector to climate change, we focus our study on this particular sector and analyse its impacts on specific crops (sub sectors) within the agriculture sector. This study seeks to determine the long-term and optimal adaptation measures by comparing the adaptation cost versus the economic losses due to climate change in Malaysia. Our findings indicate that the optimum level of adaptation varies over time with continued economic growth and the costs of adaptation tend to increase as well. Findings show that over the hundred year projection period, the optimum level of adaptation tends to be within the range of 13 to 34 percent of gross damages. The associated costs of adaptation varies from 32 million to 1,735 million ringgits. This indicates that the optimal adaptation policy is effective for Malaysia in terms of reducing the negative impacts of climate change (i.e. in terms of monetary damages). The findings indicate that benefits of adaptation policy are almost seven times the cost of adaptation for each time segment. Using this optimal adaptation information, we suggest policy choices for the national policy framework (i.e. Malaysian National Policy on Climate Change, 2009) so that the government can achieve an optimal adaptation decision to better manage the adverse consequences of climate change. Such actions and measures are adjudicated to assure cohesive participation of all concerned development bodies including government and non-government organisations along with local communities towards achieving the appropriate climate change response.

ABSTRAK

Malaysia kini mengalami kombinasi iklim kemarau dan hujan yang ekstrem. Perubahan cuaca tersebut boleh menjejaskan kualiti hasil tanaman dan agrikultur. Selain itu, ia turut mengurangkan produktiviti hasil tanaman tersebut pada masa hadapan. Sehubungan ini, tiada sebarang polisi adaptasi yang telah diperkenalkan untuk menangani isu tersebut. Kos dan impak dalam mengaplikasikan polisi ini adalah tidak tentu dan berbeza mengikut kawasan dan negara yang berlainan atau dalam setiap negara. Di samping itu, kos dan keberkesanan polisi tersebut serta kesan ekonomi dalam mengimplimentasikan polisi ini, tidak dapat ditentukan akibat kekurangan model adaptasi yang kuantitatif. Oleh yang demikan, kajian yang mendalam tentang kos pengadaptasian adalah penting untuk melaksanakan polisi ini. Ia juga membantu pihak kerajaan untuk menjana polisi adaptasi yang optimal. Kajian penyelidikan ini telah menghasilkan model adaptasi yang kuantitatif iaitu “Malaysian Climate and Economy” (MCE) model berdasarkan struktur model “Computable General Equilibrium” (CGE) untuk mengkaji kesan perubahan iklim dalam polisi adaptasi serta mengetahui kesan faktor-faktor makroekonomi terhadap ekonomi negara. Oleh kerana sektor agrikultur adalah sektor yang paling sensitif terhadap perubahan iklim, ia merupakan fokus utama dalam kajian ini. Selain itu, kami juga turut menjalankan analisis untuk mengetahui kesan hasil tanam-tanaman yang tertentu (sub-sektor) dalam sektor ini. Justeru, objektif kajian ini adalah untuk mengenalpasti tindakan atau langkah-langkah jangka panjang adaptasi yang optimal melalui perbandingan kos adaptasi dan kejatuhan ekonomi dari segi kerugian yang disebabkan oleh perubahan iklim di Malaysia. Hasil kajian ini telah menunjukkan bahawa paras optimal adaptasi akan berubah mengikut jangka masa tertentu dengan pertumbuhan ekonomi serta kos adaptasi tersebut juga turut meningkat. Selain itu, hasil kajian ini juga menunjukkan bahawa sepanjang tempoh unjuran seratus tahun, tahap optimum adaptasi tersebut mempunyai kecenderungan untuk berada dalam lingkungan 13 sehingga 34 peratus daripada keluaran kasar. Kos berkaitan dengan adaptasi berada dalam lingkungan antara 32 juta hingga 1,735 juta ringgit. Hasil penyelidikan ini menunjukkan bahawa dasar adaptasi (penyesuaian) optimum mempunyai kesan yang positif di mana Malaysia dapat mengurangkan kesan negatif akibat perubahan iklim (iaitu dari segi kerugian kewangan). Di samping itu, kajian ini menonjolkan manfaat polisi adaptasi iaitu hampir 7 kali ganda daripada kos adaptasi bagi setiap segmen masa. Dengan menggunakan maklumat adapatasi optimum ini, kami mencadangkan beberapa dasar untuk merangka kerja dasar negara (iaitu Dasar Malaysia mengenai Perubahan Iklim, 2009) supaya kerajaan dapat mencapai keputusan yang optimum mengenai adapatasi untuk mengurangkan kesan-kesan negatif akibat perubahan iklim. Langkah-langkah rangka kerja adaptasi seperti ini diperlukan untuk memastikan kerjasama daripada semua badan-badan berkanun dan jabatan pembangunan yang berkenaan termasuk organisasi kerajaan dan bukan kerajaan bersama-sama dengan masyarakat ke arah mencapai respons yang sesuai berkaitan perubahan iklim.

ACKNOWLEDGEMENTS

This research is dedicated to my friends and family for permission and assistance they extended to me in my journey to pursue the doctoral degree. This work would not have been a reality without the support of my teachers, co-researchers, administrative staffs, family and friends to whom I must express my gratitude and indebtedness.

I want to thank my supervisors for their invaluable, agreeable guidance and contribution in my doctoral process which has been a satisfying learning experience.

I wish to thank and pay my respect to my supervisors Dr. Fatimah Binti Kari and Dr. Abul Quasem Al Amin for their endless support and guidance and I consider myself privileged to be one their students.

I must acknowledge and thank some of my very special friends Madinah, Juliana and Govin who helped me by providing their joyful companionship and endless support during this period of learning.

I am also deeply indebted to my sisterly friend Rabeya Jesmin for her unconditional support that enabled me to focus and progress on my studies.

Finally, I want to thank my husband Dr. Mohammed Ziaur Rahman, whose skills and commitment as a researcher and learner have been a great inspiration to me. His love and passion helped me throughout my studies to achieve the goal. Special thanks should go to my understanding son Furqan Tanzilur Rahman, whose sweet smiles recharged me at the end of the day to continue further. I also want to thank my beloved parents for being role models in my academic achievement and for showering me with blessings and affection throughout the smooth and difficult times in my life.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1: INTRODUCTION

1.1 Overview

Climate change is among the most serious global concern on environmental issues (DFID, 2002). It is a major global challenge not only due to the predictable rise in temperature and sea levels, but also due to its associated impacts on the social, ecological, and economic systems. It is a complex phenomenon with profound impacts on virtually every aspect of life on earth. Therefore, climate change demands research from multiple dimensions and disciplines to identify the appropriate policies to reduce its negative impacts. The Inter-governmental Panel on Climate Change (IPCC) has undoubtedly confirmed the human contribution to climate change and projected further climatic changes throughout this century (Pacala et al., 2001). Social and economic activities cause Green-House-Gas (GHG) emissions. These emissions result in a new atmospheric composition that is different from the current composition of the GHGs. These circumstances accelerate changes in the ecological process, which in turn induces further climatic changes. This is a continuous and cyclic process and highlights the symbiotic relationship between the environment and economic activities.

From the schematic framework outlined in Figure 1.1, it is clear that the impacts of climate change on natural and human systems are already evident and have the potential to disrupt economic activities including agriculture, industry and services. A large number of people may fall subject to migration and relocation due to extreme weather events. Therefore, climate change is highly associated with the well-being of the population of a country.

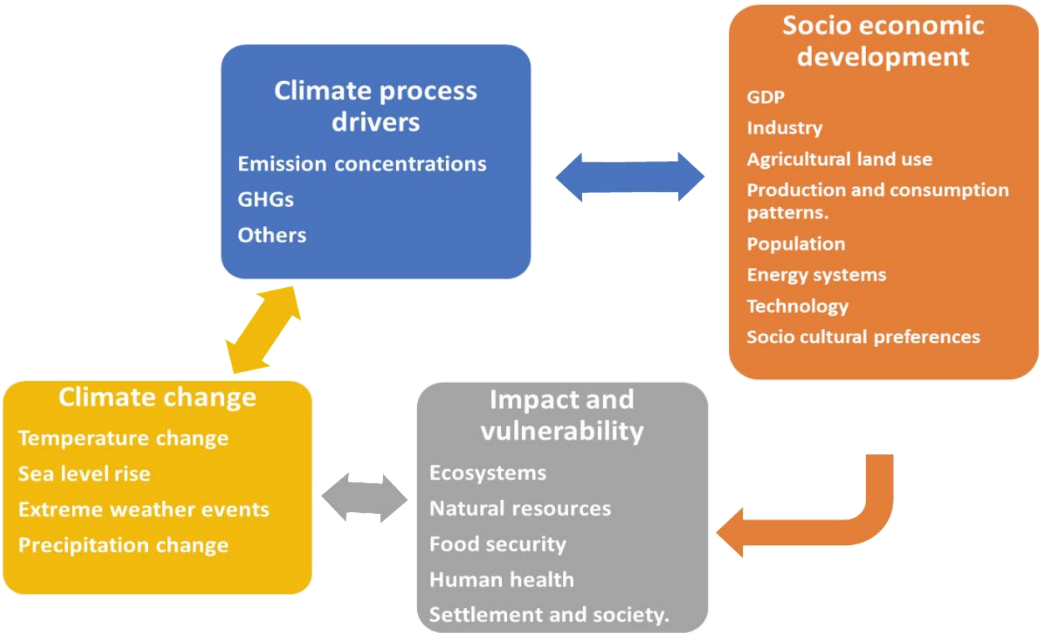


Figure 1.1: Climate change schematic framework

Strategies to adjust under changed climate conditions and minimise human contribution to climate change by reducing emissions are two effective ways to counter this problem. A suitable policy can greatly reduce the adverse effects of climate change and thereby improve the future conditions that may further decelerate the overall climate change process.

1.2 World Trends

The imminent effects of climate change will be gradually felt all over the world. According to the US National Oceanic and Atmospheric Administration (NOAA), during the last twenty years the average world temperature level increased by 0.32 degree Celsius, CO_2 emission was about 398 ppm, deforestation was about 740 million acres, 1.3 million people died from natural hazards, and, 4.4 billion people were directly affected by climate change. As estimated by the Climate vulnerable forum and the DARA group, the monetary value of this loss was over 1.2 trillion US dollars in 2010 (DARA, 2012).

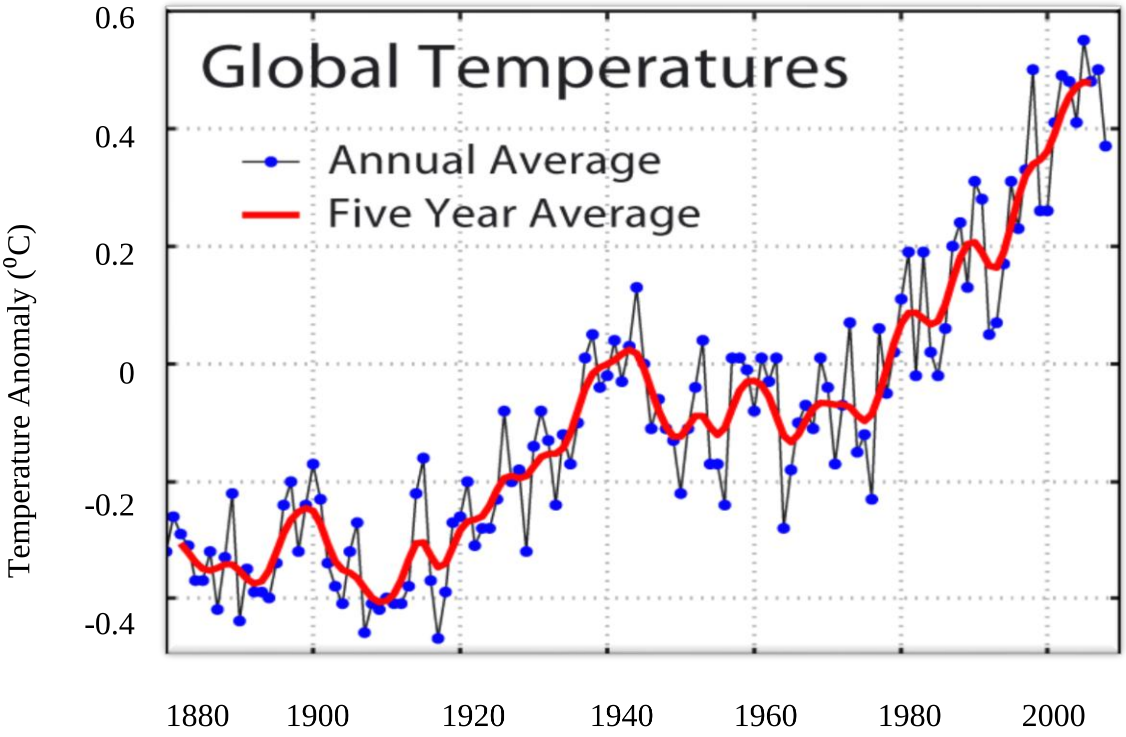


Figure 1.2: Global average surface temperature anomaly

Source: Change (2007)

Figure 1.2 shows that the global average temperature has increased by 0.7°C in the past 100 years. It signifies that the temperature is rising at a slow but steady rate. Future projections estimate that the temperature will rise at a faster rate because the GHG emissions are increasing which is playing a big role in further accelerating the climatic change.

Table 1.1 shows the projected global average surface warming and sea level rise by the end of the 21st century. This scenario reveals noteworthy challenges for the reason that an increase in global average temperature beyond 2°C is internationally recognised as a ‘dangerous’ situation. Typically, an increase in temperature by 3°C compared to the present level will reduce the world’s gross annual income by about 3% (Pearce, 2003; Pearce et al., 1996).

Table 1.1: Projected Global Average Surface Warming
and Sea Level Rise at the End of the 21st Century

Case	**Temperature Change** (^{0}**C at 2090-2099 relative to 1980-1999)**		**See Level Rise** **(m at 2090-2099 relative to 1980-1999)**
	Best Estimate	*Likely range*	*Model-based range excluding future rapid dynamical changes in ice flow*
Constant Year 2000 concentrations	0.6	0.3 – 0.9	N/A
B1 scenario	1.8	1.1 – 2.9	0.18 – 0.38
A1T scenario	2.4	1.4 – 3.8	0.20 – 0.45
B2 scenario	2.4	1.4 – 3.8	0.20 – 0.43
A1B scenario	2.8	1.7 – 4.4	0.21 – 0.48
A2 scenario	3.4	2.0 – 5.4	0.23 – 0.51
A1FI scenario	4.0	2.4 – 6.4	0.26 – 0.59

Source: IPCC Fourth Assessment Report (Pachauri & Reisinger, 2007)

The Inter-governmental Panel on Climate Change (IPCC) estimates highlight the significant relationship between temperature change and the global output (GDP). Figure 1.3 depicts that climate change monetary damage as a percentage of global outputs will increase with rising temperature levels according to both global and regional integrated climate and economy models (DICE 2007, RICE 1999).

From these IPCC estimates, a 4°C temperature increase will cause a loss of 5% of the GDP. It is an alarming situation for the whole world, but the impacts can vary for different countries depending on the geographical location, and current environmental and socio-economic conditions.

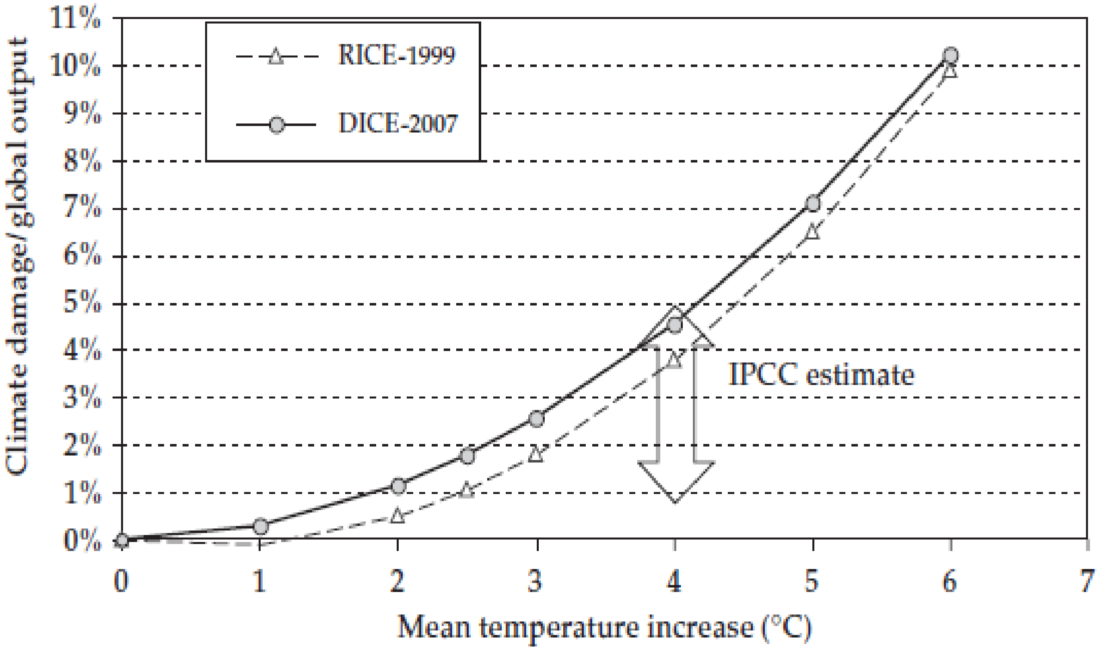


Figure 1.3: Relationships between global mean temperature rise and the monetary value of climate damage

Source: Pachauri and Reisinger (2007)

The impacts of changes in climatic parameters (especially for the case of rising temperature) depend on the present weather conditions. For example, countries in cool temperate regions are likely to benefit from global warming while countries in hot and warm temperate regions are likely to suffer from increased temperature (Mendelsohn, Dinar, & Williams, 2006; Schelling, 1992). In addition, the impacts will be noticeably different among different sectors of a country. To assess the costs and benefits of climate change adaptation policy at a local or country level, it is essential to build a comprehensive model specific to the region and to match with the local economic structure. The growing risk of climate change related damages demands strong as well as appropriate measures and actions from policymakers so as to adapt to the changed climatic conditions and minimise the risk. For instance, in 2008 the German government has devised "German Adaptation Strategy to Climate Change" (in German terms, Bundesregierung, 2008) to reduce the climate change vulnerability and increase the adaptive capability (Arndt & Volkert, 2011). Moreover, policymakers are accountable to validate the effectiveness of these projects to their electorates. Therefore, economic impacts as well as cost-benefit analysis of intended adaptation actions are to be performed prior to suggesting an adaptation policy specifically at the local levels.

1.3 Climate Change Trends in Malaysia

The Climate Change Vulnerability Index (CCVI) was developed on the basis of 42 social, economic and environmental factors for 170 countries. These factors comprise the form and frequency of natural disasters, sea-level rise, and social, environmental and economic indicators such as population, natural resources, economic status, dependency on vulnerable sector (specially the agricultural sector) etc. According to CCVI, some countries are extremely vulnerable while some belong to medium or low risk zones. Malaysia falls in the medium risk zone as per CCVI ranking due to the relatively moderate changes in temperature, rainfall, and sea level rise in this region.

In Southeast Asia, the temperature has increased at an average value of 0.15°C to 0.25°C per decade during the past 100 years (Pachauri & Reisinger, 2007). Moreover, an increasing rate of change has been observed during the later decades - specifically during the last 35 years. The observed temperature increase per decade was about 0.4°C in different places of Malaysia during the last four decades (Tangang, Juneng, & Ahmad, 2007).

Subject to different emission levels, the future climatic change - especially temperature increase for this region is projected to be around 6°C by the end of this century (Solomon, 2007). In the case of Malaysia, Juneng, Latif, and Tangang (2011) have estimated that by the end of this century, the average surface temperature will rise by 3-5°C compared to that of the last century.

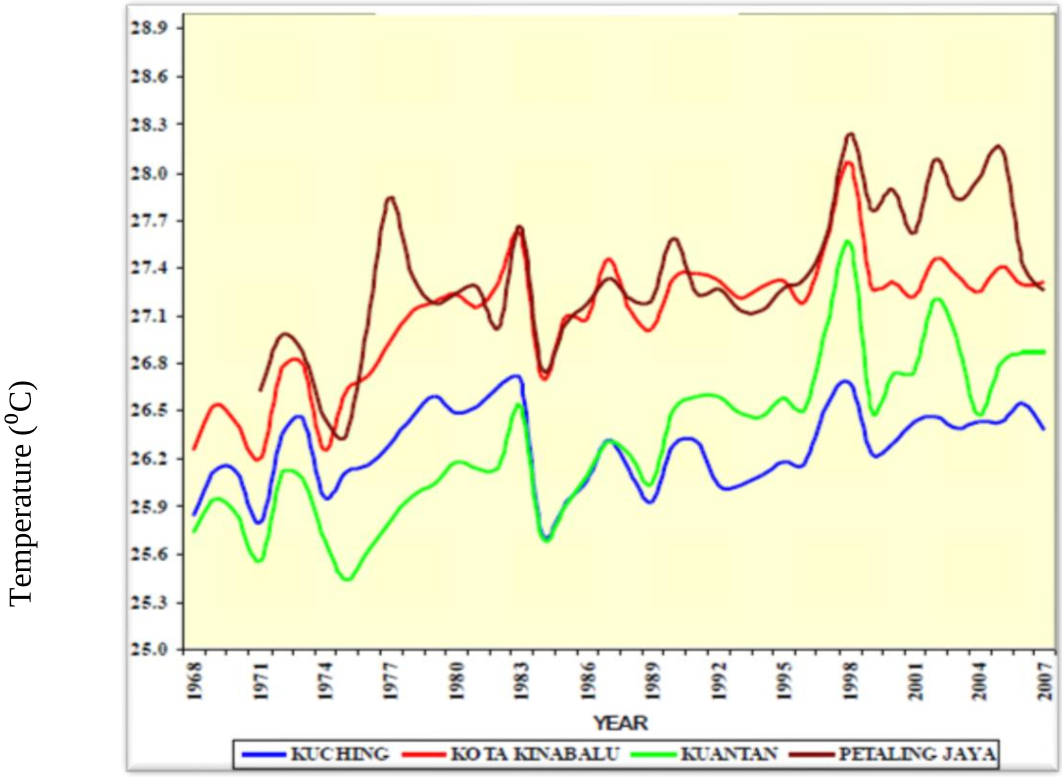


Figure 1.4: Annual mean temperature trends of the four meteorological stations in Malaysia

Source: Juneng et al. (2011)

Figure 1.4 shows the annual average temperature trends in key regions of east and west Malaysia. The IPCC designed A1B scenario shows that the projected average surface temperature for Malaysia will be around 29-30°C by the end of this century. Malaysia will also suffer from the changes in rainfall and sea level over the next hundred years as predicted in Table 1.2.

Table 1.2: Climate Variability Conditions for Malaysia in the Next 100 Years

Temperature increase	• 0.7°C to 2.6°C
Rainfall variations	• -30% to 30%
Sea level rise	• 15cm to 95cm

Sources: Adopted from Baharudin (2007); (Chong, 2000)

This highlights the fact that there are significant challenges for Malaysia ahead as an average temperature increment over 2°C is the internationally established ‘dangerous’ limit. According to Al-Amin, Leal, de la Trinxeria, Jaafar, and Ghani (2011), climate change will bring “Loss of land through sea level rise and associated salinisation” for Malaysia.

Climate change involves more than environmental issues in Malaysia. It will also adversely affect economic growth and human wellbeing. Taking into account the gravity of this matter, the Malaysian National Policy on Climate Change was developed in 2009. The main objectives of the policy are:

I. Judicious management of the available resources,
II. Enhanced environmental conservation, and
III. Strengthening institutional and implementation capacities to minimise negative impacts of the climate change.

This adaptive policy was based on the principles of sustainable development, coordinated implementation, effective participation and common but differentiated responsibilities. However, implementation of such a policy is a big challenge due to the lack of proper scientific research regarding costs and benefits of such adaptive policies. This study intends to investigate whether such adaption policies will be beneficial and to what extent for a developing country like Malaysia so that the government can implement an appropriate adaptation policy.

1.4 Problem Statement

Impacts of climate change can be felt far beyond the place of origin. It can create conflicts and rivalry over resources and responsibilities among countries. Realizing the gravity of this situation, the earth summit was held at Rio De Janeiro, Brazil, in 2012 focusing on two fundamental themes:

a) Poverty alleviation and sustainable development for introduction and implementation of green economy, and
b) Infrastructural development to enhance sustainable growth.

Proper assessment of the impacts of climate change under different actions to reduce the climate change vulnerabilities is a necessary condition for any climate resilience project to be successful. Researchers and policymakers need to think about these issues separately as the impact of climate change can vary from region to region, between countries, and even within a country. This is also true for different sectors of the economy for a country. Due to continued climate variability in addition to extreme events, the agricultural sector have to adopt more innovative measures beyond the traditional changes (OCCIAR, 2011). Table 1.3 depicts some possible impacts of climate change on the agricultural sector.

Table 1.3: Physical Impacts of Climate Change on Agriculture

Climate Change Factors	**Possible Impacts**
Increasing temperature	• Decreased crop yields due to heat stress and increased rate of evapo-transpiration • Increased livestock deaths due to heat stress • Increased outbreak of insects, pests and diseases
Rainfall variations	• Increased frequency of drought and floods causing damages to crops • Changes in crop growing seasons • Increased soil erosion resulting from more intense rainfall and floods
Sea-level rise	• Loss of arable lands • Salinisation of irrigation water

Source: Adapted from ADB (2009)

These physical losses have their own economic consequences. Figure 1.5 describes the inter-linkages between climate change impacts and economic parameters such as productivity and food security.

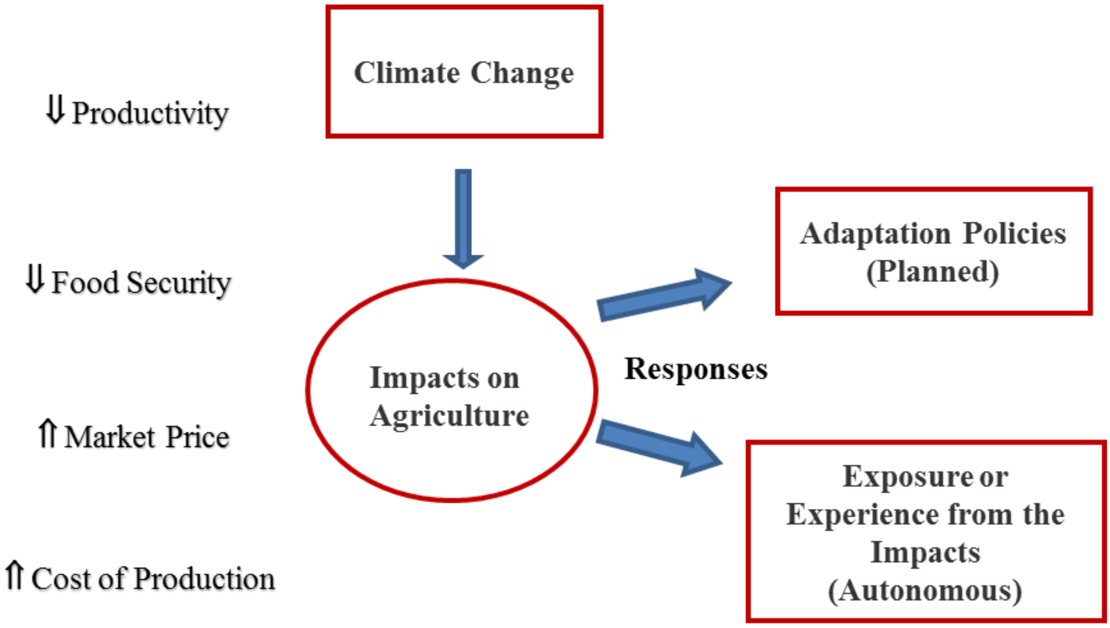


Figure 1.5: Economic impacts of climate change on agricultural sector with possible policy responses

It shows that, with the changing climate, agricultural productivity as well as food security will diminish. As a result, market price and costs of production will increase. The adaptation policy response may be autonomous (by farmers) or planned (by govt. or policymakers).

There are two basic strategies to cope up with the negative impacts of climate change, which are *i*) Mitigation and *ii*) Adaptation.

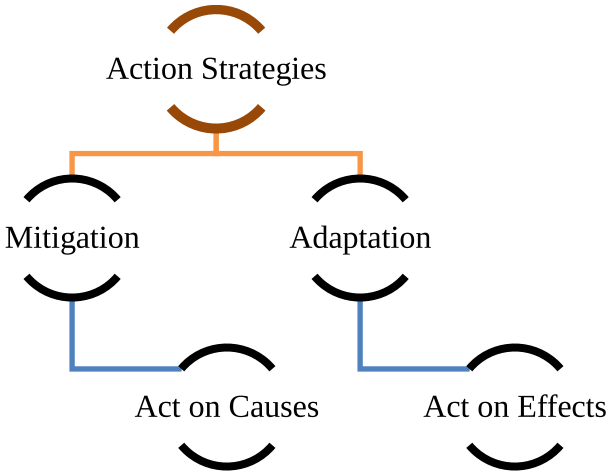


Figure 1.6: Action strategies to reduce the climate change impacts

Figure 1.6 shows these impact oriented action strategies. The "Mitigation" action tries to mitigate the degradation of climate change accelerating activities such as to take measures to reduce GHG emissions. This means that mitigation is an act to reduce the activities that causes faster climate changes. On the other hand, "Adaptation" tries to adapt under changed conditions as the earth systems are inherently adaptable and evolutionary.

Progress in reducing emissions through mitigating policies is often frustrating as it has a direct consequence on the economic growth of a country and hampers progress due to lack of alternatives for consistent economic development. For a country like Malaysia, a mitigation policy cannot be fruitful without coordination with much bigger countries especially neighbouring countries who should also adopt commensurate mitigating policy to make it successful as a whole. Furthermore, regardless of how much mitigation is achieved or will be achieved, the climate is already changing and significant change is anticipated in the coming decades due to the past emissions of GHGs. Therefore, adaptation has drawn more focus in actual discussions, and it has been recognised that more serious effort has to be made on this front in order to reduce vulnerability to the changing environment.

In one sense, the fact that human society can and does adapt to climatic changes has implications for understanding the true impacts of climate change and for devising optimal climate change strategies under given uncertainty. Alternatively, given that some level of climate changes are inevitable, it is necessary to think about and act on adaptation beforehand. Consequently, adaptation has emerged as an appealing approach to address the impacts of climate changes that are already evident in some regions. But this course of action has not always been considered relevant with science and policy (Klein, Nicholls, & Thomalla, 2003). Sometimes adaptation by changing practices alone is feasible to some extent, but otherwise it incurs significant cost for changing systems such as infrastructure. Therefore, governments and non-government organisations often work independently or collaboratively to solve the problem within their limited capacity of implementing suitable adaptive measures.

With this background, the cost-benefit analysis for adaptation actions is necessary for devising appropriate adaptation policy. This study investigates whether from economic perspective adaptation action is beneficial or not for Malaysia considering the associated costs. It also introduces ideas and concepts to achieve long-term solutions of the climate change problems so that the government can introduce an efficient adaptation framework to reduce the adverse consequences related to climate change.

To summarise, this study seeks solutions to the following problems.

a) Impacts and costs of climate change measures cannot be optimally determined on a global basis as the impacts can vary from region to region; between countries or even within a country (Hunt & Watkiss, 2011). Therefore, it is necessary to assess the feasibility of adaptation plans so that appropriate adaptation actions can be opted for a specific country.

b) The impacts of climate change can individually affect each and every sectors of an economy. Agriculture is one of the most vulnerable sectors as it is directly dependent on weather conditions. This is also the most important sector as it is directly related to poverty reduction, food security, and economic development. Agriculture accounts for approximately 33% of annual GHGs emissions worldwide (Matthews et al., 2000). Compared to 1997, a 70% increase in GHGs emissions is reported for Malaysia in 2005. For Malaysia where agriculture is a significant contributing factor, a decline of yield between 4.6 - 6.1% per 1°C temperature increment is found under the present CO_2 level (Singh et al., 1996). Therefore, it is necessary to consider the role of adaptation and assess the vulnerability of agriculture to climate change.

c) Appropriate adaptation actions can greatly reduce the magnitude of the impacts of climate change. Existing knowledge regarding adaptive capability and adaptation options are not sufficient. Therefore, there is a lack of reliability of the future projections of adaptation policy and its associated costs in terms of monetary value (B. Smith, Burton, Klein, & Wandel, 2000).

1.5 Research Questions

The study endeavours to answer the following research questions:

a) Which level of adaptation is optimal for Malaysia?

b) What will be the estimated cost of adaptation for Malaysia?

c) How does this adaptation affect the agricultural sector in particular and on the economy as a whole?

1.6 Objectives of this Study

The general aim of this study is to analyse how Malaysia could counter balance the negative impacts of climate change. Thus, this study investigates the adaptation choices as an alternative for Malaysian climate policy and their comparative dimensions to reduce future impacts and vulnerabilities of the agriculture sector. To this end, this study proposes the following specific objectives:

a) To determine the optimal level of adaptation for a period of one hundred years since 2005.

b) To estimate the climate change adaptation cost for associated optimal adaptation levels of objective (*a*).

c) To examine the impacts of climate change and adaptation policies on the agricultural sector as well as on the overall economy.

For the quantification of the economic impacts of optimum adaptation options with its associated costs, we develop a computable general equilibrium (CGE) model for the Malaysian economy. Since our special focus is on the agricultural sector, we disaggregated this into 11 subsectors and consider the impacts on each subsector individually.

1.7 Significance of the Study

The ultimate contribution of this study is to reveal the macroeconomic effects of adaptation policies on the Malaysian economy. Specifically, this study enhances the current knowledge for:

1. Setting up a long-term national climate change adaptation policy framework for Malaysia in response to the Malaysian National Policy on Climate Change (2009).
2. Filling up the research gap by finding the distribution of impacts of the costs of adaptation of different crops subsectors for the agricultural sector.
3. Creating guidelines for policymakers in the macroeconomic measurement unit with precise knowledge of the overall impacts of the adaptive measures.

Although the ultimate target groups are principally Malaysian policymakers, however, a wide range of people and organisations are expected to benefit due to the general nature of the scientific outcome of this research.

1.8 Limitations

Although CGE modelling offers comprehensive solutions to numerically estimate important economy-wide effects associated with policy, there are a few weaknesses and limitations of this approach. The weakness of CGE models is that their results are implicitly linked to the assumptions and calibrations of the model. In contrast to macro-econometric models, CGE models can only be used for simulation purposes but not for forecasts. Another disadvantage of general equilibrium studies compared to sectoral models is that, following the top-down approach, CGE models typically lack a detailed bottom-up representation of the production and supply side.

1.9 Thesis Structure

In chapter one, we presented an overview of the current and future climate change scenarios and their probable impacts on the economy in general and on the agricultural sector. We have clarified our objective, which is to investigate the cost effectiveness of the adaptation policies on the Malaysian economy. We also clarified the significance of this study and revealed our limitations. In chapter two, we present a brief introduction on Malaysian policies for climate change adaptation. In chapter three, we discuss background literatures and published results from previous studies in related fields. In chapter four, we discuss the basic features of the CGE model, theoretical and conceptual frameworks, and methodology of this study. In chapter five, we present our findings which are discussed in chapter six. Chapter seven concludes the study with policy recommendations.

CHAPTER 2: OVERVIEW OF MALAYSIAN CLIMATE CHANGE AND POLICY RESPONSES

2.1 Introduction

Malaysia is situated in Southeast Asia. Its land is geographically divided between peninsular Malaysia constituting two third of the landmass and northern part of the Borneo Island constituting the rest of the country. Malaysia has land borders with Thailand (506 km), Indonesia (1,782 km), Brunei (381 km), and Singapore. It has a maritime border with Vietnam across the South China Sea (United Nation Development Program, 2009). It possesses 329,847 square km of tropical forest (corresponding to 63.6% of its total land) located on a central mountainous range. The states in Borneo Island are mostly constituted by coastal plains having a hilly and rocky interior. The lowest point of Malaysia is located in the Indian Ocean (0 m) whereas the highest point is located in Gunung Kinabalu (4,100 *m*). The country has a total shoreline of 4,675 km of which 2,607 km is in East Malaysia and 2,068 km is in Peninsular Malaysia. According to UN, the population of Malaysia is 26.6 million as of 2009, and the population density is 80.6 people per km^2 (Austin & Baharuddin, 2012). The annual population growth was approximately 1.7% during the 2005 to 2010 period. As for the age structure, 29.8% of the population is below 15 years of age, 15.7% is 60 years and older, and 45.5% is between 15 and 60 years. Approximately 69.6% of the population live in urban areas. According to the Economic Planning Unit data (2008), Malaysia's multicultural and multi-ethnic population comprises Malays (50.4%), Chinese (23.7%), Indians (7.1%), indigenous people (11%) and others (7.8%) (Austin & Baharuddin, 2012). Approximately 5.1% of the households were living below the poverty line in 2002.

2.2 Characteristics of the Malaysian Climate

Climate change does not merely involve environmental issues but is felt across many different sectors including economic growth and human well-being (Pereira & Subramniam, 2007). Malaysia is a tropical country and its climate is characterised by uniform temperature, high humidity and abundant rainfall throughout the year. The South China Sea separates the West/Peninsular Malaysia and East Malaysia by a distance of 640 kilometres. The average temperature for Malaysia is 26 degree Celsius and humidity is 80 percent. The temperature varies between 21 to 32 ºC in the coastal region and 13 to 27 ºC in the highlands. Annual average rainfall is within 200 to 250 cm having the wet period of October-March (northeast monsoon season) and the dry period of May-September (south-west monsoon season).

Seasonal variations are minor for Malaysia and are noticeable by rainfall patterns: the north-eastern rainy season takes over between November to March, distributing moisture and rain, while between June to September, the south-western monsoon winds prevail. In Peninsular Malaysia, rainfall variations are observed in three geographic regions: the eastern coastline states, the southwest shoreline zone, and the other remaining areas. These three areas have common dry months of June and July, while differences arise in the wet season of October to November that observes high rainfall throughout west Malaysia. The geography of Sarawak and Sabah is not systematic in regards to rainfall patterns. More than 355 cm of rainfall is recorded per year in the wetlands. Considering temperature distribution, the annual variation of the daily average temperature is roughly between 2°C to 3°C while the diurnal variation may be as large as 12°C. The average temperature in the low-lying areas ranges between 26°C and 28°C (Malaysian Meteorological Department, 2009).

2.3 Climate Change and Malaysian Experience

Extreme weather events along with climate variability are a threat not only for the livelihood but also for the economy of a country. Historically, low income sectors such as agriculture and fisheries are mostly vulnerable due to their dependency on weather for productions.

Malaysia experienced rapid economic growth and transformed into an industrial economy during the late 20th century. It has now entered into the third phase of economic development with an immense development focus in the service sector. The Industrial Master Plan (IMP3) was adopted to further transform the country into a major trading hub by 2020 (vision 2020). However, the plan raises the following three major concerns.

i. Is this growth sustainable for the current and forthcoming population?
ii. What is the environmental cost associated with this development?
iii. Will this process of development expedite the adverse effects of climate change?

Since many specific circumstances may arise due to the climate change, the measurable extent of the climate change is determined by logging, periodic fires, water pollution, air pollution, human activity etc. Among tropical nations, deforestation is highest in Malaysia. The country’s annual deforestation rate has shown a marked increase of 86% between the years 1999–2000 and 2000-2005. More specifically, Malaysia lost an average of 140,200 hectares of its forests or 0.65% of its total forest area every year since 2000, whereas in the 1990s, the country lost an average of 78,500 hectares or 0.35 percent of its forests annually. There are three major contributing factors that causes this high rate of deforestation in Malaysia which are widespread urbanisation, agricultural fires and conversion of the forests into palm oil plantations. Consequently, the sustainability of forest management is being contradicted by the environmental organisations and the local timber firms. In this case, environmental organisations accuse local timber firms for ineffective sustainable forest management. Continuous forest fires have burned thousands of hectares of forests in Malaysia and particularly in Malaysian Borneo. Apart from causing air pollution, the haze originating from these kinds of fires affects individual health and wellbeing. Furthermore, Malaysia's water supply is also undiversified and creates imbalances in supply during flood and drought seasons. It could pose a substantial threat to public health due to food-water-borne, vector-borne and diarrheal diseases (Husaini, 2007).

Many rivers of Malaysia are seriously polluted due to the discharge of untreated sewage. Specially, the west coast of the Peninsular Malaysia is the most polluted area (Abdullah, 1995). On average, metropolitan areas of Malaysia produce 1.5 million tons of solid waste per year. However, the country has 580 cubic km of water, of which 76% is used for agricultural activities and 13% is used for industrial activities.

The industrial sector is one of the major contributors to green-house gas (GHG) emissions. By year 2030, these emissions are estimated to rise more than 50 percent due to rising level of energy consumption in Asia (UNEP, 2006). Human intervention poses a significant threat to the Malaysian natural environment. Agriculture, forestry and urbanisation contribute to the destruction of forests, mangroves and other thriving ecosystems in the country and landscapes are dramatically altered by human development activities such as construction of dams, administration of rivers, building road networks etc.

Rising temperature due to global warming is a significant concern for Malaysia. Agriculture is one of the key economic sectors that is most vulnerable to climate change (Pearson, Nelsonc, Crimp, & Langridge, 2011). However, the agricultural output of some countries may indeed increase due to climate change and decrease for others depending on the geographical location and adaptive capacity of the corresponding countries. Countries whose agricultural activities circulate close to the limits of the heat tolerance and moisture availability are most likely to be negatively affected by the climate change (I. Burton & Lim, 2005).

The major agricultural production components of Malaysia are comprised of commodity tree crops (mainly for export), rice and livestock (mainly for domestic consumption), and fruits and vegetables (both for export and domestic consumption). Climate variation will exceed environmental thresholds in consideration of Malaysia's natural endowments. The habitats and ecosystems may not at all recover to the existing equilibrium conditions under changed circumstances. A redistribution of species is expected respective to the lowland and upland forest habitat causing significant losses in biodiversity in the worst possible scenario (NRE, 2011).

Air pollution and the greenhouse effect are the principal causes of the climate change, which are initiated by the emissions of the greenhouse gases. Sea level rise is also a major threat for low-lying areas near the shorelines of Sabah and Sarawak.

2.4 Policymaker's Engagement in Response to the Impacts of Climate Change

Malaysia is one of the vulnerable countries to climate change. The adverse impacts of climate change are direct threats to livelihood and agricultural sustainability. A prudent adaptation policy is crucial to adapt to these changes. Based on localized socio-economic and geographical status, different countries follow different adaptation policies. Malaysia is actively involved with the climate change community to reduce GHG reductions. It is also focused on climate change adaptation needs though at a far lesser extent. Climate change adaptation came into focus since Malaysia’s Second National Communication (NC2) to the United Nations Framework Convention on Climate Change (UNFCCC). The Regional Climate Change Adaptation Knowledge Platform for Asia, also known as the Adaptation Knowledge Platform (AKP) is behind the drive for climate change adaptation. The AKP was initiated due to the demand for effective sharing of information on climate change adaptation, and to develop adaptive capacities of the Asian countries.

The terminology ‘unknown until known’ best reflects the current approach of Malaysia on how the impacts of climate change are to be viewed and acted upon, indicating that measures are reactive rather than proactive. Often, climate change responses are formulated due to Malaysia’s international obligations and commitments rather than its own interest. The three conventions playing a key role here are:

i. United Nations Framework Convention on Climate Change (UNFCCC),;
ii. United Nations Convention on Biological Diversity (CBD); and
iii. United Nations Convention to Combat Desertification (CCD).

The Kyoto Protocol of the UNFCCC which was ratified from an international treaty signed in 1992, assigned mandatory emission limitations to its signatories for the reduction of greenhouse gas emissions. The objective was to stabilise atmospheric greenhouse gas concentrations at a level that could prevent dangerous anthropogenic interference within the climate system. Malaysia is a signatory of the UNFCCC and supports the Kyoto Protocol. At present, Malaysia being a developing nation has no quantitative commitments under the Protocol. However, the climate is changing and

Malaysia like all other nations will have to face the adverse impacts of climate change unless appropriate actions are taken. Therefore, climate change impacts must be considered by Malaysia as part of its growth factor. However, being a UNFCCC member, Malaysia is bound to formulate, undertake, publish, and regularly update national level programs and regional programs containing measures to reduce the adverse climatic impacts on the human systems. Many studies have proved that developing nations are more vulnerable to the impacts of climate change but they are facing many constraints to take measures towards reducing emissions. Therefore, adaptation is becoming a growing concern as a way forward for developing countries, including Malaysia.

Malaysia developed a Non-Annex-I party to the UNFCCC on signing the UNFCCC in 1993. As a Non-Annex-I party, it has no obligation to reduce GHGs emissions under the Kyoto protocol. Ensuing the approval of the convention in 1994, policies have been formulated to deal with climate change in Malaysia. Presently, Malaysia accepts a “protective code” and “no guilt” policy, which supports its right to either mitigate or adapt as there are still many scientific doubts regarding climate changes.

Understanding the climate change effects on the budget and the social order as a whole, involves devising necessary inducements for Environmental Management. The Malaysian government has incorporated some incentives to promote environmentally comprehensive and sustainable growth in the 9th and 10th five-year Malaysian plans. The Malaysian government has recognised the lawful and institutional framework for environmental protection. The National Policy on the Environment has objectives such as, sustained cultural, social, and economic progress of Malaysia and improvement of the quality of life of its people, through ecologically balanced and maintainable growth. The objective of the strategy is to achieve a safe, healthy, clean, and productive environmental setting for the current and forthcoming populace through contributing aggressively and efficiently in local and worldwide determinations to environmental preservation and improvement. Nevertheless, there is a large indecision owing to the weak infrastructural capability, inadequate manpower for environmental and adaptation concerns, and a deficiency of authentication of local information (R. M. Adams, Hurd, Lenhart, & Leary, 1998).

Consequently, the climate change adaptation policy implications need to be analysed in order to form a well-organised and successful adaptive structure. To this end, a novel economic representation is essential for the development efforts of Malaysia to join the association of high-income countries. However, it should not ignore the environmental influences of growth. It is therefore essential to assess the conservation endowments for sustainable growth.

The National Climate Change Policy and the National Green Technology Policy (NCCP & NGTP) were adopted in 2009 to report the persistent concerns of climate change. In Malaysia, these policies aiming at implementation of plans towards a low carbon economy and achieve sustainable growth. Furthermore, a RM 1.5 billion Green Technology Financing arrangement was formulated to encourage green technology. The programs were implemented mostly under two broad schemes: i) the Dominant Forest Spine project covering 4.3 million hectares in Malaysian and ii) the Heart of Borneo scheme covering 6.0 million hectares in Sabah and Sarawak. The projects on flood mitigation in urban regions, for example the SMART tunnel and the Sungai Damansara Package 1, handled flooding in these parts (EPU, 2010).

The preservation of biodiversity is also addressed in the 5-year Malaysia Plans, as well as in other plans like the National Wetlands Policy (2004), Environment policy

(2002), National Policy on Biological Diversity (1998), National Urbanisation Plan (2006), National Physical Plan (2005), The National Forestry Act (1984), Environmental Quality Act (1974) and Fisheries Act (1985). These legal frameworks and other sectoral decrees and rules have delivered a basis upon which climate change connected policies and regulations can support sectoral activities (NRE, 2008). The use of the above-mentioned provisions created the background for environmentally aware sustainable development plans and strategies such as the National Policy on Climate Change that was drafted, established, and subsequently altered into accomplishment (NRE, 2010). Emphasis is put on mitigation and to a far lesser degree on adaptation methods.

Noticing that adaptation needs are inescapable, perhaps a unique policy for Malaysia has been formulated following ‘adaptation through climate change mitigation’ and mobilising related non-government and government institutions and bodies, such as the Southeast Asia Disaster Prevention Research Institute, the National Security Council, the United Nations Development Programme, Environmental Management and Climate Change Division, Malaysian Agricultural Research and Development Institute, the Ministry of Natural Resources and Environment (NRE), Environmental Protection Society Malaysia, National Hydraulic Research Institute of Malaysia, the Institute for Environment and Development, Environment and Development, the Malaysian Environmental and the NGOs. Even so, climate change adaptation in Malaysia includes accomplishment by affected society entities, necessitating nationwide, government, native, and community level interactions. Consequently, many of Malaysia’s adaptation reactions are developed pivoting around the notion of better-quality environmental administration, management of water resources, and protecting the agricultural productivity – each with the objective to generate results using the efficient use of the available resources as well as attaining financial benefits for the country and individually for specific communities. For this and many other reasons, less consideration has been given to support autonomous climate change adaptation in practice, and considerable emphasis is put on the evaluation and execution of prearranged policies to attain the above-mentioned goals.

Information regarding climate change adaptation for Malaysia is partially advanced and obtained from the ‘Regional Hydro-Climate Model for Peninsular Malaysia (RegHCMPM)’ which produces weather and hydrological forecasts. Another projection model ‘Producing Regional Climates for Impacts Studies (PRECIS)’ is in use in Malaysia for information sharing and assumptions on climate change influences and adaptation requirements, identification of entry points on how to formulate plans and strategies, and data distribution within and among sectors, and to guide the operations of a policy.

Adaptation at the local level can be reinforced and mobilised by concerned parties and public engagement, and policy cost-efficiency works such as reducing vulnerabilities and the associated costs. In conclusion, Malaysia has the basic information and capability required to initiate climate change adaptation in its growth agenda.

At present, Malaysia is able to engage in climate change effects given its strong environmental management programs which are supported by strong economic policies. An example of such programs include effective poverty eradication program, and, food security and production programs. It should be noted that these efforts are focused on dealing with ‘environmental change threat’ only and do not match the broader ‘climate change threat’. As such, these efforts would not reduce the overall greater climatic threats for Malaysia.

Climate change adaptation in Malaysia demands actions by affected bodies; necessitating nationwide, local governmental, indigenous and public reactions. Hence, many of Malaysia’s adaptation reactions stem from enhanced environment administration, water resource management, and protected farming output – each with a background to improve output efficiency, effective resource usage, and enhanced financial benefits for the overall economy.

The National Steering Committee on Climate Change (NSCCC) was formed within the Ministry of Science, Technology, and the Environment (MoSTE) in 1994. Afterwards, the Ministry of Natural Resources and Environment (NRE) was established on March 27, 2004. The responsibilities of the National Committee was to formulate and mobilise climate change policies including mitigation of GHG emissions and adaptation to climate change by:

i. Drafting a national policy, approach and activity plan to deal and adapt to climate change;
ii. Drafting and synchronising a countrywide operational strategy connected to climate change; and
iii. Drafting and harmonising nationwide action plans to achieve obligations as approved by UNFCCC.

In 2010, the Malaysian government created a National Green Technology and Climate Change Council, chaired by the Prime Minister of Malaysia, to harmonise and ease the application of the National Policy on Climate Change and National Green Technology Policy. Numerous Working Committees rendered support to the council as well as suggesting appropriate adaptation options. A Working Committee on Adaptation was created by the Ministry of Natural Resources and Environment with members from multiple agencies to promote the implementation of adaptation programs at all levels in the country.

International involvement in climate change adaptation is directed through the Environmental and Climate Change Management Division of the Ministry of Natural Resources and Environment (NRE). This involves two-sided and many-sided collaborations, capability enhancement events, sharing data and interacting at countrywide and global levels. The United Nations Development Programme's (UNDP) effort in Malaysia is directed towards the enhancement of a National Capacity Needs Self-Assessment (NCSA) for Global Environmental Management. The objective of NCSA is to classify national level urgencies and requirements for capacity building and enhancement to deal with ecological and conservational concerns through the fulfilment of international commitments and obligations in natural and ecological diversity, climate change, and land degradation. UNDP also provides strategic and innovative policy guidance on climate change and works with relevant government departments and their agencies to strengthen their capacities to address the challenges faced by the country, particularly as they relate to the needs of the poor and disadvantaged people of the country.

The National Hydraulic Research Institute of Malaysia (NAHRIM) was established by the Government of Malaysia as a regional water knowledge hub for water and climate change adaptation in Southeast Asia. It was established in response to the country's increasing number of water-related challenges, including floods, drought events, deteriorating water quality of rivers and coastal bodies, increased usage, erosion, accretion, sedimentation, and last but not least, the anticipated impacts of climate change on water. The Institute for Environment and Development (LESTARI) was established to serve as a reference centre to deal with environment and development issues as well as to assist the government in policy formulation based on a holistic and balanced research on environmental aspects.

The Malaysian Agricultural Research and Development Institute (MARDI) along with various Malaysian universities are currently focused to determine the adaptation needs of Malaysian agricultural sector in a changed climatic context. For example, the University of Malaya - focused on climate-related vulnerability rather than adaptations phases and recently conducted multi-disciplinary research. The particular study titled "Policy Challenges Towards Potential Climate Change Impacts: In search of agro-climate stability" investigated major Malaysian agricultural sectors such as food crops (rice) and cash or industrial crops (palm oil and rubber) under a climatic and economic perspective, quantifying the merits of the projected simulation and presenting an insight into the nature of the overall subject of suitability of adaptation options (Alam, Siwar, & Al-Amin, 2010).

The Planned Activities for Ecological Sustainability (PAES) is formed on a regional level to pursue climate change adaptation requirements of the marine environment through its involvement in Coral Triangle Initiative (CTI). This is highly significant as the global marine and coastal ecosystems capture and store more than 30% of the human originated carbon emissions from the atmosphere through mangrove forests, salt marshes, and sea grass beds; each particularly efficient for capturing and storing carbon.

Degrading and destroying these ecosystems has been observed to damage the adaptive capacity of local users to climate change. Malaysia, as a whole, has developed agreements with the CTI on:

i. Devising objectives, approaches, financing, timelines and actions toward creating the CTI Region-wide Early Action Plan for Climate Change Adaptation (REAP-CCA), and
ii. collaborating on a ‘climate change adaptation sharing policy’ and capacity building in line with finding the common ground where the CTI can stand together on policy issues in regional and global forums, and work toward shared solutions (USAID, 2010).

Efforts are also being taken to ensure sustainable development and management of coastal areas especially to cope up with impacts of climate variability and change, including sea level rise.

Considering the water sector, the majority of Malaysia’s climate change adaptation actions and emphasis has focused on integrated approaches to water management through the introduction of Integrated Water Resources Management (IWRM) plans. Malaysia has also taken measures to strengthen its infrastructure such as the ‘Storm Water Management and Road Tunnel’ (SMART), which largely contributes to mitigating urban flooding of Kuala Lumpur city.

2.5 Adaptation Needs and Priorities

In Malaysia, the majority of climate change related initiatives are focused on mitigation and energy conservation while only a few initiatives focused on adaptation. The national policy on climate change incorporates a more balanced approach to mitigation and adaptation, and indicated more emphasis on adaptation. It is also possible that the ongoing and future development efforts will allow it to fund its own adaptation projects, and as such, the projects presented below may not be the exhaustive list of up-to-date adaptation initiatives.

Currently, Malaysia appears to be implementing only a few number of adaptation projects compared to other developing countries in East and Southeast Asia. The projects we mention here involve partnerships with other neighbouring countries within the Asia-Pacific region. These projects focus on adaptation in the areas of agriculture, water, coastal zones, marine resources, natural resources management, and policy formulation. Funding for these projects has been provided by the Asian Development Bank, Asia-Pacific Network for Global Change Research APN, Global Environment facility (GEF), Southeast Asian Regional Centre for Graduate Study and Research in Agriculture (SEARCA) and the governments of Japan, Sweden and the United States.

In 2010, Malaysia launched its National Policy on Climate Change (NPCC). Although there were several environmental strategies prior to NPCC, this was the first to incorporate a major focus on adaptation and advocated a balanced approach between mitigation and adaptation (NRE, 2009). The NPCC recommended a number of “Strategic Thrusts” or policy objectives and “Key Actions” or means to address the climate change and achieve the policy objectives.

Malaysia faces many of the same adaptation challenges and vulnerabilities of the neighbouring countries, even though it is much advanced and developed than most of its neighbours. It is particularly vulnerable to changes in weather patterns and rainfall variability and intensity being a country dependent on monsoon seasons (MSTE, 2000). While temperatures are projected to rise due to climate change, no significant changes in rainfall patterns or other weather conditions are readily identifiable. The rise in sea level is another common climate change indicator that could have a significant negative impact on the country (MSTE, 2000).

After completing its first National Communication (NC1), Malaysia undertook a series of actions as follows to address its adaptation needs (NRE, 2011).

i. The development of “Regional Hydro-Climate Model for Peninsular Malaysia” - a dynamic climate projection model for west Malaysia;
ii. Introduction of Integrated Water Resources Management (IWRM) to assist in dealing with floods and droughts;
iii. Infrastructural improvement to address flooding of urban areas;
iv. Initiative for the development of drought tolerant varieties of rice, rubber, palm oil and cocoa;
v. Implementation of the Integrated Coastline Management Plans to assist in coastal management; and
vi. A Vector-borne Diseases Control Program (VDCP) to improve the public health.

According to its second National Communications (NC2), released in April 2011, Malaysia identified seven sectors that underwent through vulnerability assessments. These include water resources, agriculture, biodiversity, forestry, coastal and marine resources, energy, and, public health. Both NC1 and NC2 raised concerns about these sectors as follows:

Fresh water resources - Concerns are expressed related to supply, floods and erosion (NRE, 2011). Water resources are already constrained due to increasing demand and, in particular, due to irrigation — which accounts for 83 percent of total water consumption in the country. Prolonged periods of dry season could further threaten the limited water resources (MSTE, 2000).

Agriculture - The potential impact of climate change on key crops, namely palm oil, rice, rubber and cocoa, is a concern (NRE, 2011). Flooding due to rising sea level threatens palm oil production by as much as six percent and rubber production by as much as four percent. Rising temperature is also a major concern for the agricultural sector as it could potentially harm the crop production (MSTE, 2000).

Forest Resources - Mangrove and Mountain forests are expected to be negatively affected by rising rainfall and temperature levels (NRE, 2011).

Coastal and marine management - Sea level rise, higher sea surface temperatures and increasing intensity, duration and frequency of storms are forecasted to occur with adverse consequences (NRE, 2011). Coastal erosion and loss of mangroves also pose as a significant threat for Malaysia (MSTE, 2000).

Energy - Changing climate and extreme weather events are projected to have adverse impacts on the energy production and distribution sector. Increases in ambient temperature reduces power generation capability and put additional stress on the distribution infrastructures (NRE, 2011).

Human health - A central concern is that climate change will help spreading the vector-borne diseases, such as malaria and dengue, and water-borne diseases such as diarrhoea (NRE, 2011).

Some adaptation priorities related to agriculture, forestry and coastal zones were identified in Malaysia’s first National Communication (NC1).

Adaptation actions in the agricultural sector focuses on improving agricultural practices such as increased crop diversity, water management, food storage, and livestock practices. The forestry sector include activities for plantation management, sustainable forest management, and, reduction of forest waste. Water management policies include options for adaptation responses based on the principles of defend, accommodate, retreat, counter attack buyback, and improved coastal management zones. Further adaptation measures and recommendations for these sectors as well as for the rest have been suggested with some detail in NC2.

2.6 Assessment

Malaysia is one of the most developed countries in Southeast Asia and, as such, has considerable internal capacity to evaluate and respond to the impacts of climate change. Similar to its geographical neighbours, the priority areas for adaptation for Malaysia are agriculture, water, coastal protection and forestry. Any direct or indirect climate impacts on agriculture (for example, water shortages affecting irrigation etc.) may have devastating effects on the local economy.

Despite the above-mentioned activities, Malaysia remains far behind in its adaptation programs and activities. This is evident in regard to fulfilling the key policy and governance guidelines as suggested in the National Policy on Climate Change for climate change adaptation/ impact capacity building (NRE, 2009).

Regarding the agricultural sector, the 3rd National Agricultural Policy makes no references to either the climate change threats or to the requirement of adaptation. Regarding rice productions, drought and flood resistant varieties are to be developed and policy and government support for these efforts are yet to be formulated.

Although Malaysia has the basic knowledge and capacity for adaptation actions due to climate change, we first need to understand the economic efficiency of different choices to justify the adaptation actions. The key questions that need to be addressed for proper adaptation measures are to determine the expected cost of climate change if no adaptation measures are taken, the economic cost and benefit of possible adaptation actions, thereby determining the precise cost – benefit ratio. Currently, there is insufficient data on sectoral costs and benefits of adoption at the local level (ADB-UNDP, 2011).

This research empirically investigates whether adaptation actions are beneficial for the Malaysian economy. This study focused on the planned adaptation with the aim to analyse the impacts of climate change adaptation actions, including the cost of adaptation on the different sectors of the economy in general to measure the macroeconomic impacts. This would enable policymakers to formulate economically justified adaptation policies to overcome the adverse consequences of climate change.

CHAPTER 3: LITERATURE REVIEW

3.1 Introduction

Global concerns for global warming came to a peak when the Intergovernmental Panel on Climate Change (IPCC) was awarded the Nobel peace prize for its huge contribution to accumulate and publicise information on human induced climate change, and for gathering scientific knowledge on actions that can reduce the adverse effects of these changes. It is necessary to establish a basis whereby the outcomes of the climate change can be measured in economic terms to facilitate further studies on climate change policies such as to analyse costs and benefits of a particular policy. This chapter investigates the literature on climate change and adaptation policies. We attempt to find the relationship between climate change and agriculture. We focus on the adaptation policies and their effects on the agricultural sector of developing countries in the context of Malaysia. We discuss important issues and their related works on climate change, adaptation and agriculture, to discuss the fundamental issues of this complicated natural phenomena.

This chapter is organised as follows. Section 3.2 refers to the literatures on the impacts of climate change. Section 3.3 broadly discusses literatures on possible actions to reduce the effects of climate change while subsection 3.3.1 and 3.3.2 describes literatures on mitigation policies and adaptation responses respectively. Subsection 3.3.2 also touches on the theoretical background of adaptation to climate change. Section 3.4 discusses literatures on adaptation and agriculture. In section 3.5, we discuss works on the costs of adaptation while section 3.6 focuses on climate change studies in Malaysia. Empirical literature is discussed in section 3.7. We summarise the literature review in section 3.8 and identify gaps in section 3.9.

3.2 Climate Change Impacts

Climate change implies slow but definite change in nature and in the scale of environmental or climatic parameters. For example, globally the average temperature is increasing**.** Global warming is a severe, possibly the most serious, environmental problem human beings have ever faced. The scientific foundation of this phenomenon is sound and well recognised. The difficulty is created by the combustion of fossil (or carbon-based) fuels like coal, oil, and natural gases. The burning of these fossil fuels causes emissions of carbon dioxide gases such as CO_2, methane, nitrous oxide, and halocarbons which are collectively known as Green House Gases (GHGs). They tend to hoard in the atmosphere and remain there for decades to centuries. Higher atmospheric concentrations of GHGs result in surface warming of the land and water. The global warming is further accelerated due to the feedback effects between the land, oceans and atmosphere (Nordhaus, 2007).

This change in climate has a significant link with ozone depletion and other environmental issues like acid rain (Crutzen, Golitsyn, & Mintzer, 1992). In the previous chapter, we identified how climate change is influenced and enhanced by human economic activities through emissions of GHGs. Thus, economic growth is directly associated with some negative impacts of the climate change on human life. More generally, economic growth is adversely related to changes in social harmony and status, economic equilibrium and the environment. Policymakers and international organisations are trying to overcome this problem by taking initiatives to reduce the adverse effects of climate change. International organisations such as IPCC and UNFCCC are working to reduce the impacts of climate change due to human induced worsening of the environment, and to overcome the negative effects through appropriate policies.

3.3 Actions to Reduce Impacts

As we have discussed in chapter 1, there are mainly two policies to reduce the undesirable effects of the climate change: 1) *Adaptation* and 2) *Mitigation*. Climate change policies may comprise of either one or both policies. Before we discuss adaptation policy in detail we briefly introduce mitigation policy of climate change as follows.

3.3.1 Mitigation Policies

Mitigation abates climate change by reducing emissions or capturing carbons. Climate change mitigation consists of those activities that try to restrict the extent of long-term climate change impacts. Climate change mitigation usually includes prior actions to global warming aimed to reduce human (anthropogenic) emissions of greenhouse gases (GHGs). Mitigation can alternatively be realised by increasing the carbon sink capacity, e.g., through reforestation. In comparison, adaptation to global warming are posterior actions aimed to manage the eventual (or unavoidable) effects of global warming, e.g., through construction of dikes in response to sea level rise.

Examples of mitigation include opting for low-carbon energy sources such as renewable and nuclear energy, and building additional "sinks" to eliminate greater amount of carbon dioxide from the atmosphere through actions such as forestation and expansion of green belts etc. Energy efficiency can also play a significant role, i.e., by means of improving the insulation of buildings. Climate engineering is also another method for climate change mitigation.

The key global agreement on climate change is the United Nations Framework Convention on Climate Change (UNFCCC), which was ratified in 2002 with the aim to "prevent dangerous anthropogenic interference with the climate system”. In 2010, parties to the UNFCCC decided to restrict the future global warming below 2.0 °C (3.6 °F) relative to the pre-industrial level. The analysis suggests that achieving the 2 °C goal necessitates to reverse the growing global emission trend by 2020, and continue the decreasing emission trend till 2050 to finally reduce the emission by 30-50% compared to that of the 1990 levels. Investigations by the United Nations Environment Program and International Energy Agency recommended that the present strategies (policies as of 2013) are fairly inadequate to attain the 2°C target.

It needs a strong political motivation to implement the UNFCCC prescribed mitigating policy because of the public goods property of the climate impacts. Therefore, there is little justification to take the mitigating policy for a developing country since the impacts of changing climate are much higher for a developing country.

A newer and possible replacement of Kyoto Protocol reflects the form of achievement and obligations completed at the international level by using any one of the three scenarios (Ott, Sterk, & Watanabe, 2008). The business-as-usual scenario characterises failure to decrease emissions by post-2012 negotiations and locks the world onto a fossil fuel path. On the contrary, an ambitious and effective post-2012 scenario targets significant reduction in emissions by using adequate financial resources affordable to the developed countries and tries to adapt to the climate change from greenhouse gases already accrued in the atmosphere. The greenhouse gases (GHGs) responsible for human induced climate change are mostly emitted by various human economic activities extending from heavy industrial to domestic operations. Therefore our study focused only on the adaptation strategy for Malaysia.

3.3.2 Climate Change Adaptation Responses

Throughout the time, all societies adapt to the climatic conditions and hence some scholars believe that there is no need to explicitly consider such policies as human nature is adaptive (J. B. Smith, 1996). In contrary, adaptation as a policy is different than natural adaptation. Adaptation can be a behavioral change or it can be a technical change. In this study we are not considering “Limitationist” thought defined by (Wilbanks & Kates, 2010), where, they only gave importance to mitigation policy. Rather we consider the “realist” school of thought where changing climate is a fact that should be handled with proper adaptation measures to reduce vulnerability (Klein et al., 2003). In this dissertation we establish that adaptation should be a prominent discourse for Malaysia.

3.3.2.1 Theoretical Background of Adaptation to Climate Change

The literal meaning of adaptation is “to make or to become suitable for a new use or situation” (Hawkins & Le Roux, 1986). That means taking initiatives to adjust with a new climate condition. This responsiveness may be autonomous/automatic or induced by a strategy or specific policy frameworks. Adaptive capacity refers to the potential ability of a system to successfully respond to climate change through behavioral changes, resource management, and technological adjustments (Adger et al., 2007).

The inter-governmental Panel on Climate Change (IPCC) defines climate change adaptation as "adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderate harm or exploit beneficial opportunities" (IPCC, 2001). Adaptation is the adjustment of a system to moderate the impacts of climate change, to take advantage of new opportunities or to cope with the consequences (Adger, Huq, Brown, Conway, & Hulme, 2003). Adaptation is related to building resilience, and it will be a key response to reduce vulnerability to climate change (Stern, Britain, & Treasury, 2006), not limited to discrete projects (Leary, 1999), for example dams and sea walls.

To be more specific**,** adaptation is the way of adjustments to develop the feasibility of social and economic activities and to trim down their vulnerability to climate change, together with its existing unpredictability and extreme weather events with long term climate change (B. Smith et al., 2000). There are several strategies that farmers can implement to trim down the risk of climate change impacts from an agronomic perspective.

Adaptation involves adjustments to enhance the viability of social and economic activities and to reduce their vulnerability to climate change, including its current variability and extreme events as well as long term climate change (Smit & Wandel, 2006). Adaptation to climate change includes all adjustments in behavior or economic structure that reduces the vulnerability of society to changes in the climate system (Janssen, Schoon, Ke, & Börner, 2006).

Adaptation can be classified into several categories. The distinctions of different types of adaptation are theoretical, however in a practical sense, it is difficult to classify them (Samuel Fankhauser, Smith, & Tol, 1999). Adaptation can be divided in terms of purpose, time, scope, function, form, etc. (B. Smith et al., 2000). Adaptation may be autonomous, planned, private and public. Self-governing or Autonomous adaptation relates to those activities which are described as single establishment, venture, and societies autonomously regulate to their opinions around climate consequences. Such self-governing activities might be temporary and short-range alterations, and are frequently measured as a sensitive or lowermost-upward method. Deliberate adaptation is the consequence of thoughtful strategic choice, centred to the understanding that the circumstances that have transformed or are predicted to shift, and that certain procedure of accomplishment is mandatory to preserve an anticipated rank. Such preventive adaptation would advance from the top-down method, within guidelines, benchmarks, and capital spending arrangements.

Deliberate preventive adaptation has the possibility to reduce weaknesses and appreciate the prospects or chances related to climate change, irrespective of independent adaptation. Application of adaptation policies, strategies, procedures, agendas, and actions typically will have instant advantages and forthcoming welfares to the public. Adaptation ratio is expected to be executed only when they are reliable with or combined with choices or agendas that delivers the non-climatic pressures. The prices (costs) of adaptation are frequently negligible compared to other administrative or growth costs.

Samuel Fankhauser et al. (1999) argues that individuals must have the right incentive, knowledge, resources and skills to adapt efficiently for autonomous adaptation to be effective. The government merely plays the role of a facilitator to provide "*a conducive environment*" for adaptation, including the right legal, regulatory, socioeconomic environment for adaptation. For example, the government needs to provide the right incentives to farmers to convince them to adapt. Mendelsohn (2000) argues that private adaptation will occur and tend to be efficient as long as the costs and benefits of adapting are borne by a single decision making entity. He also argues for government involvement in adaptation based on three factors: externality, high information costs, and equity.

Private adaptation means victims of climate change will bear the costs while equity means polluters will bear the costs and thus pay for the damages due to pollution.

Government involvement is needed to shift the cost of adaptation from the victims to the polluters. Thomas and Twyman (2005), also discuss the need for government involvement in adoption to address market failures. There could be three classes of market failures: 1) adaptation is a public good; 2) transaction costs are high; and 3) adaptation requires the factors of production to be moved physically (immobility). As a result, the government needs either to facilitate autonomous adaptation or to carry out the required adaptation directly i.e. opt for planned adaptation.

Adaptation can be either reactive or proactive (anticipatory) depending on timing, goals and motivation for its implementation. Reactive adaptation refers to the case when adaptation measure is posteriori taken based on the early effects of climate change. On the other hand anticipatory adaptation is proactive in nature and emerges even when the climate change impacts are not evident. For instance, adaptation in nature is reactive while in a human system it can be both reactive and proactive (anticipatory). Such anticipatory approaches are predominantly significant for long-term implications, such as design and implementation of durable infrastructures. Consideration for climate change in the National Water Plan of Bangladesh is an example of such long-term policy.

From yet another perspective, adaptation can be sectoral, multi-sectoral and cross-sectoral. Sectoral adaptation methods target activities for individual sectors affected by climate change. For instance, in agriculture, reduced rain-fall and higher evaporation rates means change in irrigation practices. Such a change requires a national policy framework that can integrate traditional adaptation mechanisms along with development of new practices.

Multi-sectoral adaptation approach aims at actions that cover a number of sectors. It is like looking at the climate change problem from yet another perspective. It cuts across various sectors, for instance combined management of water, river basins and coastal zones. Management options linking adaptation to climate change as identified at various conventions could serve as a multi-sectoral approach.

Cross-sectoral adaptation is an integrated measure to reduce climate change adversaries. Examples of such adaptations include development of new and innovative technologies to combat salt-water intrusion or development of drought-resistant crop varieties etc.

United Kingdom Climate Impacts Programme (UKCIP) distinguishes two adaptation processes: "*building adaptive capacity*" involves prior actions to climate change such as creation of information and conditions (regulatory, institutional, and managerial) for adaptation, and "*delivering adaptation actions*" involves posterior actions to climate change that will reduce vulnerability to climate risks, or exploit new opportunities. Adaptation will be determined by the agent's education, access to information, financial and natural resources, social networks, and the presence/absence of conflicts. For the latter, the adaptation process will depend on the relationships between government, private sector and civil society, the regulatory environment, and the effectiveness of public institutions, national wealth, and economic autonomy etc.

Adaptation and adaptive capacity can also be analysed using Amartya Sen's "Capabilities approach." In this approach, capabilities reflect various "functions" a person can potentially achieve depending on the access to "freedoms" – political freedom, economic facilities, social opportunities, transparency guarantees, and protective security (Sen, 1999). Ospina and Heeks (2010) argue that the growth of adaptive capacity itself is “developmental” regardless of its actual utilisation. Roy and Venema (2002) applied this approach to examine Indian women’s vulnerability to climate change and they argued that development efforts should be directed in the capabilities framework so that these women can improve their well-being, such as access to health-care, literacy, and control over their own lives, hence acting more readily in response to climate change pressures.

Table 3.1: Concepts of Adaptation in Summary

Source	Thoughts/view
Ospina and Heeks (2010)	The adaptive capability is “developmental,” subject to the innovation and flexibility.
Stern et al. (2006)	Adaptation is a manner of building resilience, and it will be a crucial response to reduce vulnerability to climate change.
Adger et al. (2003)	Adaptation is the amendment of a structure to ease with the negative effects of climate change as well as to adjust with better opportunities to handle the adverse consequences.
IPCC (2001)	Adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderate harm or exploit beneficial opportunities.
Leary (1999)	Adaptation cannot be limited to certain projects, for example, dams and sea walls. To a certain degree it is the behavioral and institutional changes.

3.4 Adaptation and Agriculture

In Agriculture, specific adaptation options are modification of plantation periods and crop diversity; crop rearrangement; better land administration, e.g. controlling of soil erosion; and soil safeguard by means of plantation, forestation etc. Figure 3.1 shows some of specific adaptation options for agricultural sector and their possible benefits.

Developing countries whose contribution to climate change is far less than developed countries and they are ironically more vulnerable to the climate change impacts and have less capacity to adapt. Therefore, adaptation to climate change is a pressing concern for the international community. Patterns of agricultural adaptation in developing countries and even within a single country are not homogenous and have multiple objectives such as food, informal employment, security, distribution of wealth etc. Thus adaptation needs to target specific agricultural systems that play specific roles for local communities and their countries. Research, capacity building and extension are the common pillars for effective adaptation across all agricultural systems.

Considering the financial and non-financial costs and benefits from the individual farmer's perceptions, adaptation decisions may vary among farmers as everybody tries to maximise his utility. This is evident from the agricultural innovation and adoption literature that the farmer will adapt only when he is certain of the benefits (D'Emden, Llewellyn, & Burton, 2008; Greiner & Gregg, 2011; Pannell et al., 2006).

These are the most effective and least risky areas for investing in adaptive capacity building in addition to locally-specific actions from the available climate change data. Most local, state and national stakeholders use regional climate perspectives for planning adaptation, with insignificant use of formal climate science models, and their view on adaptation is the scaling-up of existing methods for coping with climate variability. The adaptation actions prioritised by both institutions and farmers tend to be extension or scaling-up of existing methods for coping up with climate variability, and research and institutional capacity building. The specific detailed actions are limited by all stakeholders' limited knowledge of future climatic trends and development scenarios.

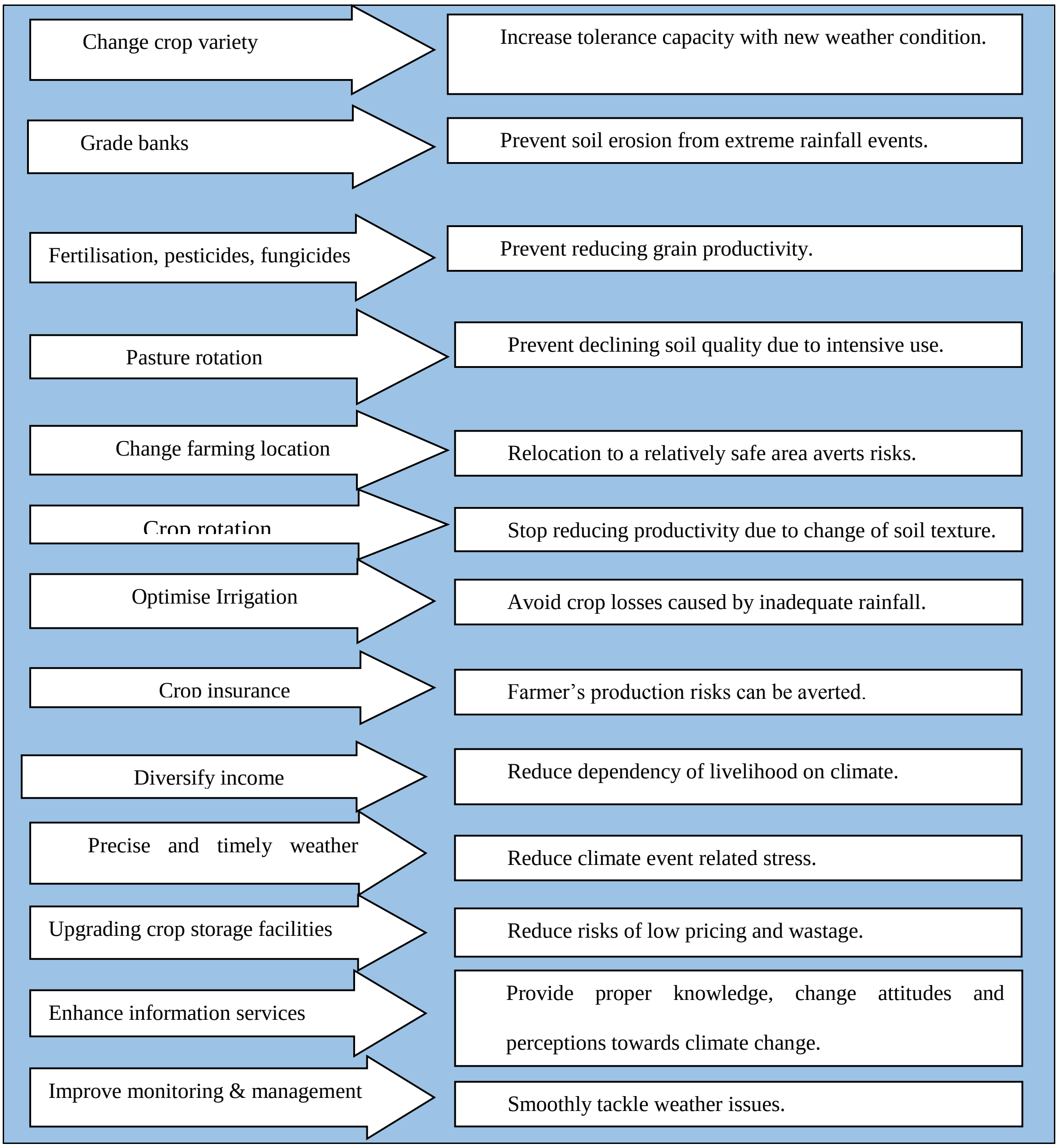


Figure 3.1: Various adaptation strategies and their benefits

Hoffmann and Sgrò (2011) distinguish that strong far-sighted measures at the national and international levels are required to transform agriculture in a way that will enable it to meet the challenges of climate change and food security. Consistent to Ostrom's polycentric approach towards addressing climate change (Ostrom, 2014) which requires involvement of actors from all levels, climate change action and policy requires to involve players from local and global policy processes. The climate change regime requires good understanding of the way in which agriculture, especially in the developing countries, works from the adaptation responses to the policy and institutional frameworks.

It should be noted that adaptation is a complicated process. Among the available adaptation strategies, which and what level of adaptation will be implemented varies among individual farmers depending on their capability and willingness to adopt (Crimp et al., 2010; Howden et al., 2007). Pannell et al. (2006) argues that the willingness to adopt depends on farmers' goals, attitudes, values, confidence levels, and risk perceptions. Also, farmers are more willing to adapt to a particular strategy on the basis of how much it affects their welfare (Edwards-Jones, 2006; Greiner & Gregg, 2011; Pannell et al., 2006).

3.5 Costs of Adaptation

According to IPCC (2001), costs of climate change adaptation policy are the "cost of planning, preparation, facilitation and implementation of adaptation measures, including transitional costs". This is countered by the benefits of adaptation (IPCC, 2001) as 'the avoided damage or the accrued benefits following the adoption and implementation of adaptation measures'.

Several international studies using CGE model have attempted to estimate the economic costs of climate change. The range of climate change effects covered includes effects on agricultural productivity, energy demand, sea-level rise, human health and tourism. These studies provide some guidance on how similar exercises might be undertaken using CGE model for Malaysia.

According to World Bank (2006), estimated costs of climate change adaptation is around 9 billion to 41 billion US$ per year. This study estimated the fraction of current investment flows that is climate sensitive, and then used a 'mark-up' factor to reflect the cost of ‘climate proofing’. They assumed that 2 - 10% of Gross Domestic Investment (GDI), 10% of Foreign Direct Investment (FDI), and 40% of Official Development Assistance (ODA) was climate sensitive, and that the mark-up to climate-proof them was 10 to 20%.

Stern et al. (2006) estimated adaptation cost to worth 4 billion – 37 billion US$. This particular investigation also applied the World Bank’s methods, but reduced the mark-up by 5-20% and a certain percentage of climate-sensitive ODA to 20%.

Oxfam (2007) estimated the adaptation cost to be more than 50 billion US$. The study includes extra cost substances to the World Bank statistics, as well as the cost of community level non-government network (extrapolated from 3 projects), and of funding NAPA-style programs (based on 13 NAPAs).

UNDP (2007) estimated the costs at 86 billion – 109 billion US$. They assumed the N. H. Stern et al. (2006) expectations, with the exception of using a 17 - 33% share for climate-sensitive ODA, and involved costs of adapting poverty reduction strategies ($44 billion p.a.) and strengthening disaster response systems ($2 billion pa).

UNFCCC (2007) estimated the adaptation cost at 49 billion – 171 billion US$ (28 billion – 67 billion US$ for developing countries). The study especially worked on five sectors (excluding agriculture, forestry and fisheries) and estimated their costs for the year 2030.

Specifically for the agricultural sector, examples of the costs of climate change adaptation are the cost of retraining farmers in new practices or for a non-farming job and costs of additional fertiliser, additional irrigation or crop varieties. The residual impacts might incorporate the harvest damages before the availability of more suitable crops and the change in crop yields and food prices that cannot be mitigated through adaptation.

3.6 Literatures of Studies Based on Malaysia

Presently farmers of Malaysia are conferring little attention in planning for potential climate change impacts on both individual and community levels. Rigorous analysis of the net impacts of climate change on agriculture is yet to be performed on account of the uncertainty associated with the success of any adaptation action to handle climate change. Generally, farmers cope up with weather patterns on a short term basis and sometimes able to adjust to potential risks and weather variability through best management practices. But climate change may pose new unpredictable risks for the future of Malaysia similar to rest of the world.

There are substantial limits and barriers to adaptation, including environmental, economic, informational, social, attitude and behavioral barriers that are not fully understood (EPA, 2013). Hence, understanding the limits and barriers to adaptation is crucial to support a sustainable and resilient agricultural sector (Stokes & Howden, 2010). The obstacles that cannot be overcome by possible responses to climate change are known as *limits to climate change adaptation* (Adger et al., 2007) while *barriers to adaptation* are obstacles that can be overcome with some efforts, for instance, creative management, or changed thinking (Moser & Ekstrom, 2010).

Each individual sector should have its own policy depending on the vulnerability to climate change and which may be different than other sectors. However, in Malaysia, “At present, no separate, specific policy exists for every economic sector that would address the effects of global warming and climate change on the individual sectors and their productivity.” (Austin & Baharuddin, 2012). Furthermore, it is necessary to provide better and accurate information on probable climatic variations for designing efficient adaptive measures (MSTE, 2000). But unfortunately in Malaysia, there is a huge lack of information in this regard.

Hence it is apparent that, for Malaysia main obstacles are lack of knowledge of climate change impacts; limited conservation facilities; political willingness etc. Moreover, there is one distinct and important challenge for Malaysia which is the continued uncertainty about how much climate change it will face. The perception is complex to understand. Current adaptation techniques may be practical in future circumstances but it may not be adequate for extreme weather conditions. It is also not certain to what extent adaptation will reduce climate vulnerability of Malaysia. Despite the uncertainties, rigorous effort is needed to facilitate decision making based on climate projections. Subsequently, for a range of climate change scenarios, adaptation options and costs should be estimated. Heath and Gifford (2006) discussed on this subject of ongoing worldwide debate about what actually are causing the climate change.

3.7 Empirical Literatures

Since the 1990s empirical studies have sought to measure the efficacy of adaptation to climate change. Earlier studies focused on developed countries, where data was more readily available and the challenges of adaptation were early recognised as an important policy issue. The focus is often on agriculture and infrastructure – the two most vulnerable sectors to climate change risks (W. E. Easterling, 1997; IPCC, 2001; Smit & Skinner, 2002; Yohe & Schlesinger, 1998).

In the last 10 years, there has been growing interest on adaptation in developing countries for the similar reasons. Many studies have been carried out in Asia, Africa, and Latin America. The various adaptations reviewed here are not necessarily fully consistent with the narrow definition of adaptation as the intention is to keep the coverage broad enough so that ideas, analytical methods, and findings relevant to climate change adaptation are included as much as possible. The climate change phenomenon has to be clearly understood by a participating body prior to opting for adaptation actions. It is thus important to have an understanding on climate change. Another important aspect of adaptation is the specific strategies that are in use by the people. Extremely relevant to policymakers are determinants of adaptation: which includes factors contributing to adaptation by the economic agents themselves and factors that are barriers to adaptation as well as the role of the institutions in adaptation. This would provide useful information for better policymaking.

Adaptation strategies can be identified by

1. Mobility - avoiding risks across space.
2. Storage - it reduces risks over the time or across assets owned by households or collectives.
3. Communal pooling - it involves joint ownership of assets and resources; sharing of wealth, labour or incomes from particular activities across households, or mobilisation and use of resources held collectively during time of scarcity. It reduces risks experienced by individual households.
4. Exchange - it is usually viewed as a means to promote specialisation and increase revenue flows, but it can equally substitute for the first four classes of adaptation strategies (Agrawal & Perrin, 2009).

The adaptation methods discussed in most empirical literature fall into one of these four classes.

Thomas, Twyman, Osbahr, and Hewitson (2007) found a large number of adaptation strategies by farmers in South Africa, such as changing farming practices (plant drought-resistant varieties, have more livestock and less crops, build cattle shelter), diversifying livelihood (get off-farm work, start a business) and forming networks (cooperatives, community horticultural projects), etc. Kirkbride and Grahn (2008) reports several traditional adaptation methods by pastoralists in Eastern Africa, such as migration, diversification of herd animal mix, adjusting herd size, supplementing grazing with feed, and harvesting rain water as an alternative to increasingly unreliable supply of groundwater.

Eakin (2005) studied adaptation to climate risks in three rural communities in Central Mexico. The focus was on the effect of social, political, and economic conditions on farmers' adaptive capacities and their selection of adaptation strategies. Experienced and educated farmers are often more likely to adapt. There are some common themes across various case studies regarding the government role in facilitating adaptation. It is worthwhile to highlight a few key points on government role, such as providing improved/extended service, improving infrastructure such as roads, irrigation etc., gather data on local climate, research and development especially developing new crop varieties, and shifting away from adaptation policies that prescribe specific adaptation methods to those that provide enabling conditions for local populations to provide alternative adaptation choices.

Early studies, such as Nordhaus (1993a) and Cline (1992), aimed at economic assessments of the impacts of climate change. Recognition of the fact that adaptation may reduce the costs of impacts substantially has more recently led economists to address the potential benefits of adaptation options (Tol, 2002a).

The early publications and tools emerging in the 1990s emphasised on assessment of the risks associated with climate change as the first step and the main source of information that can provide the basis for decisions on adaptation. There is a long record of practices to adapt to the impacts of weather as well as natural climate variability on seasonal to inter-annual time-scales – particularly to the El Nino-Southern Oscillation (ENSO). These include proactive measures such as crop and livelihood diversification, seasonal climate forecasting, community-based disaster risk reduction, famine early warning systems, insurance, water storage, supplementary irrigation and etc. They also include reactive or post adaptations, for example, emergency response, disaster recovery, and migration (Sperling & Szekely, 2005).

Recent reviews indicate that a ‘wait and see’ approach or reactive approach is often inefficient and could be particularly unsuccessful in addressing irreversible damages, such as species extinction or irrecoverable ecosystem damages, that may result from climate change (D. R. Easterling et al., 2000; B. Smith et al., 2000). Proactive practices to adapt to climate variability have advanced significantly in recent decades with the development of operational capability to forecast several months in advance the onset of El Nino and La Nina events related to ENSO (Cane, Zebiak, & Dolan, 1986), as well as improvements in climate monitoring and remote sensing to provide better early warnings on complex climate-related hazards (Dilley, 2000).

Since the mid-1990s, a number of mechanisms have been established to facilitate proactive adaptation to seasonal climate variability. These include institutions that generate and disseminate regular seasonal climate forecasts (NOAA, 1999) , and the regular regional and national forums and implementation projects worldwide to engage with local and national decision makers to design and implement anticipatory adaptation measures in agriculture, water resource management, food security, and a number of other sectors (Bates et al., 1997; Broad & Agrawala, 2000; Lemos, 2003; Meinke et al., 2009; O'Brien & Vogel, 2003; Patt & Gwata, 2002; Ziervogel, 2004). An evaluation of the responses to the 1997-98 El Nino across 16 developing countries in Asia, Asia-Pacific, Africa, and Latin America highlighted a number of barriers to effective adaptation, including: spatial and temporal uncertainties associated with forecasts of regional climate, low level of awareness among decision makers of the local and regional impacts of El Nino, limited national capacities in climate monitoring and forecasting, and lack of co-ordination in the formulation of responses (Glantz, 2001).

Recent research also highlighted that technological solutions such as seasonal forecasting are not sufficient to address the underlying social drivers of vulnerabilities to climate (S Agrawala & Broad, 2002). Furthermore, social inequalities in access to climate information and the lack of resources to respond can severely constrain anticipatory adaptation (Pfaff, 1999).

Research that has challenged empirical evidence of adaptation policy implications with its cost and benefit are limited. Adaptation benefit is the damage costs avoided or the accrued benefits following the adoption and implementation of adaptation measures. Adaptation costs is the costs of planning, facilitating, preparing for, and implementing adaptation measures, including transition costs (IPCC, 2001). The IPCC third assessment report notes that “very little attention has been devoted to the interaction of adaptation to climate change with the ongoing development projects and programs”. Therefore, adaptation policy implications including cost and benefit studies is necessary to take appropriate measure.

The literature on adaptation costs and benefits remains limited and fragmented in terms of sectoral coverage. Adaptation costs are usually expressed in monetary terms, while benefits are typically quantified in terms of avoided climate impacts, and expressed in monetary as well as non-monetary terms (e.g., changes in yield, welfare, population exposed to risk). There is a small methodological literature on the assessment of costs and benefits in the context of climate change adaptation (Samuel Fankhauser & Kverndokk, 1996; B. Smith et al., 2000; Toman, 2006).

In addition there are a number of case studies that look at adaptation options for particular sectors e.g. Shaw (2000) for sea-level rise, or particular countries e.g., J. B. Smith et al. (1998) for Bangladesh, Becken (2005) for Fiji, and, Dore, Burton, Dore, and under grant No (2000) for Canada. Much of the literature on adaptation costs and benefits are focused on sea-level rise (S Fankhauser, 1995; Nicholls & Tol, 2006; Yohe & Schlesinger, 1998) and agriculture (R. M. Adams, McCarl, & Mearns, 2003; John Reilly et al., 2003; Rosenzweig & Parry, 1994).

Adaptation costs and benefits have also been assessed in a more limited manner for energy demand (Mansur, Mendelsohn, & Morrison, 2005; Morrison & Mendelsohn, 1999; Sailor & Pavlova, 2003), water resource management (Kirshen, Ruth, Anderson, & Lakshmanan, 2004), and transportation infrastructure (Dore et al., 2000). In terms of regional coverage, there has been a focus on the United States and other OECD countries (Franco & Sanstad, 2006) although a growing number of literature is now available for developing countries e.g., (Butt, McCarl, Angerer, Dyke, & Stuth, 2005; Chambwera & Stage, 2010) .

The literature on costs and benefits of adaptation to sea-level rise is relatively extensive. S Fankhauser (1995) used comparative static optimisation to examine the trade-offs between investment in coastal protection and the value of land loss from sea-level rise. The resulting optimal levels of coastal protection were shown to significantly reduce the total costs of sea-level rise across OECD countries. The results also highlighted that the optimal level of coastal protection would vary considerably both within and across the regions based on the value of land that is at risk. Another factor increasing cost uncertainty is the social and political acceptability of adaptation options.

Tol, Van Der Grijp, Olsthoorn, and Van Der Werff (2003) showed that the benefits of adaptation options for ameliorating increased river flood risk in the Netherlands could be up to US$20 million in 2050. They concluded that implementation of these options requires significant institutional and political reforms representing a significant barrier to implanting least-cost solutions.

Adaptation studies looking at the agricultural sector considered autonomous farm level adaptation and many also looked at adaptation effects through market and international trade (R. M. Adams et al., 2003; Butt et al., 2005; Darwin, Tsigas, Lewandrowski, & Raneses, 1996; Winters, Murgai, Sadoulet, de Janvry, & Frisvold, 1998). The literature mainly reports on adaptation benefits, usually expressed in terms of increased yield or welfare, or decreased number of people at risk of hunger. Adaptation costs, meanwhile, were generally not considered in early studies (Rosenzweig & Parry, 1994); but are usually included in recent studies (Mizina, Smith, Gossen, Spiecker, & Witkowski, 1999; Njie et al., 2006; John Reilly et al., 2003). Rosenzweig and Parry (1994) and Darwin, Tsigas, Lewandrowski, and Raneses (1995) estimated residual climate change impacts to be minimal at the global level, mainly due to the significant benefits from adaptation.

However, greater inter and intra-regional variations were reported, in particular, for many countries located in tropical regions, the potential benefits of low-cost adaptation measures such as changes in plantation seasons, crop mixes etc. are not expected to be sufficient to offset the significant climate change damages (Butt et al., 2005; Rosenzweig & Parry, 1994). More extensive adaptation measures have been evaluated in some developing countries. For the 2030 horizon in Mali, (Butt et al., 2005) estimated that adaptation through trade, changes in crop mix, and the development and adoption of heat-resistant cultivars could offset 90% to 107% of the welfare losses induced by climate change impacts on agriculture.

Many studies make the unrealistic assumption of perfect adaptation by individual farmers. Even if agricultural regions can adapt fully through technologies and management practices, there are likely to be costs of adaptation in the process of adjusting to a new climate regime. Recent studies for U.S. agriculture found that frictions in the adaptation process could reduce the adaptation potential (Schneider, Easterling, & Mearns, 2000). Besides sea-level rise, agriculture, and energy demand, there are a few studies related to adaptation costs and benefits in water resource management and transportation infrastructure. Kirshen et al. (2004) assessed the reliability of water supply in the Boston metropolitan region under climate change scenarios. Even under a stable climate, the authors project the reliability of water supply to be 93% by 2100 on account of the expected growth in water demand.

Dore et al. (2000) estimated the costs of adaptation to climate change for social infrastructure in Canada, more precisely for the roads network (roads, bridges and storm water management systems) as well as for water utilities (drinking and waste water treatment plants). In this case, the additional costs for maintaining the integrity of the portfolio of social assets under climate change are identified as the costs of adaptation.

However, there are many factors that define the economics of climate changes which are relevant for policy implications. Among them, uncertainty - particularly sudden climatic hazards, improved calibration of economic climate change impact, inclusion of non-market impacts etc. are important. Adaptation does not occur without influence from other factors such as socio-economic, cultural, political, geographical, ecological and institutional effects that shapes the human-environment interactions (Eriksen et al., 2011). Adaptation to climate change is needed both in the short term and long term basis (Adger et al., 2003), but the effectiveness of various adaptation policies may vary from region to region. Here, we widen the scope by the proposed study to evaluate some adaptation policy including cost and benefit so that the authority can choose an appropriate climate change policy.

Recently, huge number of researchers, policy planner and environmentalist applied the dynamic Computable General Equilibrium (CGE) model to examine the effects of climate change, its adaptation cost and impact on the economy of a country. This is especially done in assessing the impacts of reforms on macroeconomic variables and adaptation cost management for agricultural sectors.

From this extensive review of background literatures, we conclude that computable general equilibrium (CGE) model is widely used to minimise climate change adaptation costs. It also focused on the global impact on economy especially on the agricultural sector. However, (R. M. Adams et al., 1998; Berrittella, Hoekstra, Rehdanz, Roson, & Tol, 2007; Calzadilla, Zhu, Rehdanz, Tol, & Ringler, 2009; Dixon & Rimmer, 2002; Hassan, 2010), and many others utilise CGE model for their researches on climate change adaptation policy options in agriculture to determine optimum climate adaptation cost.

Z. Zhang (1998) analysed the macroeconomic special effects for regulating China’s CO_2 emissions by means of a time-recursive dynamic computable general equilibrium

(CGE) model of the Chinese economy. The base case scenario for the Chinese economy over the period till 2010 was first developed under a set of assumptions about exogenous variables. Next, he integrated the macroeconomic implications of two less restrictive scenarios under which China’s CO_2 emissions for climate change adaptation in 2010 will be cut by 20% and 30% corresponding to the base case with the assumption that carbon tax revenues are reserved by the state. Finally, he computed the efficiency enhancement of four indirect tax offset scenarios corresponding to the two tax holding scenarios above.

O'Ryan, De Miguel, Miller, and Munasinghe (2005) focused on the key inter-relations amidst the financial, social and environmental components of the maintainable development triangle. They used the CGE model ECOGEM-Chile to model the extensive economy effects of numerous environmental, community and joint strategies for the Chilean economy. Thus, precise engagement of community strategies would advance environmental policy understanding, while decreasing poor income distribution inequalities. The results recommend that environmental strategies, policies and plans may have community effects, but not vice versa. It also show that the ECOGEM-Chile model is beneficial for examining efficiently and inclusively, diverse extensive economy strategies, policies and their effects on the Chilean economy.

R. M. Adams et al. (1998) showed that potential impacts of long-term climatic change on agriculture has motivated substantial research works over the past decade. They concentrated on potential physical impacts of climate change on agriculture, for example variations in crops and livestock production, as well as the economic consequences of these potential changes in yields. They similarly studied the present works on physical and economic impacts and interpreted the findings based on the role of human adaptation responses to climate change, possible regional impacts to agricultural systems and potential changes in patterns of food production. Key areas of uncertainty are highlighted by considering limitations and sensitivities of these findings. Finally, some speculations are drawn regarding potential importance of interpretation and usage of information on climate change and agriculture.

John Reilly, Sarofim, Paltsev, and Prinn (2006) showed that crop harvests, grassland and forest output would be affected as a result of the impacts of climate changes on the global agricultural sector and would have significant economic consequences. They examined the collective impacts on crop, grassland and forests due to climate changes, rising levels of carbon dioxide (CO_2) concentration, and variations in troposphere ozone, and assessed their consequences on adaptation costs for the global and regional economies. They also highlighted scenarios where there is partial or insignificant effort to regulate these substances, and policy scenarios that limit CO_2 emissions and ozone precursors. Unless optimum adaptation is opted, the costs could well surpass the associated benefits due to climate change adaptation. They found that the estimated economic effect of a country can be strongly affected by resource allocation among sectors in the economy, and trade among countries.

Deke, Hooss, Kasten, Klepper, and Springer (2001) analysed how the physical and biological arrangements are affected due to climate change in numerous areas of the planet. The adaptive capabilities within a region as well as across regions dictate the extent of economic damages for human systems on earth. They used an economic General-Equilibrium model and an Ocean-Atmosphere model in a regional and sectoral disaggregated framework to analyse climate change adaptation in different regions of the world. Significant differences in climate change vulnerabilities were found across regions as well as it is established that the direct climate impacts could be significantly reduced by overall adjustment of the economic system to the changed climatic conditions.

Hertel (2002) discussed the works on applied general equilibrium analysis of agricultural and resource policies. He started from the basic principles and moved onto the assessment of benefits of this methodology for examining sectoral policies. He analysed queries about disaggregation of commodities, households, regions and factors of production. He also discussed parameter specification and model closure as well as problems of modelling policies that would affect agriculture. Special sections are drawn on agriculture and the environment, product differentiation and imperfect competition, adaptation cost, and model validation.

Böhringer and Löschel (2006) investigated the application of computable general equilibrium (CGE) models for evaluating the effects of strategies and policy intervention on policy-relevant environmental, social (institutional) and economic indicators. They found that the operational CGE model used for energy–economy–environment (E3) investigations comprehensively cover the central economic indicators. Environmental indicators, for example energy-related emissions with direct connections to economic activities are extensively covered, while indicators for complex natural science representation such as water stress or biodiversity loss are barely represented. Social indicators are also poorly covered mostly due to fact that these parameters are inherently vague and incommensurable. Their investigation depicts the future prospect of integrated modelling linking standard E3-CGE-models to theme specific environmental and social complementary modelling.

P. D. Adams and Higgs (1990) estimated the share parameters of a CGE model by calibrating the model using a benchmark year-of-record equilibrium dataset. The synthetic benchmark equilibrium datasets portray economy in a notional base year and arguably this data set can be used for calibration of the model too. In the process, they describe the development of a synthetic agricultural sector in the benchmark equilibrium dataset of the ORANI model for the Australian economy. Finally, they provided a comparison between the results obtained by comprehensive tariff cut simulation in ORANI computed with both the synthetic benchmark equilibrium dataset and a particular year-of-record dataset.

Liu, Arndt, and Hertel (2004) focused on current studies in macro-econometric estimation and designed a method to parameter estimation for a widely used global CGE model for climate change adaptation cost. The set of optimal elasticity values is found by maximizing an approximate likelihood function proposed in the model, in the context of a back-costing exercise. Additionally, they perform two statistical tests. The first test compares the standard GTAP elasticity vector with the estimated trade elasticity vector. The null hypothesis of equality is rejected among the two sets of trade elasticities. The second test investigates the well-known "rule of two" hypothesis which sets the elasticity of substitution across imports by sources to twice the elasticity of substitution among domestic goods and imports. They suggested that far more can be gained by nesting CGE models within an estimation framework as it opens the way for official assessment of the model presentation, performance and parameterisation.

Nordhaus and Yang (1996) treated global warming as a single-agent problem. They presented the Regional Integrated model of Climate and the Economy (RICE) model. The model examines different national strategies in climate-change policy considering individual countries such as *i.* pure market solutions, *ii.* Efficient cooperative outcomes, and *iii.* Non-cooperative equilibria. This study found that cooperative policies indicate far greater levels of emission reductions than the non-cooperative plans and policies;

that there are considerable gap in the level of controls in both cooperative and non-cooperative policies among the countries, and that high-income nations may lose the most due to cooperation.

Robinson, Burfisher, Hinojosa-Ojeda, and Thierfelder (1993) incorporated the CGE model for sectoral import demands using a flexible functional form, an empirical improvement over earlier solutions, and using a constant elasticity of substitution function. They recognised trade-offs among bilateral trade growth, labour migration, and agricultural program expenditures under alternative FTA scenarios using the model. Trade liberalisation in agriculture significantly increases urban migration. However, bilateral trade growth falls with increasing support for the Mexican agricultural sector. The results indicate a policy trade-off between rapid gains from trade liberalisation versus having a transition period long enough for seamless assimilation of the displaced labour in Mexico.

John Reilly, Hohmann, and Kane (1994) estimated the possible consequences of three different climate scenarios for world agriculture. The scenarios showed that the impacts vary widely between scenarios and nations. As per their study, the economic winners and losers are determined by the direct impact of climate change on harvest, the global effect on commodity prices, and the export/import status of a country. The trade effects and the high level of uncertainty are critical considerations in adaptation policies.

Kane, Reilly, and Tobey (1992) used the CGE to model the economic effects of twice the atmospheric carbon dioxide absorption on world agriculture under two different empirically estimated crop response scenarios. The outcomes comprise both changes in the prices of agricultural commodities as a result of changes in domestic agricultural harvests, and fluctuations in economic welfare subsequent to altered global consumption and production patterns of agricultural commodities. With a few exceptions, the outcomes on national economic welfare are found to be quite modest under both scenarios, while the prices of agricultural outputs are estimated to rise noticeably under the more pessimistic scenario. Increased agricultural prices would reduce consumer surplus and diminish the benefits from climate change that some nations having positive estimated yields would otherwise receive.

Tol (2002b) used CGE model to estimate the potential impacts of climate change in economic terms on agriculture, forestry, unmanaged ecosystems, sea-level rise, human mortality, energy consumption, and water resources. Estimations are obtained using GCM based scenarios from globally comprehensive and internally consistent works. An underestimate of the uncertainty is assumed. Following the meta-analytical approaches described here, new impact studies can be incorporated. A 1ºC increase in the global mean surface air temperature would have a positive effect on the OECD, China, and the Middle East, and a negative effect on other nations. Global estimations are found based on the aggregation rule - using a simple sum the world impact of a 1ºC warming would be a positive 2% of the GDP, having a standard deviation 1%, while using global average values, world impact would be a negative 3% (standard deviation: 1%) and using equity weightage global impact would amount to 0% (standard deviation: 1%).

Hamilton, Maddison, and Tol (2005) estimated the global impacts of climate change on tourism with DICE (Dynamic Integrated Climate and Economy) model considering adaptation as an implicit variable in the model. DICE has no regional or sectoral disaggregation. Its economic core is a neoclassical growth model in which gross output is produced by capital and labour via a Cobb-Douglas production function, but temperature-change-induced damages and investment in emissions abatement are deducted in computing the “net output” that is available for consumption and investment. The model includes equations that relate emissions to gross output and abatement, temperature to emissions and damages to temperature.

Hope, Anderson, and Wenman (1993) calculated the economic and non-economic damages for eight world regions with PAGE (Policy Analysis from Greenhouse Effect) model. The model includes uncertainty by incorporating parameters from a random sample and repeated runs. The recent version of the model (PAGE2002) distinguishes eight regions but has no sectoral disaggregation. Global emissions drive regional temperature via a reduced-form representation of the greenhouse effect, also accounting for the cooling effect of sulphate aerosols. It accounts for market and non-market damages of climate change - all temperature driven, including the catastrophic effects that could occur if global temperature exceeds a catastrophe threshold. The Monte-Carlo approach is adopted for simulations with PAGE2002, each simulation being run 1000 times with random draws of the model's parameters to generate probability distributions of results rather than point estimates.

Manne, Mendelsohn, and Richels (1995) estimated global and regional impacts of GHGs emissions with Model for Evaluating Regional and Global Effects (MERGE) - model of greenhouse gas reduction policies. This model considers market and non-market damages to determine the optimum mitigation level. Like PAGE, the MERGE model has regional disaggregation but it also distinguishes between energy and non-energy production. The production functions include the inputs of capital, labor and energy, with substitution allowed between capital and labour, electric and non-electric energy and capital/labour and energy. The model distinguishes between market and non-market damages both of which are temperature driven. Market damages decrease the quantity of gross output that is available for consumption, investment or net exports.

Emissions from energy production and non-energy sources drive global temperature changes, accounting for the effect of carbon sinks.

These models emphasise on the analysis of aggregate welfare costs and benefits of climate change policy rather than on the structural penalties of climate change and climate change policy. Because of the long timeframes over which the effects of climate change are spread, a particular concern with normative issues of time discounting has emerged.

A common approach being used in more recent impact modelling has been to assume levels of adaptation. Applications include Nicholls, Leatherman, Dennis, and Volonte (1995) for coastal zones, Mendelsohn, Nordhaus, and Shaw (1994) and Rosenzweig and Parry (1994) for agriculture, Sohngen and Mendelsohn (1998) for timber, and Rosenthal, Gruenspecht, and Moran (1995) for space conditioning in buildings. These studies validate that adaptive measures can significantly alleviate adverse impacts of climate change and benefit from opportunities associated with changed climatic conditions (Helms, Mendelsohn, & Neumann, 1996). The models of Rosenzweig and Parry (1994) showed that, food production could increase under climate change scenario in many regions of the world for assumed level of adaptations. Stuczyiński et al. (2000) concluded that climate change would decrease Polish agricultural production by 5–25% without adaptation; while production is estimated to change by –5 to +5% of current levels with assumed level of adaptation.

Downing (1991) demonstrated the possibility of adaptations to reduce food deficits in African countries from 50% to 20%. Mendelsohn and Dinar (1999) estimated that private adaptation could decrease the possible climate damages for Indian agriculture from 25 to 15–23%. John Reilly et al. (1994) estimated global “welfare” losses in the agri-food sector between 0.1 billion to 61.2 billion US$ without adaptation, compared to +70 to –37 billion US$ with assumed level of adaptation. These works highlight potential opportunities of adaptation than threats as the adaptation reduces damages (i.e. benefits from opportunities) due to the changes in mean climatic conditions.

Tobey, Reilly, and Kane (1992) challenged the hypothesis that negative yield effects in key temperate grain producing regions of the world as a consequence of global climate change would have a serious impact on world food production by using CGE model. Their results show that even with simultaneous output losses in the major grain producing regions of the world, global warming will not perturb world agricultural markets significantly. Country and regional crop yield variations induce interregional production and consumption adjustments that serve to buffer the severity of climate change impacts on global agriculture and will result in moderate impacts on global as well as domestic agricultural prices.

Gebreegziabher, Stage, Mekonnen, and Alemu (2011) analysed the economic influences of climate change on Ethiopia’s agriculture using a nationwide computable general equilibrium (CGE) model. The effects on agriculture are based on outcomes from a Ricardian model where current (and future) agricultural productions are examined as a function of temperature and precipitation. They project that the outcome of general climate change will be relatively moderate until 2030 after which it will deteriorate noticeably. Their simulation outcomes specify that over a 50-year period, the predictable reduction in agricultural productivity may lead to 30 percent less average incomes, compared to that of the assumed scenario where there would be no climate changes. Autonomous adaptations that the farmers would formulate in climate change response and corresponding government policies will determine the future growth of Ethiopia.

Bosello, Campagnolo, and Eboli (2013) performed an economic assessment of climate change impacts by the study of four major crop families covering more than 80% of agricultural outputs in Nigeria. The results are obtained by modelling land productivity in a computable general equilibrium system to represent Nigerian economy until 2050. It also incorporates detailed land usage scenario by differentiating different agro ecological zones based on productivity. Indecision and uncertainty regarding future climate are captured, using yield changes computed by a crop model as input and covering the whole range of variability produced by an envelope of one RCM and ten GCM runs.

After 2025, in the medium term, climate change is unmistakably negative for Nigeria with production losses, rise in crop prices, higher dependency on foreign food imports and GDP losses in all the simulation runs. In the second part of their paper, a cost effectiveness analysis of adaptation for Nigerian agriculture is discussed. A mix of cheaper "soft measures" and more costly "hard" irrigation expansion are considered as adaptation actions. The main result is that the cost effectiveness for the overall economy depends on the alternative and low cost adaptation responses. In this case, all climate change damages can be offset with a positive benefit over cost ratio for all different climate scenarios. Costly responses such as irrigation expansion should be restricted for only smaller areas proportionate to the soft measures. Full adaptation cannot be cost-effective when adaptation costs are estimated from the high-end. Thus, it demands cautious preparation and application of adaptation responses irrespective of their type and needs to be focused on controlling their unit costs.

In a similar work Carraro and Sgobbi (2008) demonstrated how this type of modelling can be used in conjunction with detailed information about the impacts of climate change on a particular national economy, in this case, the Italian economy. The authors assessed the direct economic costs of climate change on four areas in Italy: alpine regions, regions prone to floods and landslides, coastal zones, and arid zones. For cost assessment, they accounted for all the costs of adaptation measures that are likely to be undertaken (e.g., the costs of artificially enhancing snow cover in alpine areas and the costs of protecting against sea-level rises in Venice). To compute the overall implications of these direct effects for the Italian economy, they were fed into the FEEL global CGE model. The model accounts for the autonomous adaptation resulting from the responses of agents in the economy to climate-change-induced changes in relative prices, including the responses of the economy's trade flows.

3.8 Summary of Literature Review

We summarise the literatures that have been discussed in this chapter in the Appendices.

3.9 Literature Gap

The international literature on the integrated assessment of climate change work at an aggregate level and lack the regional or structural detail that will be necessary to inform the debate about climate-change policy in any country. In particular, most of those economic models have little sectoral or regional disaggregation. To our knowledge a model with explicit adaptation at the local level that includes the distribution of impacts and costs of adaptation among each crop individually, is necessary. Climate condition and impact is different for every country and every sector depending on bio-geo-physical conditions. However, most of the studies are global and regional. In addition, no similar study has been conducted for Malaysia for identifying the impacts of cost of adaptation in the agricultural sector and in the economy as a whole. Therefore, our research plan is to analyse the impact of climate change adaptation costs on the agricultural sector in particular and on the other sectors of the economy in general to measure the macroeconomic impact (Gross domestic Product-GDP variables).

In the next chapter, we discuss the proposed conceptual framework and methodology to achieve the desired objectives.

CHAPTER 4: METHODOLOGY

4.1 Introduction

In this chapter, we present the specific methodology for this research along with theoretical framework based on Computable General Equilibrium (CGE) model. Specifically, in this chapter, detailed procedure of the CGE model development is discussed here.

The general equilibrium framework is the best economic model (Döll, 2009) that can represent wide impacts of various policies and external shocks. The computable general equilibrium model permits simulating different sorts of shock on exogenous variables and the effects of these shocks on various endogenous variables for example, effects on output, prices, employment and welfare (Brocker, 2004). Examples of the exogenous shocks include the rising level of carbon dioxide concentration in the atmosphere and rapid increase in the average global temperature. Hence, the CGE modelling has been chosen for this study, as it provides the best analytical tool and robust measurement. This model also provides an empirical representation of inter-sectoral relationships of an economy and allows users to trace the economic impacts of a change in the demands for commodities (goods and services). The impacts of an adaptation policy on a specific sector and on the overall economy can be comprehensively analysed using CGE model (Bezabih, Chambwera, & Stage, 2011). Specifically, CGE models are able to capture wide-effects of a economy, with and without adaptation policy.

4.2 The Theoretical Framework of the Study

From the past literature, we have identified some crucial theories to develop a conceptual framework for this study with a view to accomplishing its objectives. For example, we have used theory of transitions to develop the concepts of the optimum adaptation path. In this section, we enlighten these theories that are utilised in this study.

4.2.1 General Equilibrium Theory

We developed a country specific (Malaysia) dynamic computable general equilibrium model to examine the impacts of climate change on the economy (with and without adaptation policy). The CGE model is based on general equilibrium theory developed by Walras in 1954. This theory was established on competitive market exchange which explains a position where all markets will be in equilibrium simultaneously. Therefore each individual sector will be in equilibrium at the same time. The total market demand for every commodity output and every factor in total is equivalent to the total market supply. The price of each commodity is fixed in a way so that an equilibrium profit for any firm is zero after all payments given to the factors. Household expenditures must be equivalent to household income. The value of transfer payments of the government to the consumers is equal to the government's revenue from taxes. Therefore, Walrasian equilibrium for this model is a set of prices such that supply side of an economy is in equilibrium by ensuring all firms to maximise their own profits'. Similarly demand side is in equilibrium by ensuring all households to maximise their utility conditional upon a budget constraint given by the value of their endowments, and excess demand for every commodity is zero. This general equilibrium model assumes that all markets are perfectly competitive for both consumption of goods and factors of production.

As an example, assume that the economy produces only two commodities, x and y, accompanied by two factors of production, (capital, k and labor, l). Every individual's choices/preferences are depicted by an indifference map and all individuals are assumed to have identical preferences. The inter-linkages between inputs and outputs can be represented by the PPC (production possibility curve). Assuming the fixed volume of capital (*k*) and labor (*l*), the PPC can be constructed.

Figure 4.1 describes an Edgeworth box diagram which depicts all the different combinations that are possible with the use of existing capital and labor (*k* and *l)* to produce the commodities (*x* and *y)*. Every single point in the Edge-worth box represents a fully employed allocation of the prevailing resources to commodities, *x* and *y*

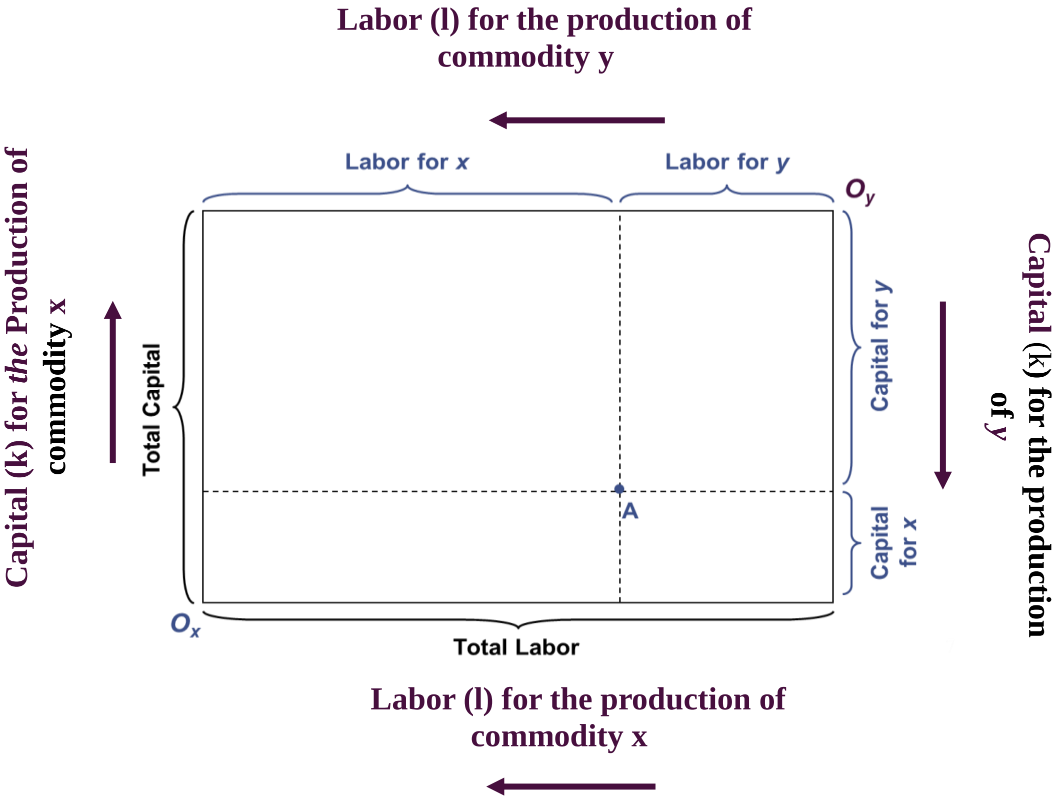


Figure 4.1: Allocation of available resources to *x* and *y*.

From Figure 4.1, it is clear that, not all allocations in the Edgeworth box are technically efficient technically; many of them are actually inefficient. This is due to the fact that, by shifting the labor *(l)* and capital *(K)* around, production of either commodity can increase. To get efficient allocation, the model uses isoquant maps for the commodities (the isoquant map for commodity *x* uses O_x as the starting point or origin and the isoquant map for commodity *y* uses O_y as the starting point or origin) shown in Figure 4.2.

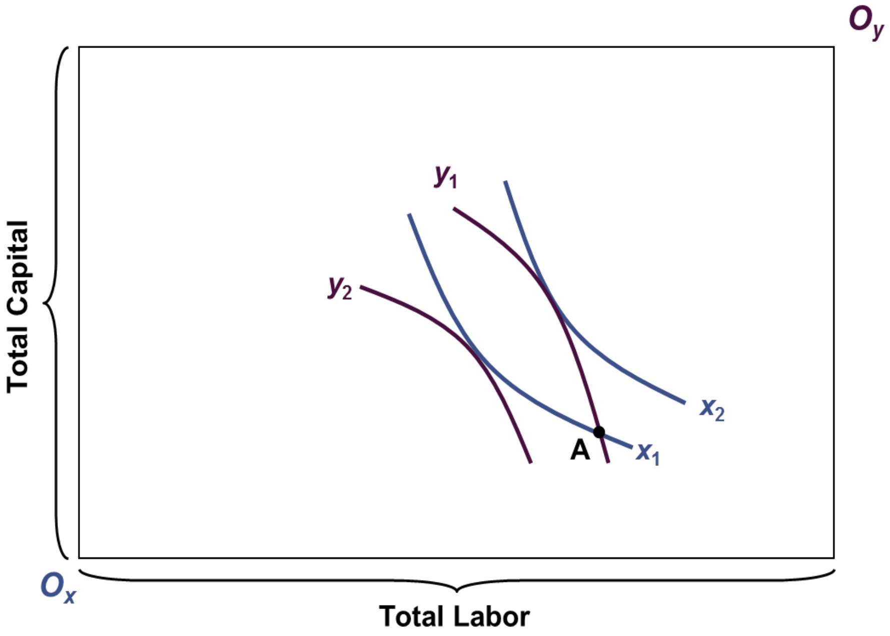


Figure 4.2: Isoquants for commodities

Figure 4.2 shows that the efficient allocations can find out a point where both isoquants are tangent to each other. Point *A* is inefficient because, by moving along y_1, productions of commodity x can be increased from x_1 to x_2 while holding *y* constant or productions of commodity y can be increased from y_1 to y_2 while holding *x* constant by moving along x_1. At each efficient point, the rate of technical substitution of *k* for *l* *(RTS*) is equal in both *x* and *y* production. Firms will maximise their profit at the point where p_x / p_y ratio is equal to the *rate of product transformation (*RPT*), which is the slope of production possibility curve.* Utility maximisation requires that marginal rate of substitution of *x* and *y* (MRS) should be equivalent to the p_x / p_y ratio. Equilibrium position occurs when individuals and firms have the identical price ratio so that there exists neither excess supply nor excess demand ($x^* = y^*$) for all goods together.

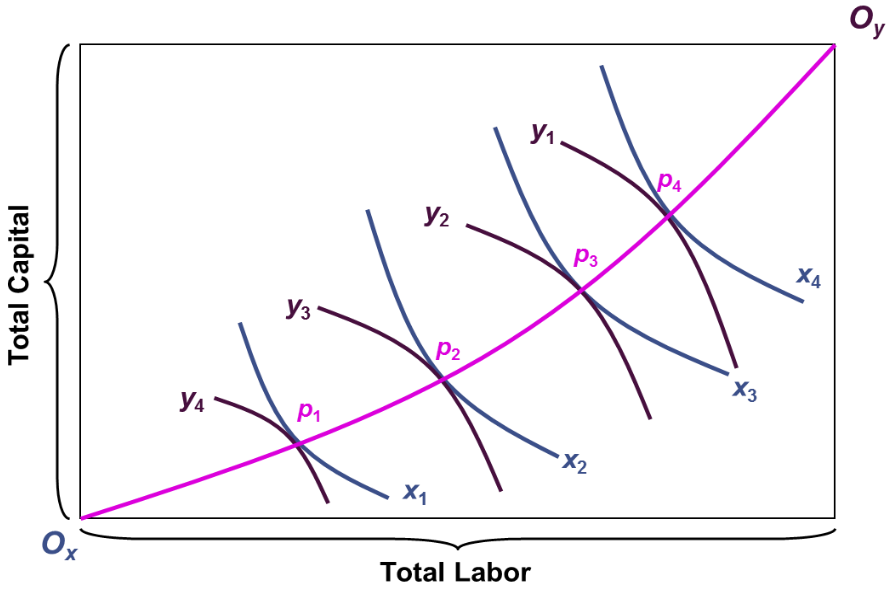


Figure 4.3: Efficient point path of general equilibrium

From Figure 4.3, the locus of efficient points depict the highest/maximum level of output for commodity *y* that can be produced for arbitrary level of output for commodity *x*. Each efficient point of production becomes a point on the production possibility frontier.

4.2.2 The Theory of Transitions

Our study intends to find a steady optimum adaptation path over time. To conceptualise this optimum adaptation path, this study has considered "The theory of transitions (Blomström & Hettne, 1984)", which identifies four stages of economic development i.e.

I. **Pre-development**: It is the period before any development policy takes place. In our case we relate this to the situation before taking the adaptation policy.

II. **Take off:** It is the stage immediate after taking the development policy. In our study, it stands for the starting period of adapting the policy.

III. **Acceleration:** The stage when the economy is developing rapid. In our study, we consider a country in this stage since it adopts the optimum level of adaptation.

IV. **Stabilisation**: This stage is the last stage of development process when the economy is stabilised. In our study, this stage refers to a fully adapted economy for changed climatic conditions.

4.2.3 Action Theory of Adaptation

"Action theory of adaptation" (Eisenack & Stecker, 2011) explains that adaptation is exercised by human actors and it requires resources to achieve the intended goals. This study considers that actors are the policymakers who employ necessary resources to adapt to a suitable policy to reduce the negative impacts of climate change. This requires monetary investment as costs of adaptation at appropriate level of actions by the policymakers specifically the government (Malaysian government, as our study focus is on Malaysia).

4.2.4 Social Ecological Resilience Theory

"Social ecological resilience theory" (Adger, 2000) states that social and ecological factors are inter-linked. Based on this theory, we conceptualise that adaptation policies or decision influence the capabilities to adapt, which in turn plays a vital role on the impacts of climate variability on the society. Climate change negative impacts may lead to further climate variability. This is a circular process as described in Figure 1.1, (Chapter 1).

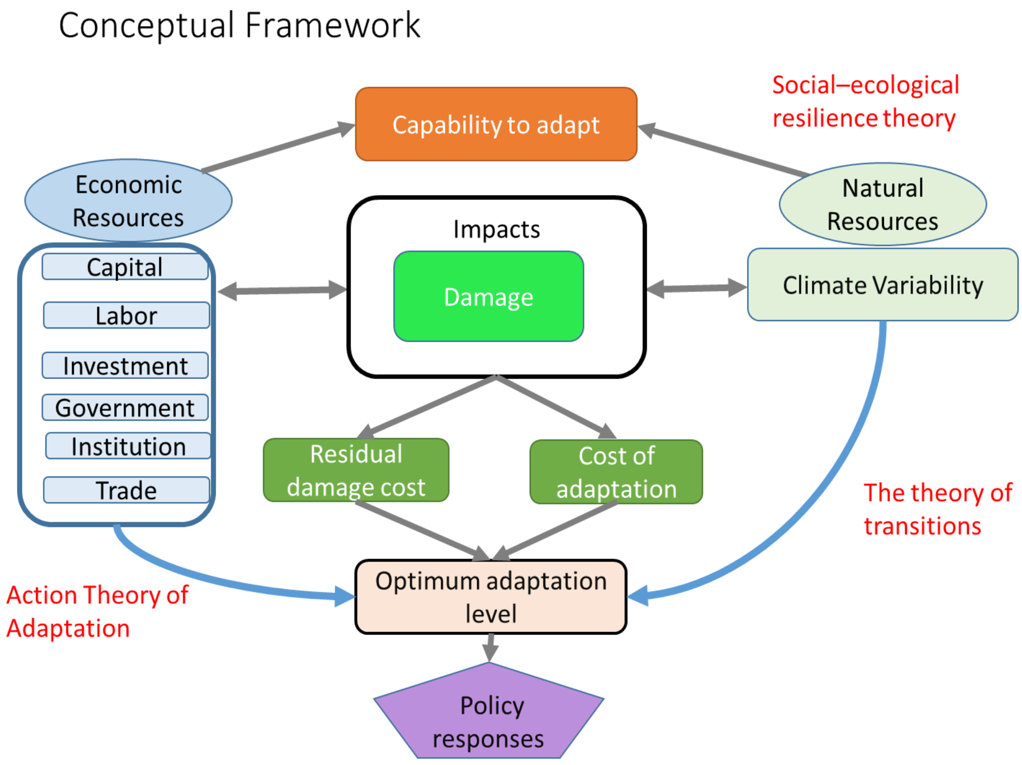


Figure 4.4: Conceptual framework of the study

4.3 Conceptual Framework of the Study

From the adaptation literature, we devise the conceptual framework for this study as shown in Figure 4.4. The conceptual framework shows that the capability to adapt depends on natural resources particularly climate variability and on economic resources such as capital, labor, investments, institution, trade etc. Also, Impacts and damages are dependent on the capability as well as it has a both way relationship between climate variability and economic resources. This damage can be expressed by sum of residual damage costs and costs of adaptation in monetary term. Considering the climate variability and economic resources for associated damage, the optimum adaptation level can be determined. The cost of damage for this optimum level can be used to find out the policy response. That means what will be the impacts on the economy if the costs of adaptation are added to the production cost to establish whether the policy is cost effective or not.

Planned adaptation[1] policies will increase the government expenditure by the amount of the implementation costs for that policy. Therefore, as a developing country, it is necessary for Malaysia to find out the cost effectiveness of this policy, so that this policy does not become a burden for the society as a whole.

4.4 Modelling Method

In order to achieve the aims of the study, we have used the computable general equilibrium model which is based on the general equilibrium framework. The general equilibrium framework has been chosen for this study because CGE models have the ability to represent sectoral and regional scopes of the impacts and policy responses in a comprehensive way. Hence, it can consider sector specific and global/regional/local climate damage functions in the most straightforward manner.

This study considers quantitative approach of analysis. Figure 4.5 shows steps and procedures for this study. This study is based on the secondary data which has been collected from different institutions of Malaysia. The main sources are the Department of Statistics (DOS), the Economic Planning Unit (EPU), Household Income and Expenditure survey (HIES) and Labor Force Survey (LFS). We constructed the Social Accounting Matrix (SAM) for Malaysia based on the available data according to our study objectives. After construction of the SAM from different data sources for different time periods, the SAM needs to be balanced for the calibration process. Thus the next step is to balance the data by RAS method to get a systematic and balanced SAM. The last step is to use this SAM for calibration of the policy impacts to achieve the study objectives. There are varieties of Integrated Assessment models (IAMS) under the CGE

---

[1] "Planned adaptation is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change, and that action is required to maintain, or achieve, a desired state." IPCC AR4

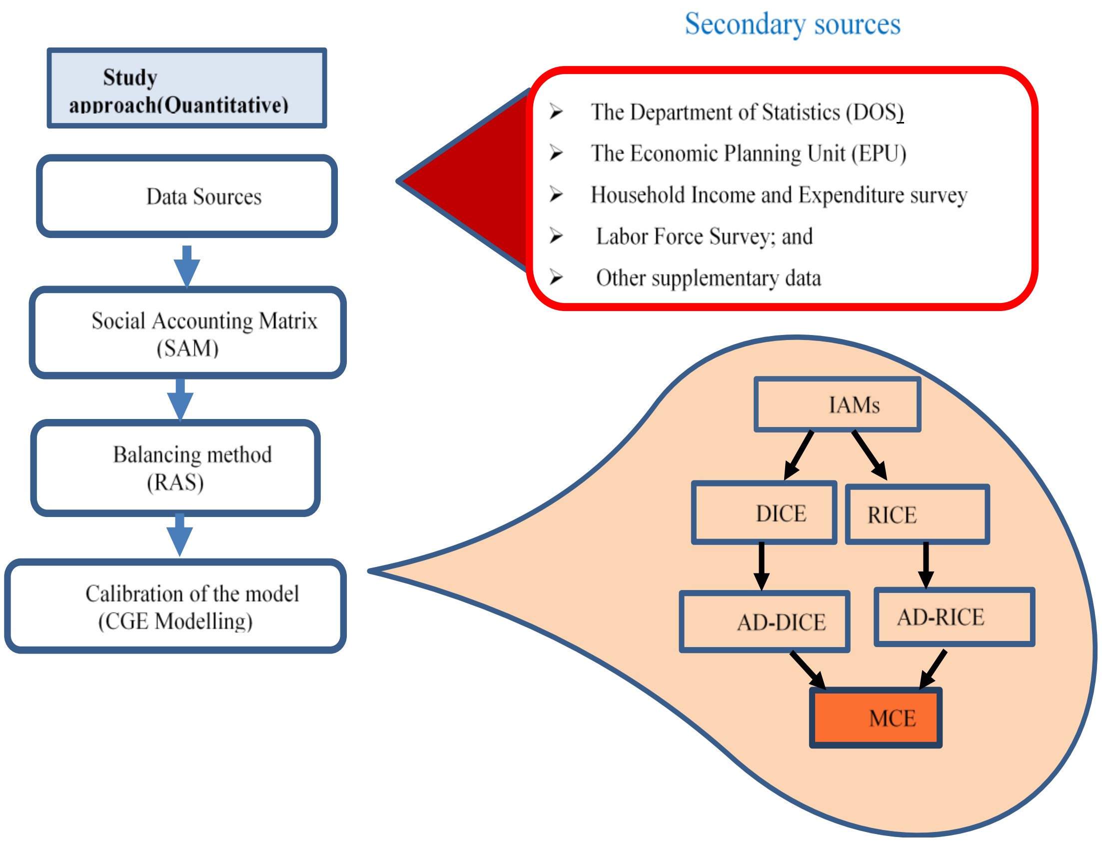


Figure 4.5: Process for the development of Malaysian Climate Economy Model (MCE)

framework, among which we find DICE (Dynamic Integrated Climate and Economy) and RICE (Regional Integrated Climate and Economy) models to fit the environmental policy impacts on the global and regional economy.

However, these models do not consider adaptation as explicit variable in the model while there extensions (AD-DICE and AD-RICE) do. Therefore, for the calibration, we consider AD-DICE and AD-RICE models as our base model to construct our country specific model Malaysian Climate and Economy (MCE) model.

In order to measure the distributional and simultaneous effects of the climate change adaptation policy on the Malaysian economy, a dynamic computable general equilibrium model has been developed for this study. *MCE* investigates the policy responses on the economy by applying an optimum level of adaptation, and measure the responses of the economy with and without adaptations. The novelty of this specific

CGE model is that it captures the economy wide- impacts together with environmental and cost effects. Specifically the sectoral changes in outputs, net consumptions, government revenues and other macroeconomic variables resulting from the policy changes are available from this model.

4.4.1 Detailed Data Sources

This study uses data for all sectors of the economy collected from recent I-O tables issued in 2005. From the I-O table of 2005, we have used the data on Intermediate Inputs, Final Goods and Services, Production, Total Demand, Total Supply, Export and Import, Labor and Capital used and Indirect taxes. In order to construct a SAM for 2005, a time-series data for the year (2005) are used.

Besides that, typical SAMs also require additional data such as total household income (by income category), factor of payments in total, total amount of government revenues and expenditures (including inter-government transactions), institutional distribution of income, and transfer payments (both for production sectors and households). It is also combined with the national accounts and Household Income and Expenditure Survey (HEIS) data within a consistent framework for expenditures and savings patterns. Specifically, the secondary time series data is used to construct the SAM for 2005 are HEIS and National Account Statistics Data for the year (2005) published by the Department of Statistics, Malaysia (DOSM) and Malaysia Government Expenditures and Revenues Data for the (1990 - 2010) period published by the Ministry of Finance.

For calibration of the model, additional data on climate change from different sources are used. Specifically, data on Malaysian temperature change are taken from Malaysian Metrological Department (MMD), the data on emission concentration of

Malaysia are taken from World Bank estimates. The values of adaptation coefficient, damage exponents, sea level rise, etc. are taken from the Ad-RICE estimation model for middle income country.

4.4.2 Instrument for Data Analysis

This study utilised three instrumentals techniques for the data analysis. In order to develop a benchmark database of SAM 2005 and reconcile it with Input Output data with SAM framework, this study will use the Excel 2013 software for database development. Secondly, to balance the SAM, RAS method will be used. The main instrument for analysis to achieve the objectives of the study is the *General Algebraic Modelling System* (*GAMS*). This software is used to solve nonlinear and mixed-integer problems and make the economy-wide complex mathematical models which is easier to construct.

4.5 Assumptions in the CGE Model

The CGE modelling is based on an estimated Social Accounting Matrix (SAM) framework for the Malaysian economy in 2005. In line with this, few assumptions have been made in this study. Nevertheless, few modifications in terms of functional form and model's assumptions in the production function technology have been made especially to align with the research objectives that are to capture the economy wide effects of adaptation policy on the economy. The specific assumptions of the CGE model are as follows:

i) The models comprise of *set of non-linear simultaneous equations* having different order of degrees.

ii) Producers maximise the profit subject to the “*constant return to scale”* which indicates same proportional change between outputs subsequent to a proportional change in inputs.

iii) Producers minimise the costs subject to a production function with the choice between factors governed by a *Constant Elasticity of Substitution (CES)* in the production function.

iv) The production technology is organised by a *nested structure* which means that the elasticity of substitution may vary at the different level of nesting hierarchy i.e. *Constant Elasticity of Substitution (CES)* and *Leontief Fixed Proportion,* and are independent of each other.

v) Total sectoral output, represented by a *CET* aggregation of goods and services supplied to the export market (*E*), and goods sold on the domestic market (*D*) while composite commodities Q_i represent the *Armington* function differentiated for sectoral imports (*M*), and domestic good supplied to the domestic market (*D*).

vi) The fundamental equations must satisfy certain restrictions of general equilibrium theory which includes the “*Market Clearing Conditions*” and “*Macroeconomic Closure”* process which feeds back into the behavioral equations for demand and supply of commodities and factor market, as well as macroeconomic balances (i.e. Saving-Investment Balance and Balance of Payments) that creates simultaneous equilibrium quantities.

vii) Producers maximise profit by taking the equilibrium of input and output prices as given at the supply side while consumers maximise utility subject to their budget constraints defined by their initial factor endowments at the demand side.

viii) The primary factors of the production (i.e. labor and capital) are assumed to pay the same average wage or rental irrespective of sectors.

Before we proceed to specific detail of our MCE model, the standard of CGE model and SAM are discussed in the following section. It also describes pros and cons of the general CGE approach and how the impacts of climate change are implemented in CGE models.

4.6 The Standard Computable General Equilibrium (CGE) Modelling

The basic idea of CGE modelling is to perform empirical implementation of the theoretical economic models. In order to estimate the impacts of different policies on the social welfare, a general equilibrium approach is taken supported by empirical data. The CGE model is established on the basis of Walrasian General Equilibrium (GE) theory. A system of equations representing the supply of goods by producers, demand for goods by consumers, and the equilibrium condition that demand equal supply on each market is explained simultaneously (Arrow & Debreu, 1954). However, the CGE model allows for some modifications like imperfect markets and externalities.

In order to explain the term CGE it is useful to proceed by literal meanings. Computable stands for numerical calculations by computer. The term Equilibrium refers to the concept of market equilibrium. This concept includes the micro foundation of profit maximizing firms and utility maximizing households. Hence agents have no incentive to revise their decisions. Finally, the approach is General since all markets are interconnected and not considered separately in a partial equilibrium.

The Walrasian equation system represents the inter-dependencies between markets via commodities and corresponding payment flows between market agents. These circular flows represent a closed system. Closed means that there cannot be a payment or commodity flow from one agent that has no recipient. The budgets of all agents have to be balanced. Agents obtain a certain income that can be spent on goods (Shoven & Whalley, 1984).

The general procedure of a CGE can be explained in nine steps (Brocker, 2004). The procedure uses the formalised system of equations for Walrasian general equilibrium theory:

1. The first step is to delineate agents (producers, consumers, state) and markets (food, cars etc).

2. The next step is to organise the data for a computer program. In a so called Social Accounting Matrix (SAM).

3. A market form (usually perfect competition) is assumed.

4. An arbitrary benchmark price is chosen.

5. The functional forms of supply and demand are specified to set up the model.

6. The sixth step is the calibration of the model. This is a crucial point. Only one time period is included in the SAM and parameters are chosen, to reproduce the benchmark data. There is no information on reactions of the agents, which is needed to specify the slope parameters (elasticities). Estimation of these slope parameters is only possible with longer time periods. Since this is not the case within the CGE analysis this information has to come from econometric analysis outside the CGE.

7. The next step is to compute the policy effects.

8. The procedure continues with the analysis of welfare effects.

4.6.1 Pros and Cons of the Basic Model

In CGE models like all general equilibrium models price changes cause simultaneous reactions in all other markets. This property is important for the two main advantages which are the micro foundation and the inclusion of economic feedback processes. The micro foundation consists of three conditions, namely market clearance, zero profit of firms and income balance of the households. These principles are considered in the formulation of a CGE. Because of the inclusion of economic feedback processes (due to price changes that lead to quantity changes), CGE can be used for long-term perspective analysis (Walz & Schleich, 2009).

A significant weakness of CGE is the already mentioned poor empirical foundation of the calibration. Only observations from one year are used to calibrate the shift parameters. The production and utility functions are constrained to constant elasticity of substitution (CES). The parameters for these functional forms come exogenously from empirical estimation of elasticities and not from the calibration process. These best guess values add a large uncertainty into the model. Specially the chosen elasticity has a significant effect on the results (West, 1995).

4.7 The Basic Social Accounting Matrix (SAM)

A Social Accounting Matrix (SAM) is a matrix form representation of the micro economic and macroeconomic transactions record of a socio-economic system, which particularly capture the transfers and transactions among all agents in the economic system (Pyatt & Round, 1985); (Relnert & Roland-Holst, 1997). It is an exemplification of the National Accounts for a specific country, though it can be extensive to comprise multi-national accounting flows, and thus it is able to be constructed for whole regions or global context. SAM recognises all monetary flows from sources to recipients, within a disaggregated national account.

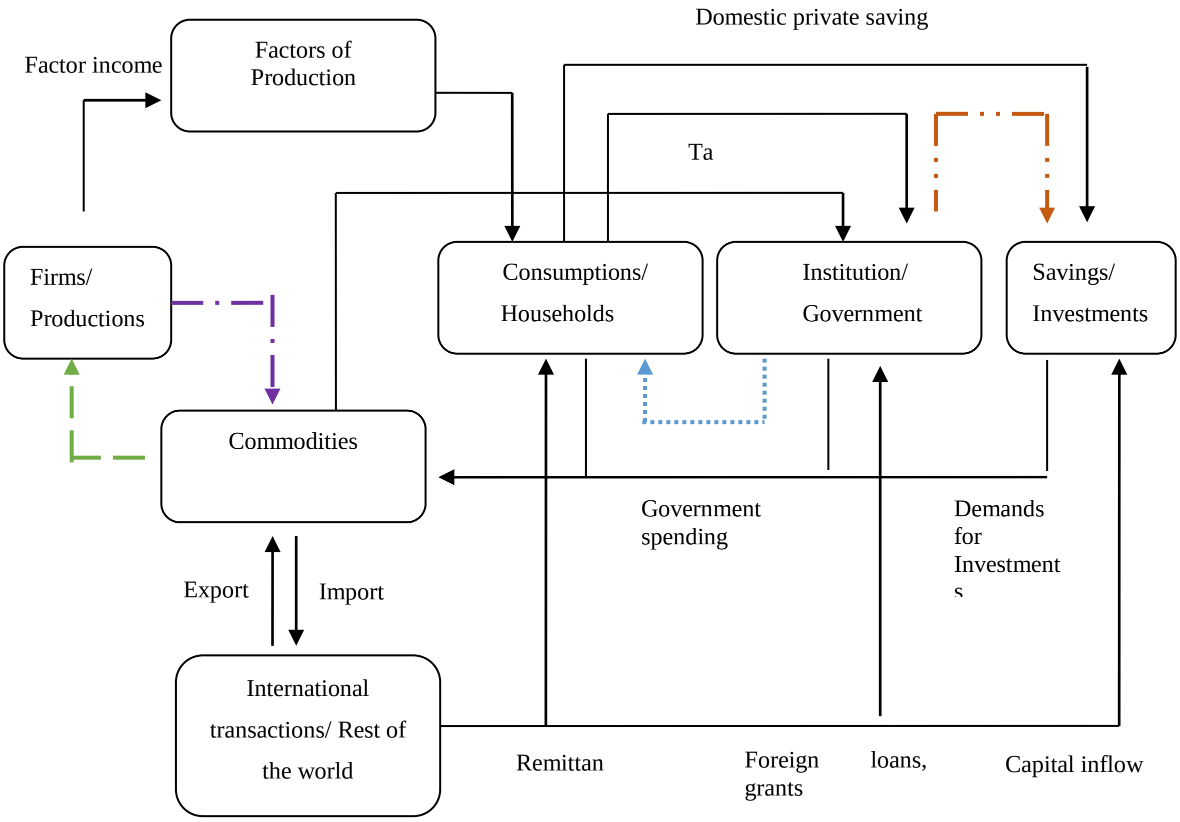


Figure 4.6: Circular flow diagram of an economy

For well understanding, we can consider the circular flow diagram of an economy showed in figure 4.6 that captures all real transactions including all transfers among institutions and sectors. Production procedure is required to hire factors of productions such as capital, land, and labor inputs (with the rental/wages) from the factor markets, and from the commodity markets, it requires intermediate inputs to produce final goods and services. These domestically produced commodities are supplemented by imports of commodities. Thus completing the total amount of commodities that are sold through markets to the households, the investors, the government and the foreigners. Figure 4.6 explains the circular flow of the economic activities which shows that each institution’s income becomes another institution’s expenditure. For instance, the government and households transfer income to the producers by purchasing the commodities. Yet again producers use this income to carry on further production activities. Also, further inter-institutional transactions, for example savings and taxes, ensure that the circular flow of incomes is a closed system. More specifically, all expenditure and income flows are accomplished, whether it is domestic or international transactions and there are no overflows from the system.

In figure 4.6, dotted arrow indicates government transfers to households. The dashed arrow indicates firm’s income from selling the commodities. The dot and dashed arrow shows intermediate demands. The double dot and dashed arrow shows fiscal surplus of the government. For all solid arrows, the indicators are stated inside the diagram.

Likewise, a social accounting matrix (SAM) is also a framework that assigns numerical values to the expenditures and the incomes in the circular flow of economy. It is a matrix representation of the circular flow diagram with real monetary figure. SAM is a square matrix, meaning, number of rows must equal to the number of columns in which each column and row is denoted as an “account.” Table 4.1 shows a SAM of an economy that associates to the circular flow diagram in figure 4.6. Every single box in the diagram is considered as an account in the SAM. Each and every cell in the matrix signifies a monetary flow from a column account to a row account. For instance, the private consumption spending of the circular flow diagram indicates a flow of funds to the commodity markets from households. In the SAM, this value is represented by the commodity row and the household column. The total expenditure must equal to the total revenue for each and every account in the SAM (to satisfy the principle of double-entry accounting systems). Thus, for every account, column and row totals must be the same.

Table 4.1 shows the general components of a SAM. The SAM differentiates between the “commodities” and the “activities”. The activities are the entities that produce goods and services for an economy while commodities are those goods and services produced by activities. They are differentiated for the reason that, an activity is able to produce more than one type of commodity (by-products). Likewise, a commodity can be produced by more than one type of activity. For instance, rice can be produced by large-scale or small farms. The monetary values in the activity accounts are typically calculated in producer prices which implies, factory gate or farm gate prices. Activities produce commodities (goods and services) by using the factors of production along with intermediate inputs. This fact is displayed in the activity column of the SAM, where each activity pays to the factors of production, i.e., the rents, wages and profits they generate during the production procedure (that is, value-added). Since it is a payment transferred from activities to factors, therefore, in the SAM, the value-added entry appears in the factor row and the activity column [Row 3-Column 1].

In the same way, the payment for intermediate demand is transferred from activities to commodities. [Row 2-Column 1]. Accumulation of value-added and intermediate demand is needed for gross output. The data on production mechanism included in the activity column is the input part of a usual “input–output table,” which implies the required factor and the required intermediate inputs for per unit of output. Goods and services are either produced domestically and supplied domestically [Row 1-Column 2] or imported from other countries [Row 7-Column 2]. For domestically produced commodities, indirect sales taxes are paid to the government while for imported commodities, import tariffs are paid to the government [Row 5-Column 2].

Table 4.1: Fundamentals of a Standard SAM

	Activities	**Commodities**	**Factors**	**House-holds**	**Govt.**	**Savings and investment**	**Rest of the world**	**Total**
Activities		Domestic supply						Activity income
Commodities	Intermediate demand			Consumption spending	Recurrent spending	Investment demand	Export earning	Total demand
Factors	Value-added							Total factor income
Households			Factor payments to households		Social transfers		Foreign remittances	Total household income
Government		Sales taxes and import tariffs		Direct taxes			Foreign grants and loans	Government income
Savings and investment				Private savings	Fiscal surplus		Current account balance	Total savings
Rest of the world		Import payments						Foreign exchange outflow
Total	Gross output	Total supply	Total factor spending	Total household spending	Govt. expense	Total investment spending	Foreign exchange inflow	

As mentioned earlier, activities purchases commodities for using it as intermediate inputs for the production process [Row 2-Column 1]. However, final demand for each commodity consists of household consumption expenditure for that commodity [Row 2-Column 4], government expenditure (recurrent) [Row 2-Column 5], investment or gross capital formation [Row 2-Column 6], and export demand of that commodity [Row 2-Column 7]. The SAM in Table 4.1 shows only single commodity and activity rows and columns.

However, a SAM usually comprises of a number of various commodities and activities. For example, in our study we have 15 different activities and commodities based on our study focus. As our main focus is on the agricultural sector of Malaysia, we disaggregated the SAM into 10 different agricultural sectors and 5 other sectors.

Households are usually the ultimate owners of the factors of production, and therefore, they receive the incomes earned by the factors during the production procedures [Row 4-Column 3]. Also, they receive transfer payments (TP) from the government [Row 4-Column 5] (for instance, pensions and social security) and from the rest of the world (ROW), they receive the remittances from foreign workers [Row 4-Column 7]. On the other hand, households pay direct and indirect taxes to the government [Row 5-Column 4] and households purchase commodities to consume [Row 2-Column 4]. The surplus income (if positive) will be saved or dissaving (if expenditure is higher than income) [Row 6-Column 4]. The data for household accounts is typically collected from the national accounts and household income and expenditure surveys from the country's bureau of statistics.

From the ROW, the government receives transfer payments (TP) in a form of foreign grants and development assistance [Row 5-Column 7]. Total government revenues thus consist of income from all type of taxes and TP from ROW. Now in the expenditure side, the government pays for recurrent consumption expenditure [Row 2-Column 5] and transfer payments to the households [Row 4-Column 5]. The gap between total revenues (TR) and total expenditures (TE) is the fiscal surplus (or fiscal deficit, if expenditure is higher than revenue) [Row 6-Column 5]. Information about the government accounts are normally available from public-sector budgets published by a country's Ministry of Finance.

In keeping with the concepts of ex-post accounting identity, the total investment or gross capital formation (including changes in inventories or stocks) must be equal to the total savings. The total capital inflows (from aboard) is the difference between the total investment demands and the total domestic savings and is referred to as the current account balance [Row 6-Column 7]. Information on the current account (or rest of world) is drawn from the balance of payments, which is generally published by a country's central bank.

4.8 SAM Market Closure

There are three conditions of market closure that the standard SAM must satisfy for the CGE model;

4.8.1 Market Clearance Condition

The Market Clearance Conditions involves commodity market balance and factor market balance**:**

a) *Commodity market balance* implies that the quantity of each commodity X_i, produced by *i* producer will equal to commodity demanded by *j* producer in *n* industries, as an their intermediate inputs (Z_{ij}) to production and by the representatives' agents in the economy as their final demand, F_j, that absorb that commodities:

$$X_i = \sum_{i=1}^{n}\sum_{j=1}^{n} Z_{ij} + \sum_{j=1}^{n} F_j \tag{4.1}$$

b) *Factor Market Balance* implies that all industries in the economy are fully employed by the factor endowment available in the market, in other words, the quantities demanded by primary factor inputs used by all producers, is equal to supply of factor endowments by the representatives agent's, V_j:

$$V_i = \sum_{j=1}^{n} V_j \tag{4.2}$$

4.8.2 Normal Profit Conditions

The second condition is Normal Profit which implies that all industries are assumed to receive a zero profit where the values of the output generated by producer, X_i must equal to the of the values of the inputs of the intermediate goods Z_{ij}**,** and primary factor $V_{j,,}$ that is employed in the production. In other words, total revenue (price times quantity of output produced) generated by producers is equal to total costs derived from the utilisation of intermediate inputs and the value added or primary factors in the production. Since profit is calculated on monetary terms, hence this equation must be timed with the price for cost of intermediate inputs Pi, and the cost of value added W_f. Here, we assume that the average cost for the value added i.e. rental and profit is equal to the average wages of the labor employed and the total revenue is equal to the price P_i, times output X_i.

$$Total\ Revenue = Total\ Cost$$

$$Total\ Revenue \ = \ Cost\ Intermediate\ Inputs + Value\ Added\ Cost$$

$$Total\ Revenue\ (P_i X_i\ ) \ = \sum_{j=1, i=1}^{n} P_i \cdot Z_{ij} + \sum_{j=1}^{n} W_f \cdot\ V_j \tag{4.3}$$

4.8.3 Factor Market Balance

Factor income (m) received by the representative's agents of factor endowments must equal to the value of producer payments V_j (the total value added payments) that utilise the primary factor endowments and equal to the factor's gross expenditure on goods and services which is a total final demand, $F_{j.}$ This condition implies that income must balance with the sum of the elements of V, which in turn must equal to the sum of the elements of total final demands, F.

$$m = \sum_{j=1}^{n} V_j = \sum_{j=1}^{n} F_j \tag{4.4}$$

These are the three basic macro balances that are used to achieve the general equilibrium condition.

4.9 Balancing a SAM

The SAM accounts are represented as a *square matrix* where the inflows (receipts) and outflows (expenditures) for each account are shown as a corresponding row and column of the matrix. As it is an accounting framework, the total receipts by rows and total expenditures by columns for each account must balance following the principles of double-entry accounting systems. However, as the required information to construct a SAM comes from different sources, such as government budgets, household surveys, national accounts, the balance of payments etc., placing all these data within the SAM framework often generate inconsistency between expenditures and incomes of corresponding accounts. For instance, the value of government expenditure in national accounts might vary from the value that is stated in the government budget. Therefore, it is needed to balance the social accounting matrix so that total receipts equal total expenditures.

There are a number of statistical estimation techniques for balancing the SAM. We present a balancing technique that makes it possible to reconcile this information in order to balance a micro-SAM. This technique minimises the changes to the base data using a RAS method, a widely used optimisation technique for balancing SAM. It is an iterative method of bi-proportional adjustments of rows and columns that has been independently developed when new information on the matrix row and column sums are accessible and need to be adjusted with the existing matrix. The RAS technique illustrated by Schnieder and Zenious (1990) is as follows:

Consider a matrix M_{ij}, where M_j, is the vector of column totals. From this matrix, a coefficients matrix A_{ij}^0 can be obtained, as follows:

$$A_{ij}^0 = M_{ij}/M_j$$

Pre and post multiplying this matrix by vectors r_i and s_j, another matrix A_{ij}^1 is obtained. A_{ij} and $A_{ij}^1$are the vectors of target row and column total. This coefficient matrix is now ready to undergo a sequence of iterative multiplications, which is denoted in equations (4.5 (a)) through (4.5(f)). Pre and post multiplication of the initial coefficient matrix by corresponding row and column produces the next iteration coefficient matrix as follows.

$$A_{ij}^1 = r_i A_{ij}^0 s_j$$

The original coefficient matrix is now multiplied by the row of a target column total, M_j* to obtain matrix F_{ij}.

$$F_{ij} = A_{ij}^0 M*_j$$

The row summations of this matrix are represented by the vector u_{i}. A multiplication coefficient r_i for the current iteration is found from the ratio of $u*_i$ to u_{i}. Multiplyng F_{ij} by r_i obtains a new F_{ij}, taking into account of this ratio. A row vector v_j of column totals is obtained from the summation of F_{ij} s for all j column values. It is used in equation (4.5 *e*) to calculate the multiplication coefficient s_j for F_{ij} to balance the columnar differences. The entire sequence of operation is represented in equation (4.5):

$$\begin{aligned} u_i &= \sum_j F_{ij} && (a) \\ r_i &= u_i^*/u_i && (b) \\ F_{ij} &= r_i F_{ij} && (c) \\ v_j &= \sum_i F_{ij} && (d) \\ s_j &= v_j^*/v_j && (e) \\ F_{ij} &= s_{ij} \cdot F_{ij} && (f) \end{aligned} \qquad (4.5)$$

The iterative process in equations (4.5 *a*) to (4.5 *f*) continues until the condition $u_i = u_i^*$ and $v_j = v_j^*$ are met. At that point, the matrix F_{ij} is assumed to be the best estimate of the true posterior matrix M_j*.

4.10 A CGE Model for Malaysian Economy

This section presents a Computable General Equilibrium (CGE) model that is developed as an appropriate method for assessing the economy-environmental effects of adaptation policies in the Malaysian economy. We name it as *Malaysian Climate and economy (MCE)* model. In our study, we have divided the Malaysian Economy into 15 sectors of interest to model the agricultural versus rest of the productions based on Malaysian Input Output (I-O) table. We considered two factors of production, labor and capital. The institutions in the model represent Government, Firms, Households, and Rests of the world and capital account. The next subsection discusses basic structure of the model.

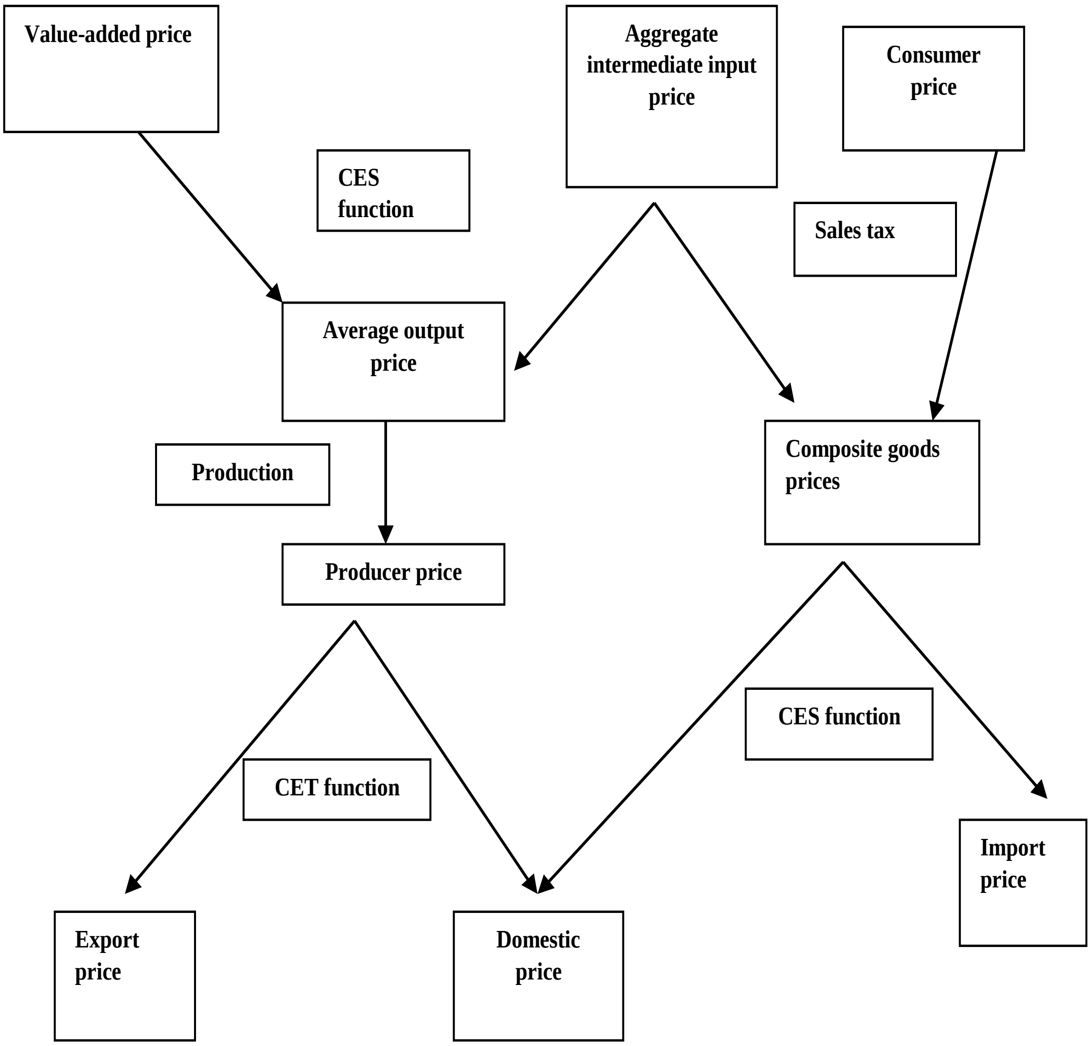


Figure 4.7: Price structure for the MCE model

4.10.1 Basic Structure of the Model

4.10.1.1 Prices

We reasonably assumed that, as a small country, Malaysia is a price taker country that means it has no power to change world import prices. Thus import price is considered as exogenously taken in the model. The country export demand function is downward sloping. Figure 4.7 shows price structure of this economy. The domestic prices of imports and exports are determined by world prices (*pwm* and *pwe*, respectively), exchange rate (*EXR*) and import tariff (*tm*) or export subsidy (*te*). The system of price of the model is rich, mainly due to the assumed quality differences among commodities of different origins and destinations (imports, exports, and domestic outputs that are used domestically).

Table 4.2: Sectors in the Model

Sectors		Sectors from 2005 I-O table
SEC1-A	Paddy	1
SEC2-A	Food Crops	2
SEC3-A	Vegetables	3
SEC4-A	Fruits	4
SEC5-A	Rubber	5
SEC6-A	Oil Palm	6
SEC7-A	Livestock	9-10
SEC8-A	Forestry and logging	11
SEC9-A	Fishing	12
SEC10-A	Other Agriculture	7-8
SEC11-A	Crude Oil & Natural Gas & Mining and Quarrying	13-16
SEC12-A	Industrials	17-94
SEC13-A	Transportation & Communication	95-101
SEC14-A	Financial services	102-107
SEC15-A	Services	108-120

4.10.1.2 Productions

The I-O tables (for Malaysia) for the year 2005 consist of a different number of sectors to represent total economic inter-transactions. Specifically, they have 120 groups of sectors. However, to meet the research objectives, sectors were re-grouped into different group of sectors. Among the 120 sectors 73 are industrial, 12 are agricultural and the rest are broadly crude oil and minerals, transportation and communication, financial services, and services sectors. As our main focus is on agriculture we consider the 10 subsectors among which 9 are directly taken from I-O table while the 10th subsector represents the rest of the three least significant crops. To represent the entire economy we accumulated all other sectors into 5 broad sectors namely Crude oil, natural gas, and, mining and quarrying; Industry; Transportation and communication; Financial services; and Services sectors. Table 4.2 shows the re-grouped sectors for our modelling.

Figure 4.8 shows the nested structure of production activities that capture the income generation by the activities in the production of commodities and net supply of different types of commodities by various kinds of domestic production activities. The sources of production activities incomes are received for the supply of different kinds of commodities through domestic and foreign resources/intermediate inputs (imports) and also through the supply of intermediate commodities to other production activities. It also generates income from the consumption of goods and services by other domestic and foreign (exports) agents in the economy.

All producers are assumed to maximise profits and each faces a two-level nested *Leontief/CES* production function. This flow represents the total gross domestic product that is produced locally of each production activity in part of purchasing raw materials either as domestic products or as import (foreign). However, the rest of the production costs (value added factor payment) indicates values paid out to the factors of productions in the form of wages (labor), rents (land or natural resources), and profits (capital) to resources market (through enterprises) as well as the tax payment to the government.

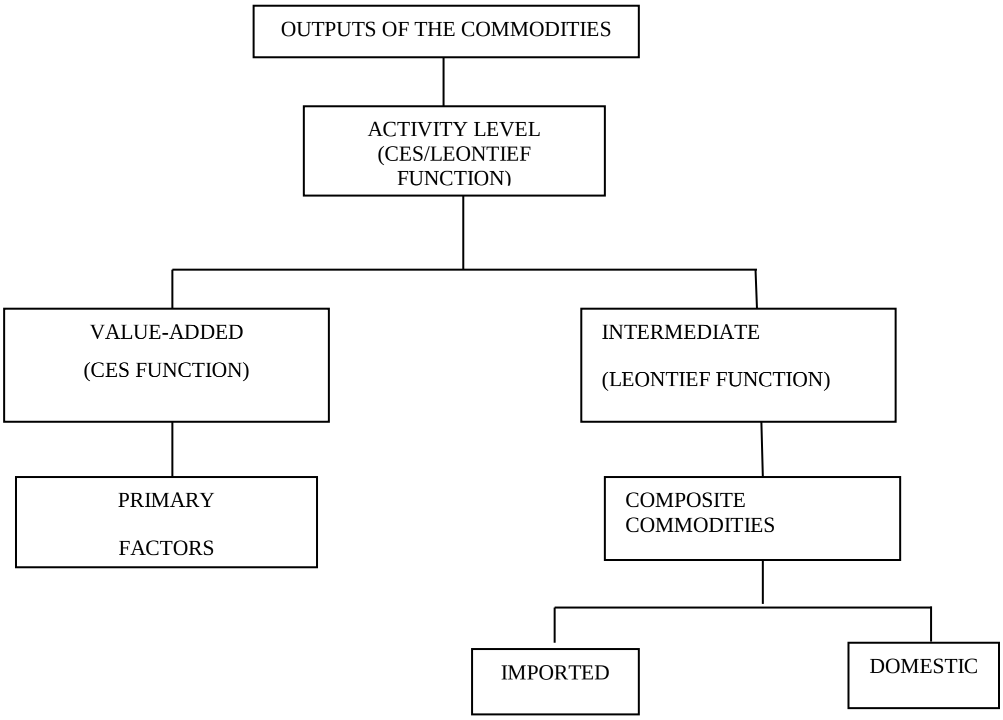


Figure 4.8: Production structure for the MCE model

4.10.1.3 Domestic demand

Figure 4.9 shows the demand structure of the economy. Total composite demand consists of household consumption, government spending, investment demands and intermediate demands. All these four components have a fixed share, for example, the demands for government expenditure are exogenously fixed because government decides how much to demand in particular. Consumption demands imply household’s consumption expenditures in order to maximise household’s utility. Intermediate demands are subject to fixed input-output coefficients. The demands for investment are derived from capital composition matrix (CCM). Total composite demand broadly grouped into total domestic commodity demand and total import demand from the rests of the world.

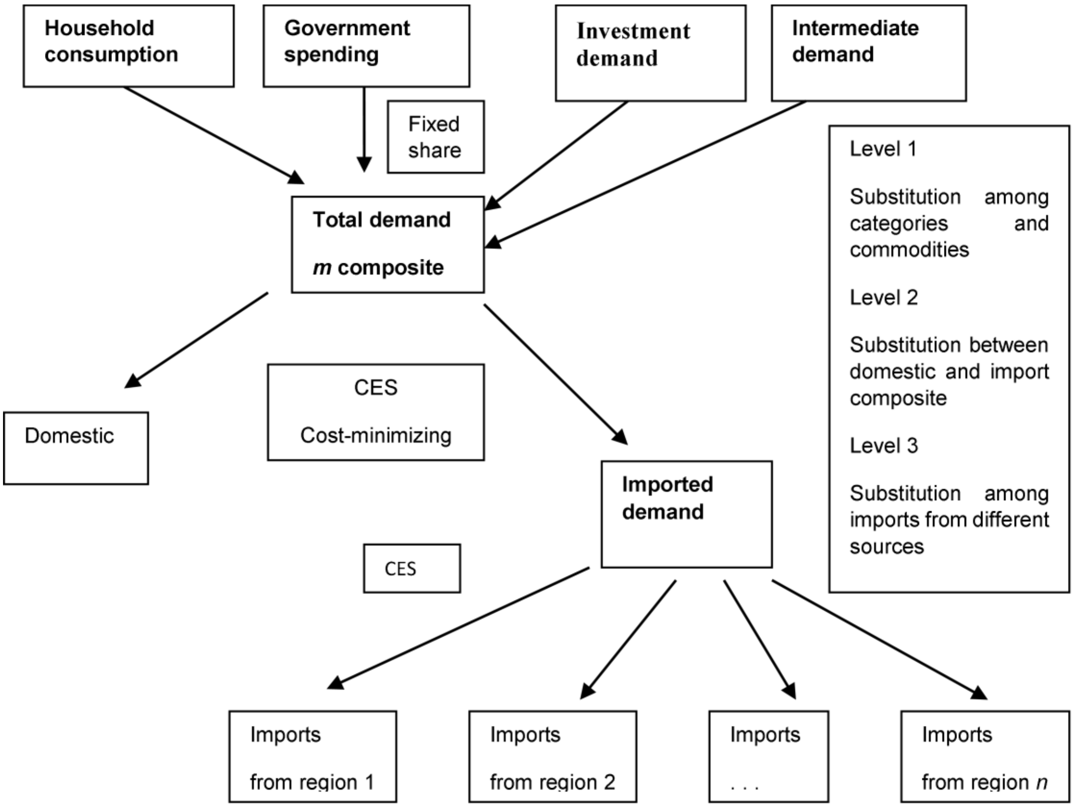


Figure 4.9: Demand structure for the MCE model

4.10.2 Mathematical Statement and Specification of the MCE Model

This section presents mathematical modelling of the MCE model. In its mathematical form, the CGE model consists of a set of nonlinear simultaneous equations where the number of equations is equal to the number of endogenous variables. The model equations, divided into ‘blocks” for prices, production and commodities, institutions, climate change and system constraints. Explanatory boxes are added for each block of equations. According to our study objectives, we considered five different blocks of equations. A brief overview of each equation block is given in Figure 4.10.

Price Block

Import price
Export price
Composite price
Activity Price
Composite intermediate input price
Value added price
Consumer price index

Production And Commodity Block

Production function
Value added function
Armington function
Import demand function
Output transformation function
Export supply function

Institution Block

Household income function
Households' sectoral consumption function
Households saving investment equation
Govt. income equation
Govt. expenditure equation

Climate Change Block

Gross damage function
Climate impact function
Monetary damage function
Residual damage function
Adaptation cost function

System Constraint Block

Factor market equilibrium
Product market equilibrium
Foreign exchange market equilibrium
Saving investment closure

Figure 4.10: Block of equations

4.11 Price Block

As mentioned earlier, Malaysia is a developing country; therefore, it acts as a "price taker" for imports and exports. The 'small country' model is assumed in MCE means that the prices of imports and exports are exogenously driven. The price block contains equations in which endogenous model prices are associated with other prices (exogenous or endogenous) and to non-price model variables. The corresponding equations are given below:

4.11.1 Import Price

The import price (PM_c) in domestic-currency units (DCU) is the price paid by the domestic users for imported commodities (exclusive of the sales tax). Equation (4.6) state that it is a transformation of the world price of these imports (pwm_c), considering the exchange rate (EXR) and import tariffs (tm_c) plus transaction costs per unit of the import (icm). For all commodities, the market price paid by domestic commodity consumers is the composite price, PQ (in this equation, PQ applies only to payments for trade inputs). The exchange rate and domestic import price are flexible, while the tariff rate and the world import price are fixed, following the "small-country" assumption.

$$PM_c = (1 + tm_c) \cdot EXR \cdot pwm_c \tag{4.6}$$

Where

PM_c = import price in domestic currency units (DCU) including transaction costs

pwm_c = C.I.F. import price in foreign currency units (FCU)

tm_c = import tariff rate

EXR = exchange rate (DCU per FCU)

4.11.2 Export Price

The export price (PE_c) in *DCU* is the price received by the domestic producers when they sell their output in export markets. This equation is structurally similar to the import price definition. The main difference is that the tax and the cost of trade inputs reduce the price received by the domestic producers of exports. We assume that the set of exported commodities are all produced domestically.

$$PE_c = (1 - te_c) \cdot EXR \cdot pwe_c \tag{4.7}$$

Where

PE_c = export price in DCU

pwm_c = F. O. B. export price in FCU

te_c = export tax rate

EXR = exchange rate (DCU per FCU)

4.11.3 Composite Goods Price

Under *Armington assumption*, domestically produced and imported goods are imperfect substitutes in CGE modelling. With this assumption, a constant elasticity of substitution (CES) function is derived (also known as Armington function). Composite commodity price is total domestic spending on a commodity at domestic consumer prices. Equation (4.8) defines it excluding the sales tax. Absorption is expressed as the sum spending of domestic outputs and imports at domestic sales prices, PD_c and PM_c. Prices PD_c and PM_c include the cost of trade inputs but exclude the commodity sales tax.

$$PQ_c \cdot QQ_c = [PD_c \cdot QD_c + (PM_c)_{c \in CM}] \cdot (1 + tq_c) \tag{4.8}$$

Where,

$QQ_c =$ Quantity of goods supplied to domestic market (composite supply)

$QD_c =$ domestic sales quantity

$PD_c =$ domestic sales price

$PM_c =$ imports price

$tq_c =$ sales tax rate (as share of composite price inclusive of sales tax)

4.11.4 Domestic Output Price

For every single domestically produced commodity (QX_c), the marketed output value at producer prices (PX_c) is stated as the sum of domestic sales and exports values. Domestic sales (QD_c) and exports (QE_c) are valued at the prices received by the suppliers, *PDc* and PE_c, both of which have been adjusted to account for the cost of trade inputs.

$$PX_c \cdot QX_c = PD_c \cdot QD_c + (PE_c \cdot QE_c) \quad (4.9)$$

Where

PX_c = aggregate producer price for commodity

PD_c = domestic sales price

QD_c = aggregate quantity of domestic output

PE_c = exports price

QE_c = quantity of exports

4.11.5 Activity Price

The activity price (PA_a) is the gross revenue for each activity (i.e., the unit return from sale of output). It can also be expressed as the summation of the amount of production per activity unit multiplied by the activity-specific commodity prices for all commodities. This allows the fact that activities may produce multiple commodities.

$$PA_a = \sum PX_c \cdot \theta_{ac} \quad (4.10)$$

Where

PA_α = activity price

PX_c = aggregate producer price for commodity

θ_{ac} = quantity of commodity c′ as trade per exported unit of C produced and sold domestically

4.11.6 Value Added Price

$$PVA_a = PA_a - \sum PQ_c \cdot ica_{ca} \quad (4.11)$$

Where

PVA_a = value added price

PA_a = activity price

PQ_c = Composite commodity price

ica_{ca} = non exported commodities

4.11.7 Consumer Price Index

$$\overline{CPI} = \sum PQ_c \cdot cwts_c \tag{4.12}$$

Where

$\overline{CPI}$ = $c$onsumer price index (exogenous variable) and

$cwts_c$ = weight of commodity c in the consumer price index

4.11.8 Producer Price Index for Non-traded Market Output

$$PPI = \sum PDS_c \cdot dwts_c \tag{4.13}$$

Where

PPI = producer price index (exogenous variable), and

$dwts_c$ = weight of commodity c in the producers price index

Equations (4.12) and (4.13) define the consumer price index (*CPI*) and the producer price index (*PPI*) for domestic market outputs. The *CPI* is the weighted sum of composite goods prices whereas PPI is the weighted sum of domestic goods prices. Either index can be used as ***numeraire*** price so that all other prices are measured relative to it.

4.12 The Production and Commodity Block Equations

As stated in the model assumptions, each sector produces a gross output (*xi*) with constant returns to scale and minimise their costs subject to a production function. The technology of production is usually represented by a series of Constant Elasticity of Substitution (*CES*) functions which can be organised by a nested structure reflecting the production hierarchy (Shoven, 1992). This means that the elasticities of substitution may vary at different levels of the nesting hierarchy and independent of each other.

4.12.1 Factor Income

Equation (4.14) defines the total income for each factor (YF_f). Here, this income is split into domestic institutions in fixed shares after payment of direct factor taxes ($(1 - t_f)\cdot YF_f$) and transfers (*trnsfr*) to the rest of the world (*ROW*). The latter are fixed in foreign currency and transformed into domestic currency by multiplying with the exchange rate (*EXR*). This equation becomes references to the set of domestic institutions (household, enterprises, and the government, a subset of the set of institutions, which also includes the rest of the world).

$$YF_f = shry_{hf} \sum WF_f \cdot WFDIST_{fa} \cdot QF_{fa} \tag{4.14}$$

Where

YF_f = income of factor f

4.12.2 Household Income

$$YH_h = \sum YF_{hf} + tr_{h,gov} + EXR \cdot tr_{h,gov} \tag{4.15}$$

Where

YH_h = income to domestic institution i from factor f

$\sum YF_{hf}$ = total of factor incomes

$tr_{h,gov}$ = transfer from factor, $government\ and\ ROW$

EXR = *Exchange rate*

4.12.3 Household Consumption Demand

Private consumption is showed in equation (4.16) by summing household demands determined using fixed expenditure shares.

$$QH_{ch} = \frac{\beta_{ch} \cdot (1 - mps_h) \cdot (1 - ty_h) \cdot YH_h}{PQ_c} \tag{4.16}$$

Where

QH_{ch} = Private consumption

PQ_c = Price of composite good

mps_h = Hoousehold saving rates

YH_h = Household income

ty_h = Household income tax rate

β_{ch} = Household expenditure shares

4.12.4 Investment Demand

Fixed investment demand ($QINV$) is defined as the base-year quantity ($\overline{qinv}$) multiplied by an adjustment factor ($IADJ$). For the basic version of the model, the adjustments factor is exogenously determined, and therefore the quantity of the investment turns out to be exogenous.

$$QINV_c = \overline{qinv}_c \cdot IADJ \tag{4.17}$$

Where

$QINV_c$ = quantity of fixed investment demand for commodity,

$\overline{qinv}_c$ = base − year quantity of fixed investment demand

$IADJ$ = investment adjustment factor (exogenous variable)

4.12.5 Government Revenue

Total government revenue (YG) is the sum of revenues from taxes ($TINS$), factors (tf_f) and transfers from the rest of the world ($trnsfr_{gov,row}$).

$$\begin{aligned} YG = \sum TINS_i \cdot YI_i + \sum tf_f \cdot YF_f + \sum tva_a \cdot PVA_a \cdot QVA_a \\ + \sum ta_a \cdot PA_a \cdot QA_a + \sum tm_c \cdot pwm_c \cdot QM_c \cdot EXR \\ + \sum te_c \cdot pwe_c \cdot QE_c \cdot EXR + \sum tq_c \cdot PQ_c \cdot QQ_c \\ + \sum YIF_{gov,f} + trnsfr_{gov,row} \cdot EXR \end{aligned} \tag{4.18}$$

Where

YG = Government Revenue

4.12.6 Government Expenditure

Total government spending (EG) is the sum of government spending on consumption and transfers.

$$EG = \sum tr_{h,gov} + \sum PQ_c \cdot qg_c \tag{4.19}$$

Where

EG = Government Expenditures

4.13 System Constraints Block

4.13.1 Factor Markets

Factor market equilibrium requires that for each factor, total demand (QF) for that factor must be equal to the supply of that particular factor ($\overline{QFS}$). In the basic version of the model, at a given time supply of factors is fixed while the demands are flexible/variable. The model uses WF_f (The factor wage paid by each activity) as an equilibrating variable, to satisfy factor market equilibrium. An increase in increases WF_f the wage paid by every single activity, $WF_f . \overline{WFDIST}_{fa}$, which is inversly related to the quantity demands for factor, $QF_{f\,a}$. All factors are movable among the demanding activities.

$$\sum QF_{f\,a} \quad = \quad \overline{QFS}_f \tag{4.20}$$

Where

$\overline{QFS}_f$ = quantity supplied of factor (exogenous variable)

4.13.2 Composite Commodity Markets

Composite commodity market equilibrium requires that, demand for composite commodity must be equal to the quantity supplied for it. The demand for composite commodity consists of endogenous terms and changes in inventories which is exogenous. In the basic version of the model, *QG* and *QINV* are fixed. The supply of composite commodities, QQ_c, drives quantity demand for domestic commodity *QD*, and imports *QM*. The domestic prices *PDD* and *PDS* are acts as market clearing variable along with quantities of import supply, for the output of the domestic market.

$$QQ_c \;=\; \sum QINT_{ca} + \sum QH_{c\,h} + qg_c + QINV_c \tag{4.21}$$

Where

qg_c = quantity of stock exchange

4.13.3 Current-Account Balance for the Rest of the World (in Foreign Currency)

The current-account balance (expressed in terms of foreign currency) usually indicates country's expenditure to the rest of the world and must be equal to the country's income in foreign currency. That means spending for imports and factor income outflows must equal to income from exports and factor income inflows (foreign saving, *FSAV*). For the basic version of the model, *FSAV* is fixed and the real exchange rate (EXR) plays the role of balancing variable in the current account.

$$\sum pwm_c \cdot QE_c + \sum tr_{i,row} \; + \; FSAV = \sum pwm_c \; \cdot QM_c \tag{4.22}$$

Where

$FSAV$ = foreign savings (FCU)(exogenous variable)

4.13.4 Savings-Investment Balance

Equation (4.23) states that total investment must be equal to total savings. The total savings is the sum of savings of the national non-governmental institutions, the government savings and the savings from the rest of the world, the last element of being converted in local currency. Total investment is the sum of the values of the changes in stocks and fixed investments (gross fixed capital).

$$\begin{aligned} &\sum mps_i \cdot \; (1 - \; ty_h) + YH_h \; + (YG - EG) + EXR \cdot \; FSAV \\ &\qquad = \sum_{c \epsilon C} PQ_c \cdot \; QINV_c + WALRAS \end{aligned} \tag{4.23}$$

Where

YH_h = household consumption expenditures

Price Normalisation

$$\sum PQ_c \cdot \; cwts_c = cpi \tag{4.24}$$

4.14 Climate Change Block

CGE models are commonly used for quantifying the costs and benefits of an environmental policy. The aim is to simulate how economic activity affects the environment and vice versa. Furthermore, CGE models deal with question how technological development and production are influenced by environmental policies (Dellink, Hofkes, van Ierland, & Verbruggen, 2004). The impacts of global warming are usually entered into the CGE model as monetised damages. Aggregate monetised gross damage (*GD*) is modelled as a function of the climate variable:

Then, gross damage is a function of climate variable.

$$GD_t = \propto_i \Delta T_t^2 \tag{4.25}$$

Where, the change of global mean temperature (ΔT_t) compared to a base year is used and α_i are the parameters of the damage function. Mostly, the functional form is assumed to be quadratic (or at least the power is greater than 1). This allows for increasing impact on costs when temperature rises.

Again, the climate impact function is

$$T_t = \propto_j T_{t-1} + \propto_k EM_t \tag{4.26}$$

Where, as the exogenous shock, an increase in carbon dioxide emissions (EM_t) by a certain amount leads to an increase in the global mean temperature (T_t) compared to the level of the period before.

Damages grow linearly with GDP is a constant fraction of GDP. This linear trend can be influenced by further factors shifting the amount of damages up or down. For example population growth results in increased number of consumers. Then income growth affects people's valuation of impact and this result in a change of tastes affecting valuation.

$$EM_t = \Omega \cdot Y_t(1 - \mu_t - AL_t) \tag{4.27}$$

Where, cumulative emission depends on output and adaptation and mitigation policies. For our study we considered no mitigation policy therefore emission depends on output and adaptation level.

Here, mitigation cost is zero as there is no mitigating policy and the adaptation cost depends on the output as well as adaptation level.

$$\frac{AC_t}{Y_t} = \gamma_1 \cdot AL_t^{\gamma_2} \tag{4.28}$$

Gross damage depends on output and emission values.

$$\frac{GD_t}{Y_t} = \omega \cdot M_t \tag{4.29}$$

Again, Gross damage of climate change can be expressed as the function of climate variables.

$$\frac{GD_t}{Y_t} = \propto_1 \Delta T_t + \propto_2 \Delta T_t^{\propto 3} \tag{4.30}$$

To get the monetary value of Gross damages as a percentage of GDP/ Output can be expressed as a summation of RD_t (residual damage) and AC_t (adaptation costs).

$$\frac{GD_t}{Y_t} = \frac{RD_t(GD_t, AL_t, AB_t)}{Y_t} + \frac{AC_t(AL_t, AB_t)}{Y_t} \tag{4.31}$$

Gross damage as a percentage of output depends on the residual damage and adaptation cost for a certain level of adaptation.

$$RD_t = (1 - AL_t).\ GD_t \tag{4.32}$$

The value of residual damage depends on gross damage GD_t and adaptation level AL_t.

Consumption is given as output minus all climate change costs:

$$C_t = Y_t - RD_t - AC_t - MC_t \tag{4.33}$$

Net consumption is the value of the output minus the cost of climate change policies. In our Malaysian model we consider MC_t- mitigation cost is zero. Thus it depends only on adaptation cost, residual damage and output.

Finally, social welfare can be maximised through utility maximisation.

$$U_t = \sum_{t=1}^{Z} \rho_t\ .\ (C_t) \tag{4.34}$$

Where ρ_t is discounting factor and C_t is consumption after adaptation policy.

The mathematical statement starts with alphabetical lists of sets, parameters, and variables as shown in appendix.

4.15 Calibrating the CGE Model

Standard SAM procedures require additional parameter values to carry out the estimation and simulation using CGE modelling. Once the operators are identified and their optimisation behavior is identified by algebraic equations, the parameters in the equations should be evaluated. Data on exogenous and endogenous variables at a given time are usually used for this purpose. This process is known as calibration. Calibration is performed to estimate the related coefficient parameters (if data are sufficient and available) or a benchmark data from the existing literature is used (if there is a lack of data) in order to standardise the parameters used in the calibration technique. The parameter and elasticity values (i.e. *CES*, *CET*) that are employed in the modelling equations for CGE are vital to assess the impact of various policy effects or external shocks. The accurate estimation of the model parameters is crucial to find consistent results. Generally, two types of parameter estimates are widely used by researchers to develop CGE models: the econometric approach and the calibration method that enables the static module equations to generate a base-year equilibrium observation or short run solution (Sánchez & Vos, 2007). The calibration approach was introduced by Jorgenson in 1960 and the econometric approach was first used by Jorgenson and Wilcoxen (1993). The econometric approach uses statistical tools to estimate parameters. Generally, elasticities and parameters of productions and consumption functions are determined econometrically using time series data. Each parameter is associated with a standard error (SE) and correlation factor (R) which define the accuracy of the estimation. However, the econometric estimation consumes time and resources. In most cases, econometric estimation of parameters is likely to be unrealistic due to lack of degree of freedom. This is especially true for under developed economies where there are lack of accurate time series data.

The calibration procedure assumes that the economy is in equilibrium. This is established by a benchmark dataset that represents equilibrium for an economy so that the model is actually solved from equilibrium data for its parameter values (Shoven, 1992). Particularly, the benchmark dataset is systematically represented in the compiled SAM. Equilibrium exists because the SAM is square and row, column sums for a given account are equal because all income must be accounted for by an outlay of another type (Pyatt & Round, 1985). When these parameters are correctly estimated, the result using the initial data must match with the base year equilibrium data. When results are not identical, it is necessary to modify the model until it can replicate the base-year observation. Nevertheless, the calibration approach has been criticised for the following reasons: it parameters estimated are deterministic in nature, and therefore, there is little scope to support the reality of the coefficients; it estimation of the parameters is a function of the selected benchmark year.

The calibration method, however, remains widely used for various reasons. Accounting for the model sector-factor-institution breakdown implies that many of the parameter values (sometimes thousands) are needed to solve the model. The simultaneous stochastic estimation of all these parameters is unrealistic due to the scarcity of data specially for developing countries, the required sophistication of techniques, and the need for severe identification restrictions (Gunning & Keyzer, 1993). Despite these criticisms, the major advantage of the calibration method is that only a few data are needed because the parameter estimation only one observation, which may, however, involve gathering a great deal of data when a SAM is estimated (Sanchez 2004). Furthermore, in most CGE applications for LDCs, the calibration approach is widely used because of the infeasibility of full-fledged econometric estimations.

Hence, the Social Accounting Matrix (SAM) has been widely used as a base data for calibration. Hence, in this study, the same calibration approach is used to determine the model parameters. For solving the parameter, the CGE model and equations are written in General Algebraic Modelling System (GAMS). The GAMS has been developed to solve this type of models and makes the process of programming and running CGE models even simpler.

4.16 Perform Scenario Simulations within the CGE Model

Simulations based on different scenarios are performed using the developed CGE model. Scenarios include cases of different degree of temperature changes combined with the imposing of an optimum adaptation policy versus no adaptation policies. Special focus is given to the impact on agricultural sector, impact on production and effects on important economic variables (i.e. real income, inflation, unemployment and social welfare). Lastly, the estimated findings from the CGE simulation results are interpreted to rationalise the research objectives,

4.17 Conclusion

From the above discussion on methodology and frameworks, it is clear that to quantify the economy wide impacts of adaptation, an integrated approach of general equilibrium models based on I-O model, SAM model and Computable General-Equilibrium (CGE) model, is more robust and competent. This is mainly due to the fact that the integrated approaches are accomplished and policy shocks of price reforms are best captured within the general equilibrium modelling approach.

We interpret and discuss our findings in Chapters 5 and 6 respectively for different policy scenarios to check whether optimum adaptation policy is effective in terms of costs and benefits.

CHAPTER 5: FINDINGS

5.1 Introduction

The main objective of this study is to find the impacts of the climate change adaptation policy and its associated costs on macro-economic variables such as real gross domestic product (RGDP), government expenditure, exports, net consumption and sectoral output. The agricultural sector of the Malaysian economy is our focused sector as it is directly affected by the climate change. In this chapter, we investigated the findings of this study using our CGE model called Malaysian Integrated Climate and Economy (MICE) and interpreted to establish whether the adaptation policy is effective in terms of reducing the climate change monetary impact. We also simulated the effects of adaptation policy on different sectors as well as on the overall economy using the developed CGE model.

5.2 Policy Scenarios

Our study focused only on Malaysia, even though analogies can be easily applicable to some other countries. The focus was on how climate change impacts are translated into monetary damages and how these damages can be reduced via adaptation.

Under CGE framework, there are several types of Integrated Assessment Models (IAMS). Among the climate change related global impact model, well-recognised models are: *Dynamic Integrated Climate and Economy* (DICE) model which was introduced by Nordhaus (1991) and its extended AD-DICE model that considered adaptation as a decision variable. Moreover, the regional version of this model is called *Regional Integrated Climate and Economy* (RICE) model and its extension for adaptation is the AD-RICE model (de Bruin, Dellink and Tol 2009; de Bruin, Dellink and Agrawala 2009). This model analyses at a regional level not distinguishing sectors or economic and non-economic categories.

In this study, we considered AD-DICE as well as AD-RICE models as our base models and then reconstructed a specific model which only considered one country (Malaysia) with its own economic data and tried to find out locally optimum policy without considering any externalities and spillover effects of the global activities and policies. We assumed populations are constant over time, and all parameters are non-zero. In our model, the values of the elasticity of substitution was exogenously taken from GTAP data base (X.-g. Zhang & Verikios, 2006). For consistent growth rate, we took the real GDP growth rate data from World Bank estimates for Malaysia.

Every economic activity causes emissions by default and therefore, emission is a linear function of the economic output. These emissions can be reduced only by mitigation effort, but for a single country like Malaysia, it will be mostly unsuccessful without coordination with neighboring countries. Therefore, disregarding any mitigation effort, we assume adaptation is the only viable option for a country's climate change policy. Accordingly, the emission level for a country will change with continuing economic activities. Thus in our model, net emission value is dependent on the output or the total production value of a country. Disregarding any mitigation effort implies that the costs of mitigation will be zero. We know that net damage not only depends on a country's own emissions, rather it depends on cumulative global emissions, but for simplicity, we assume no spillover effect or no externalities. Thereby we assume that the net damage of a country will only depend on its own emissions.

This study considered temperature change as an exogenous shock and simulated the effects of adaptation policies over 100 years period based on the 2005 base year Social

Accounting Matrix (SAM) for the Malaysian economy[2]. We examined the policy effectiveness by simulating scenarios with and without adaptation options. To achieve this, at first we make a business as usual referred here as Base Case Scenario (BCS) simulation when no adaptation policies are engaged. Also, this situation does not consider monetary value of the climate change damages in economic figures. Thus we figure out the economic costs of the climate change without any adaptive policy and compare its impacts on the economy. Then we introduce our optimum adaptation policy into the simulation and see whether it is effective in terms of reducing the climate change related damages.

Therefore, we consider the following three scenarios:

i. Base Case Scenario (BCS)
ii. Climate Impact with No Adaption (CINA)
iii. Climate Impact with Adaption Actions (CIAA)

5.2.1 Base Case Scenario (BCS)

The first scenario of this study is a base case or business as usual scenario. In this scenario, we consider that the country's economic developments will not be affected by the climatic change and will continue following the existing trend.

5.2.2 Climate Impact with No Adaption (CINA)

This scenario considers what will be the worst-case economic condition when the projected climatic parameters change having its associated impacts; but the policymakers, economic agents, and stakeholders do not respond and hence do not take any adaptation policy and so there is no investment for adaptation.

---

[2] This data base provides a consistent representation of the Malaysian economy

5.2.3 Climate Impact with Adaptation Actions (CIAA)

This scenario represents the case when policymakers engage optimum adaptation actions and bear the associated costs for adaptation. Thus this case highlights the economic impacts of adaptation. Also the comparative analysis of CINA and CIAA fulfills our objective to measure the effectiveness of adaptation policy in terms of its economic impacts.

5.3 Description of Simulations

In this study, we estimate the climate change impacts over a period of hundred years. We divide these 100 years into 6 different time segments, each having 20 years duration and these time segments are independent of each other. We consider 2005 as the benchmark year or base year for this study. Therefore all the simulations start from this benchmark year and end on 2105. Table 5.1 shows time segments 1 to 6, starting on 2005 and ending on 2105.

Table 5.1: Time Segments for this Study

Time segment 1	Year 2005
Time segment 2	Year 2025
Time segment 3	Year 2045
Time segment 4	Year 2065
Time segment 5	Year 2085
Time segment 6	Year 2105

5.4 Objective One: Optimum Level of Adaptation

To achieve the first objective of this study (i.e. optimum level of adaptation), we follow the AD-RICE model (de Bruin et al 2009), which defined the optimum level of adaptation using equation (5.1) as follows.

$$\boldsymbol{AL^{*}_{j,t}} = \left(\frac{\boldsymbol{\omega_j . M_t}}{\boldsymbol{\gamma_{2,j} . \gamma_{1,j}}}\right)^{\frac{\mathbf{1}}{\boldsymbol{\gamma_{2,j}-1}}} \tag{5.1}$$

Where, $\left(\omega_j . M_t\right)$ is the value of the gross damage that we have found from the Malaysian model, and the rest of the parameters are adaptation coefficients. We estimate the value of these coefficients from the AD-RICE model adapted for a middle income country (as Malaysia is currently a middle income country). We consider the values of these coefficients exogenously from the AD-RICE model to achieve the optimum level of adaptation. These values are tabulated in the appendix.

The non-stop cumulative global emissions are responsible to accelerate the rate of change of the temperature. This study has used the temperature change data as projected by the meteorological department of Malaysia.

Figure 5.1 shows the projected temperature rise for Malaysia under A1B emission scenario for each time steps compared to that of year 1900[3].

---

[3] Adopted and adapted from the data of MMD 2009 (Malaysian Meteorological Department)

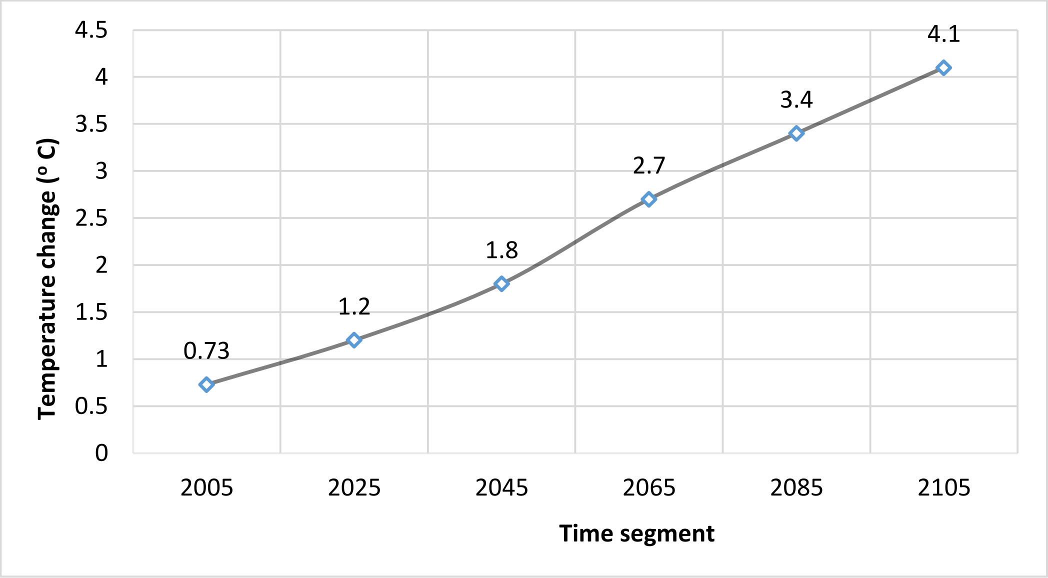


Figure 5.1: Projected changes in temperature compared to year 1900

The temperature change trend indicate that in the year 2005, the temperature has increased by 0.73 degree Celsius compared to 1900. However, in the year 2105, the projected change is 4.1 degree Celsius compared to 1900 or 3.37 degree Celsius compared to the year 2005. The projection also shows that the trend is linear and the rate of temperature change remains nearly constant over time.

Figure 5.2 shows estimated Malaysian emission values for each time frame (without taking any mitigating policy) based on the emission growth model by the World Bank. The World Bank data for CO_2 emission of Malaysia from 1970 to 2010 is considered as the base data for this estimation. The final growth rate is measured to be 3.4% or more exactly, 0.033745 per year.

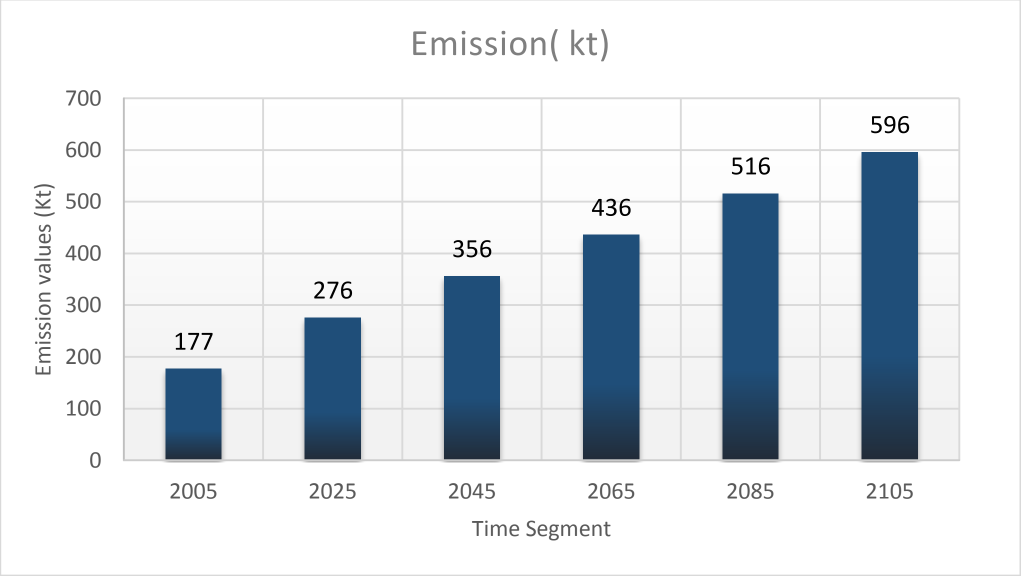
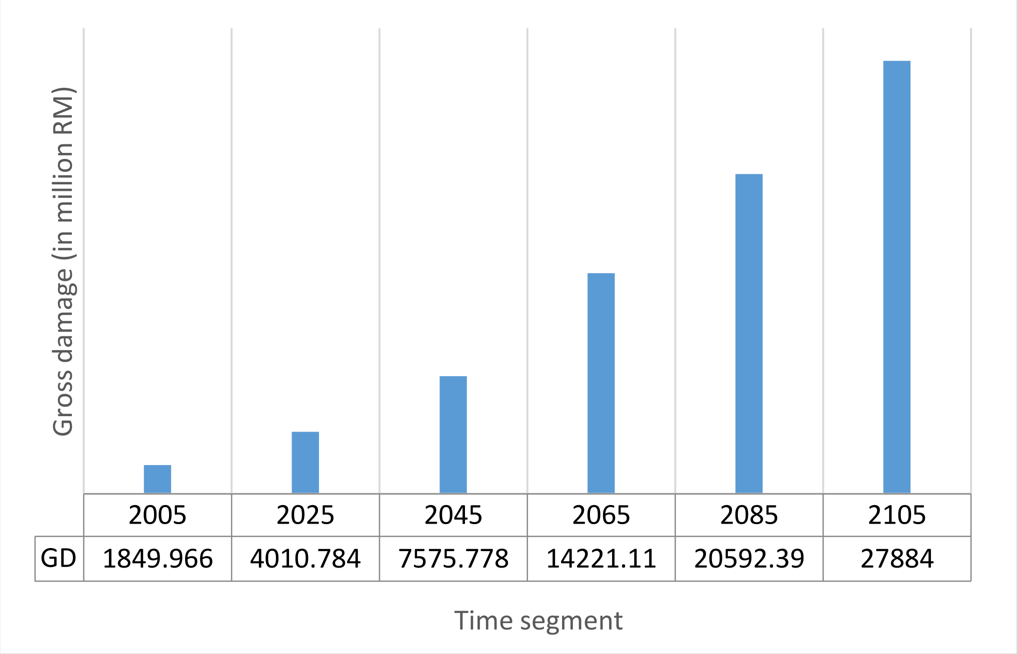


Figure 5.2: Estimated emission values for each time segments

Considering the temperature and emission values, we estimate the different gross damage values for each time frame from our CGE model simulation. Figure 5.3 shows estimated values of the gross damage. The resulting gross damage values indicate that, as the temperature as well as emission values are projected to increase continuously along with the economic activities, the value of the gross damage will also increase over time.



	2005	2025	2045	2065	2085	2105
GD	1849.966	4010.784	7575.778	14221.11	20592.39	27884

Figure 5.3: Gross damage value in RM million

Figure 5.3 also established that the rate of change of gross damage is anticipated to increase over time.

Hence, from our model, we estimated the optimum adaptation level i.e. the value of equation (5.1), for the period of 2005 to 2105. Figure 5.4 shows the estimated value of the optimum level of adaptation for each time segment. With continued economic activities along with increased gross damage values, the optimum level of adaptation is projected to increase over time (without considering any mitigation policies).

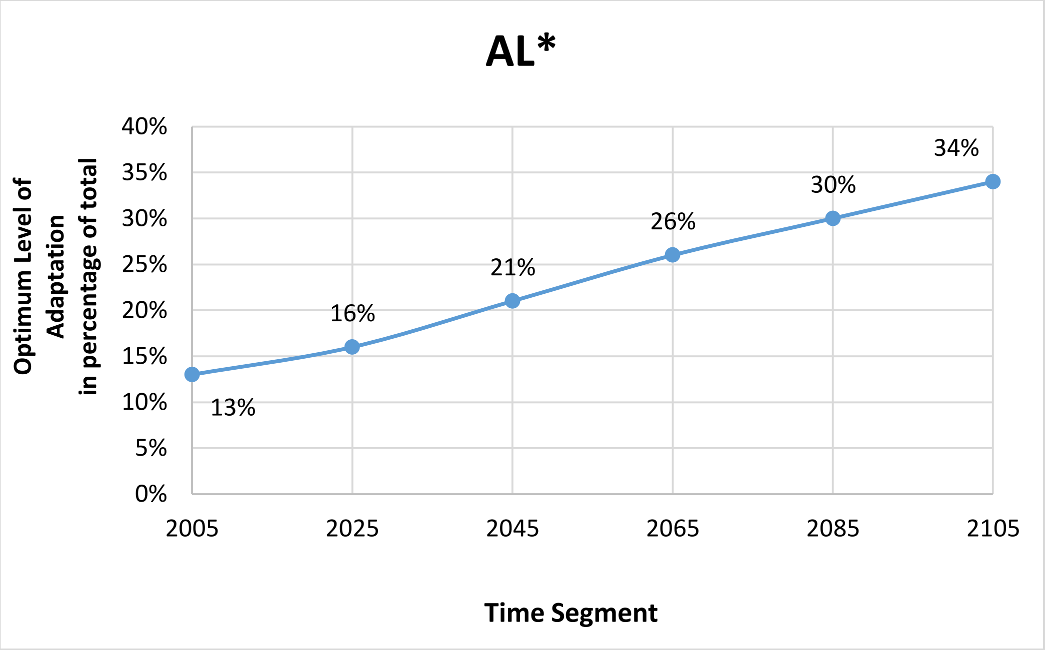


Figure 5.4: Optimum level of adaptation

Figure 5.4 shows that the optimum level of adaptation will be increasing with growing economic activities along with associated climate change monetary damage values. In 2005, if adaptation policy was to be taken, the optimum level of adaptation would have been 0.13 or 13% of the total damage. In 2105, the optimum level of adaptation increases to 34%. The overall results show that the optimum level of adaptation increasingly depends on corresponding damage and economic growth.

5.5 Objective Two: Costs of Adaptation

To achieve the second objective of this study (i.e. to measure the costs of adaptation when adaptation is at its optimum level), we follow the AD-RICE model (e.g. de Bruin et al 2009), which describes the optimum costs of adaptation by the equation (5.2) as follows.

$$\boldsymbol{AC_t = \gamma_1 \,.\, AL_t^{\gamma_2} . Y_t} \tag{5.2}$$

For each time segment, we estimate the cost of adaptation for the optimum level. The cost of adaptation varies with the corresponding optimum level of adaptation along with respective gross damage values.

Figure 5.5 shows the costs of optimum level of adaptation for each time segment. The costs of adaptation increase over time with the augmented optimum level of adaptation.

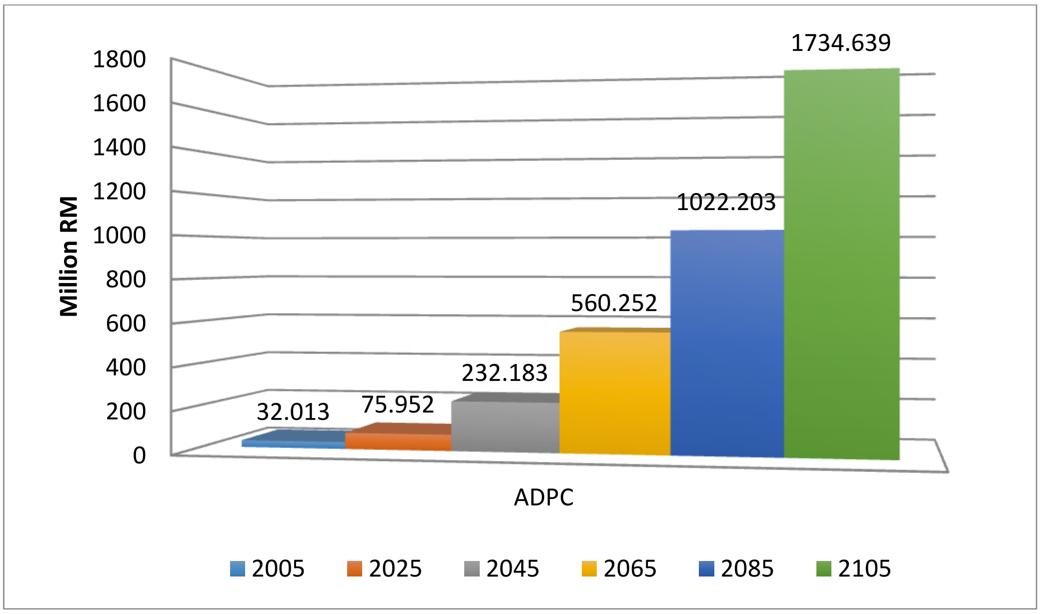


Figure 5.5: Monetary costs of adaptation (in RM million)

Figure 5.6 shows, the estimated costs of adaptation policy as a percentage of respective year real GDP. The results establish that the costs of adaptation are only a very small percentage of the estimated real GDP. Interestingly, the result presents that the early action costs are as little as % (0.006492 for year 2005), whereas if the action is taken at a later stage, the cost increase exponentially as % of GDP. The results indicate that an early action could potentially reduce the overall cost of adaptation.

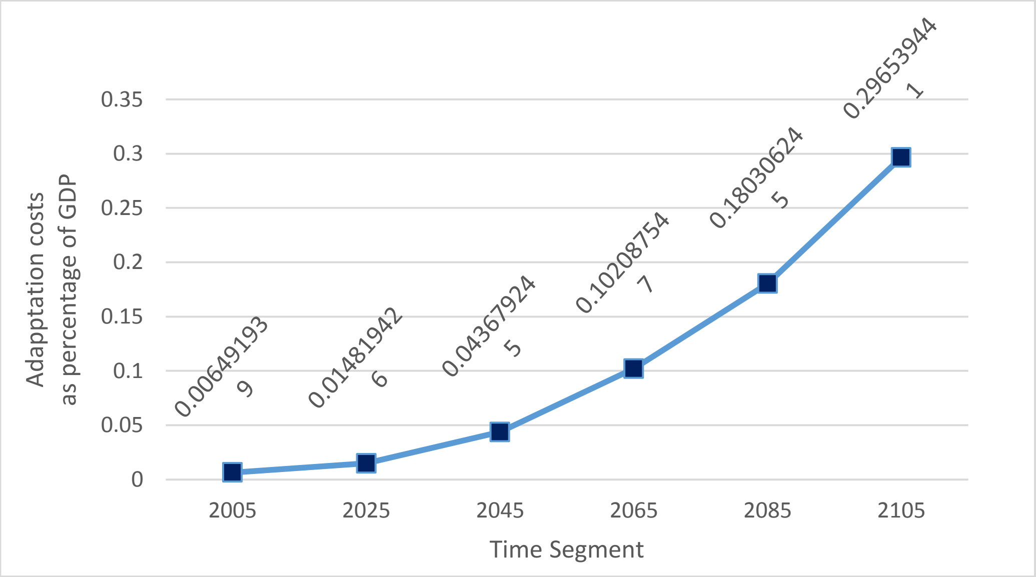


Figure 5.6: Costs of adaptation as percentage of GDP

Table 5.2 and Figure 5.7 show the costs of adaptation for each sector of the economy derived from our model. For Malaysian economy, industry as well as services are the highest contributing sector in terms of their contribution to the GDP. However, our study focuses only on agriculture, therefore we disaggregated this sector among 10 different subsectors to get each sector wise results. These results further indicate that palm oil (0.476212 for the segment 2005) was the highest contributing sector in agriculture (in terms of the production value). Thus the cost of adaptation is also high whereas for paddy (0.023446 for the segment 2005) it was the lowest. These values increase consistently over the entire simulation period of the hundred year period starting from 2005 to 2105. However, the rate of change for each crop is not same. For example, in the year 2005, the costs of adaptation for paddy was 23.446 thousand ringgits, whereas, the costs of adaptation for food crops was a little higher, 24.358 thousand ringgits. In the last time segment, (2105), costs of adaptation for paddy (1240.252 thousand ringgits) is higher than the costs of adaptation for food crops (1119.802 thousand ringgits). This is because of the elasticity of substitution for each crop is different.

Table 5.2: Costs of Adaptation by Sectors

Time segment/sectors	***2005***	***2025***	***2045***	***2065***	***2085***	***2105***
Paddy	0.023446	0.055336	0.168315	0.404195	0.734087	1.240252
Food Crops	0.024358	0.055836	0.165043	0.385368	0.680894	1.119802
Vegetables	0.009881	0.023475	0.071855	0.173589	0.316932	0.538331
Fruits	0.030594	0.072078	0.218941	0.525259	0.953366	1.610221
Rubber	0.132789	0.314184	0.957883	2.305319	4.195413	7.101814
Palm Oil	0.476212	1.131983	3.466549	8.378399	15.30991	26.01695
Livestock	0.129986	0.308467	0.943159	2.276191	4.153561	7.049213
Forestry and logging	0.176344	0.411917	1.240476	2.950343	5.308705	8.889088
Fishing	0.160314	0.375742	1.135663	2.711534	4.898979	8.237933
Other agriculture	0.122318	0.291722	0.896195	2.172609	3.981558	6.784847
Crude oil	2.099117	5.037155	15.56241	37.92473	69.83718	119.5382
Industrials	12.50672	29.58809	90.20247	217.0846	395.0785	668.8094
Transportation and communication	1.949119	4.632559	14.18663	34.29216	62.67659	106.5429
Financial Services	3.150741	7.437711	22.63192	54.37884	98.83095	167.1146
Services	11.02106	26.21574	80.33548	194.2889	355.2464	604.0455

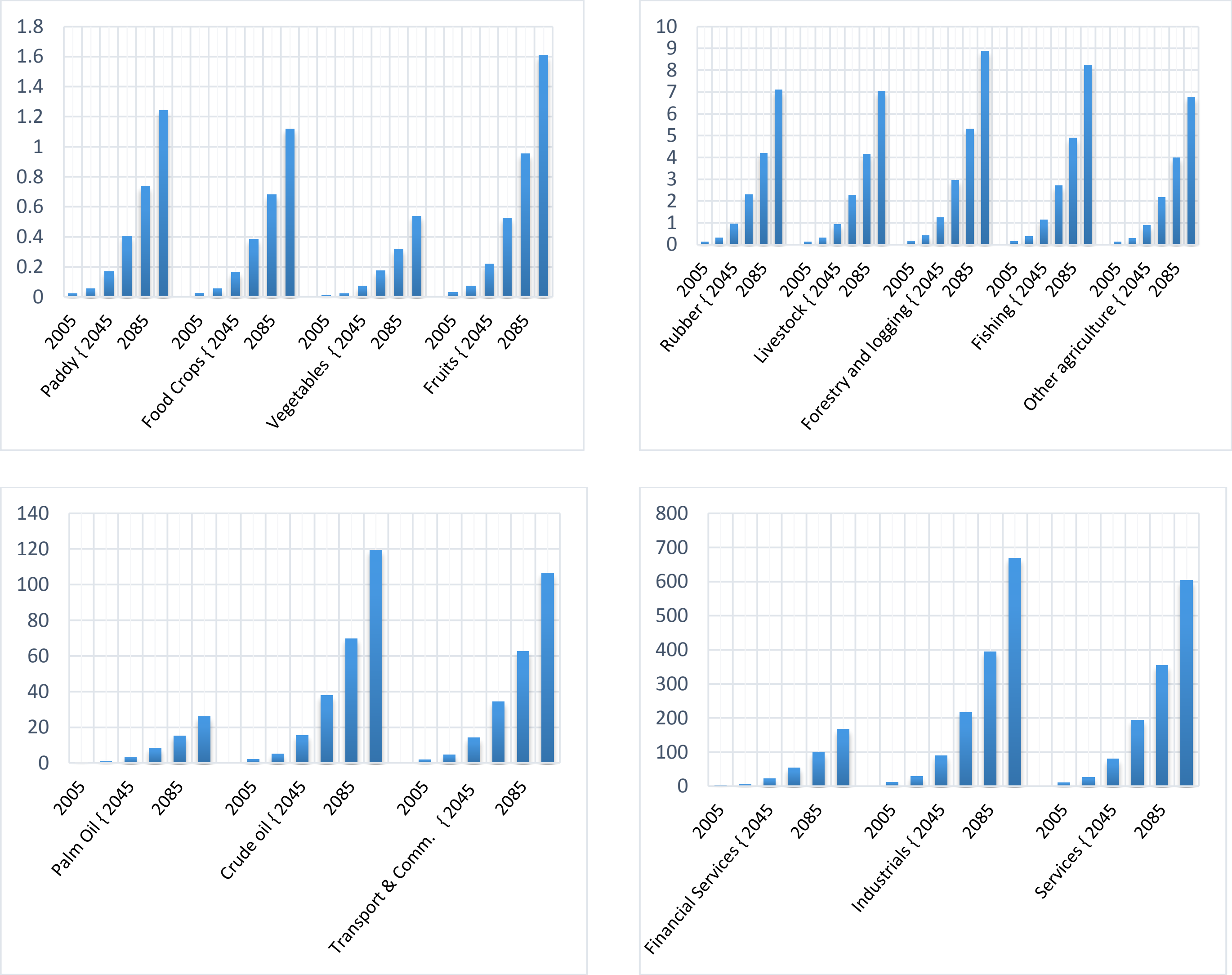


Figure 5.7: Sector wise adaptation costs (in RM million)

In order to find the overall cost of the agricultural sector in particular, we accumulate the costs of all agricultural subsectors. Figure 5.8 shows the cost of adaptation for the overall agricultural sector in million ringgits.

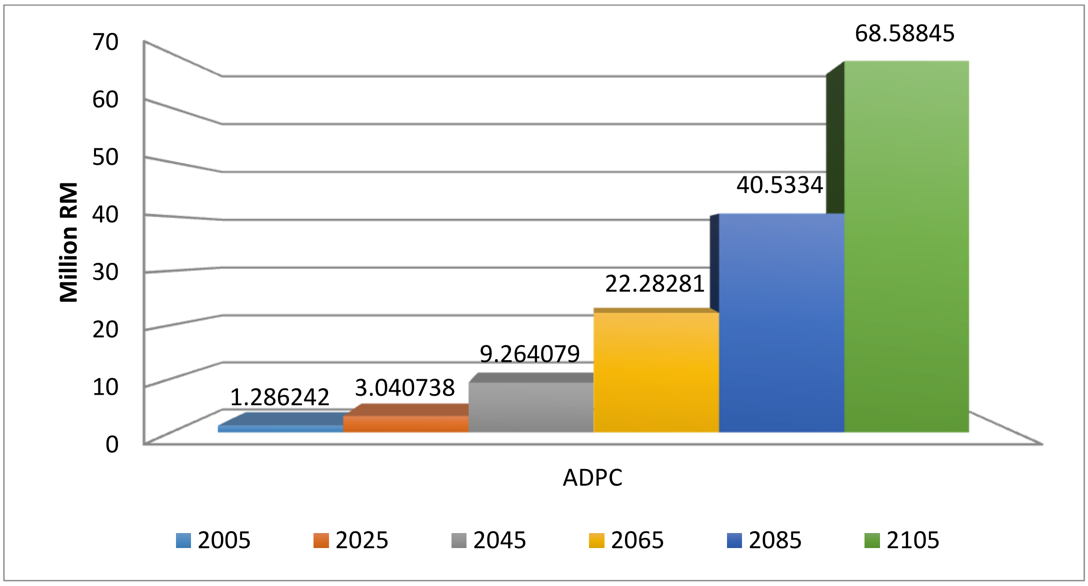


Figure 5.8: Costs of adaptation policy for the overall agricultural sector (in RM million)

It is evident from Figure 5.8 that the simulated value of the cost of adaptation for the overall agricultural sector shows an increasing trend over the projected hundred year period. The optimum level of adaptation also increases due to continued economic activities and nonstop emissions, and therefore, the cost of adaptation increases both considering the sector specific and overall economy. Figure 5.9 shows costs of adaptation for the overall agricultural sector as a percentage of the respective real GDP for each time segment. This indicates that adaptation is a continuous process and gradually increases according to the steady optimum adaptation path (theory of transition) through “take off”, “acceleration”, and “stabilization” phases.

Costs of adaptation corresponding to the optimum adaptation level continuously vary with time. These are the continuous costs towards a steady stabilized adopted economy.

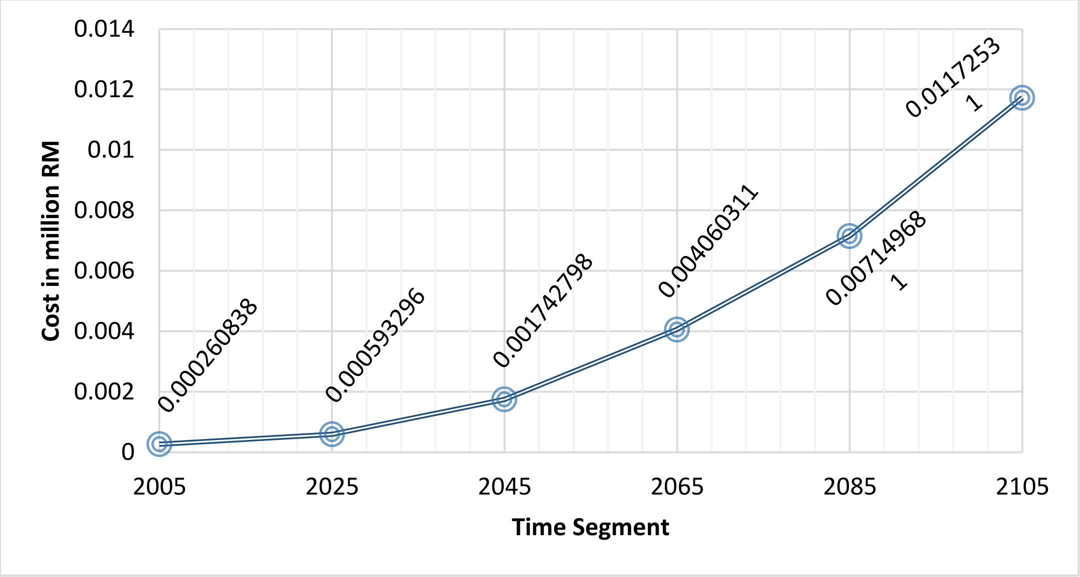


Figure 5.9: Adaptation costs in agriculture as percentage of GDP

It is established from Figure 5.9 that the cost of adaptation is very small as the percentage of GDP for the agricultural sector. However, the increasing trend indicates the early adaptation action costs are as minimal as percentage of GDP (0.000261 for the segment 2005), whereas if the action is to be taken at a later stage the cost increases significantly as the percentage of GDP (0.011725 for the segment 2105).

5.6 Comparison of BCS, CINA and CIAA scenarios

This study simulated each of the three scenarios (base case scenario, climate impact without adaptation and with adaptation actions) to investigate the impacts of adaptation policy in terms of the associated costs on the economy. The following sections depict the numerical results derived from the Malaysian climate and Economy (MCE) model. This study examines the impacts of the adaptation policy on real GDP, productions of commodities, government expenditure etc.

5.6.1 The Effect on Real Gross Domestic Product (RGDP)

Table 5.12 with Figure 5.11 show the estimated RGDP values (in RM million) for the three simulation cases.

Table 5.3: Comparison of RGDP (in RM million) for BCS, CINA and CIAA

	2005	***2025***	***2045***	***2065***	***2085***	***2105***
BCS	494663.9	515965.2	538184.6	561361.9	585538.1	610756.4
CINA	492925.914	511954.401	530119.541	545242.614	560686.275	574925.561
CIAA	493119.249	512516.476	531563.672	548795.635	566926.011	584960.636

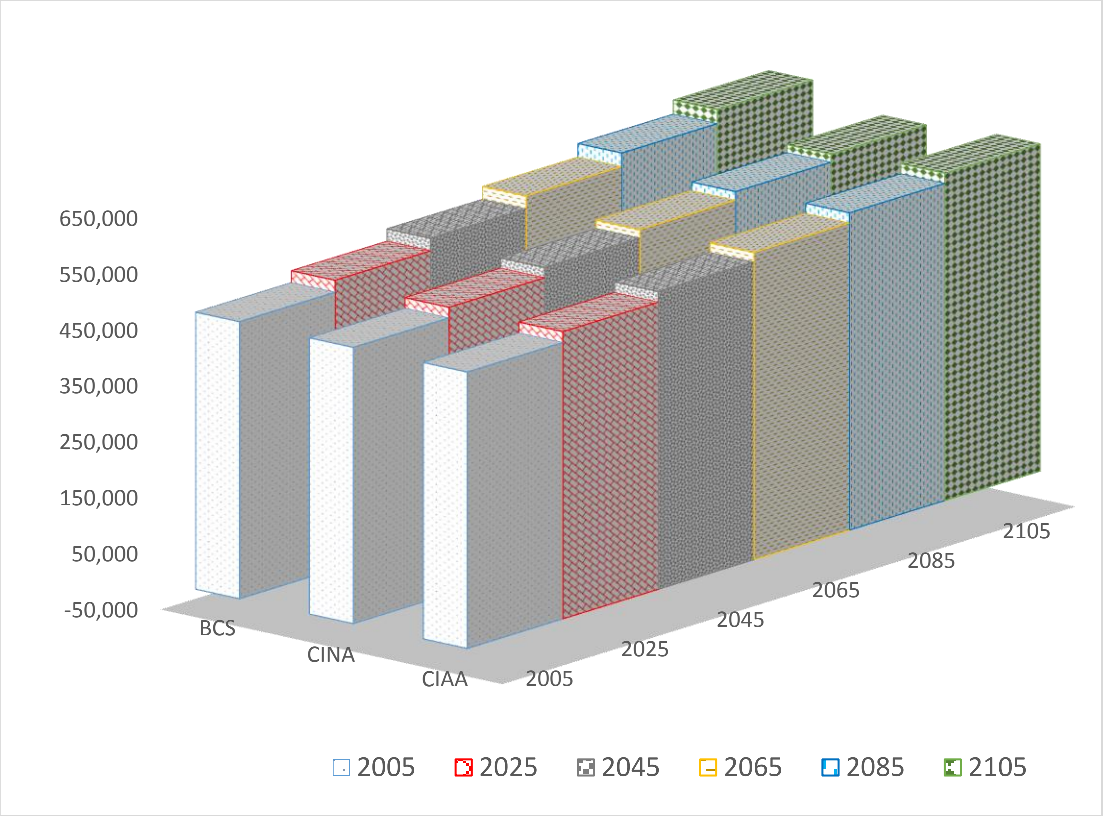


Figure 5.10: Comparison of RGDP for BCS, CINA and CIAA scenarios

In general, the value of RGDP increase over time for all three cases as the economic activities progress with time. However, the RGDP is lower for CINA and CIAA cases than BCS. This is because BCS does not consider any adverse effect of climate change.

Among CINA and CIAA we find that RGDP is consistently higher for CIAA even though it takes adaptive actions having associated costs. On the other hand CINA does not include any additional cost of adaptive actions, however, its RGDP is lower due to the loss in economy for climate change related damages. The result indicates that the adaptation is effective in reducing the loss of RGDP due to climate change.

5.6.1.1 Loss of RGDP due to climate change

Table 5.4 and Figure 5.11 show the RGDP monetary losses for CINA and CIAA compared to BCS RGDP. It is the difference between the BCS and CINA, CIAA RGDP values. This scenario results indicate that if no policy is taken, the loss of real GDP will be increasing at a higher rate over time. On the other hand, when adaptation measures are taken, the rate of loss in RGDP is stabilized to a near constant value, as evident from the last four time segment RGDP values for CIAA scenario.

Table 5.4: Loss of RGDP Due to Climate Change (in RM million)

Time segment	***2005***	***2025***	***2045***	***2065***	***2085***	***2105***
CINA	1737.986	4010.799	8065.059	16119.286	24851.825	35830.839
CIAA	1544.651	3448.724	6620.928	12566.265	18612.089	25795.764

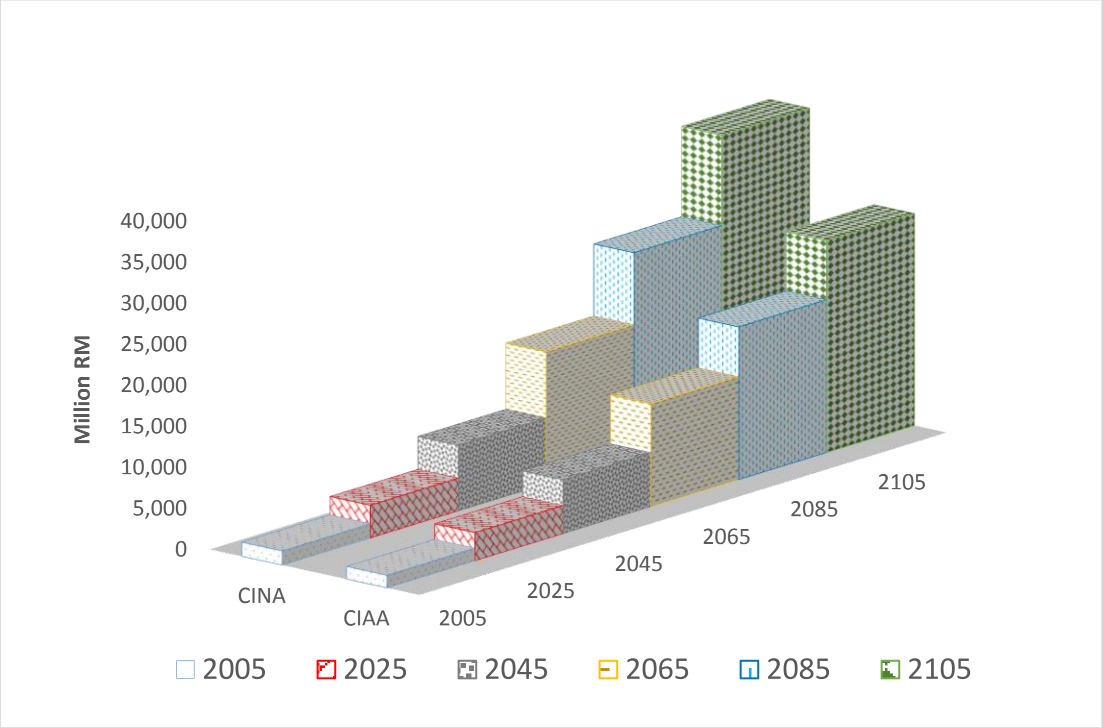


Figure 5.11: Loss of RGDP due to climate change

It is evident from Figure 5.11 that RGDP losses are significantly less for CIAA than CINA. Therefore, it shows that the proposed optimal adaptation level is beneficial for the economy even though it has additional adaptation costs.

5.6.1.2 Effectiveness of the climate change adaption

Figure 5.12 shows the RGDP gains achieved for climate change adaptation (CIAA) compared to that of without adaptation (CINA). It is the difference between RGDP with and without adaptation policy. It is clearly evident that climate change adaptation policy is beneficial or effective in terms of the monetary value of real RGDP as illustrated in Figure 5.14 below.

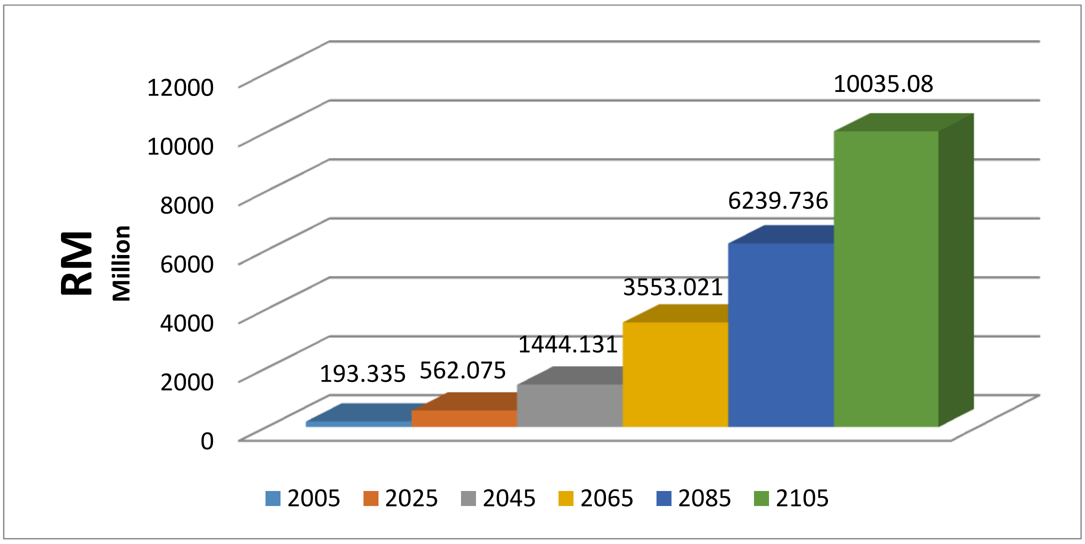


Figure 5.12: RGDP benefits for CIAA than CINA

From above results, we conclude that without investment for adaptation, climate change will cause remarkable losses in the RGDP (almost 5.7% of RGDP). On the contrary, adaptation policy can significantly reduce the losses and thus economically beneficial. Figure 5.13 shows the benefits of adaptation as percentage of RGDP. The values also establish that the benefits of adaptation is increasing at a higher rate over the time.

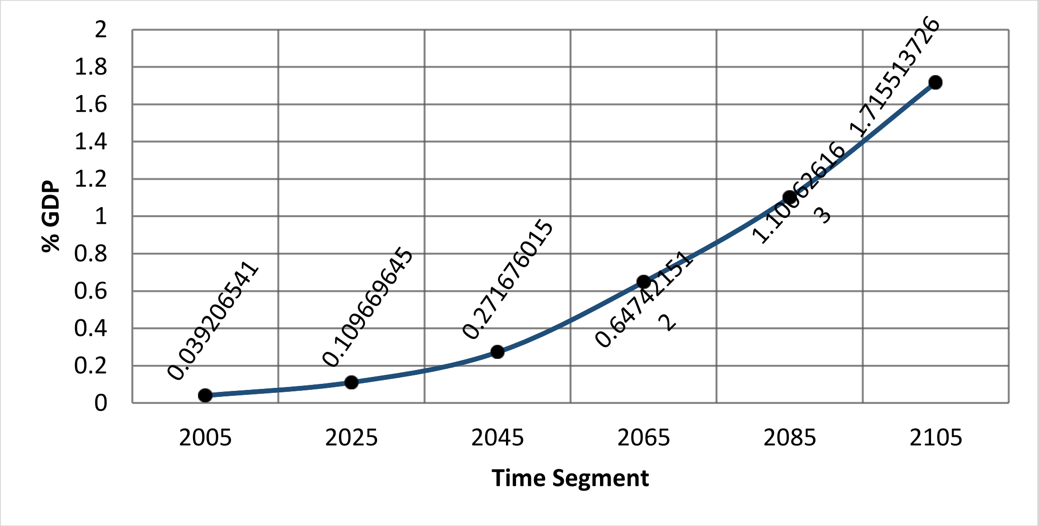


Figure 5.13: Adaptation benefits as percentage of GDP

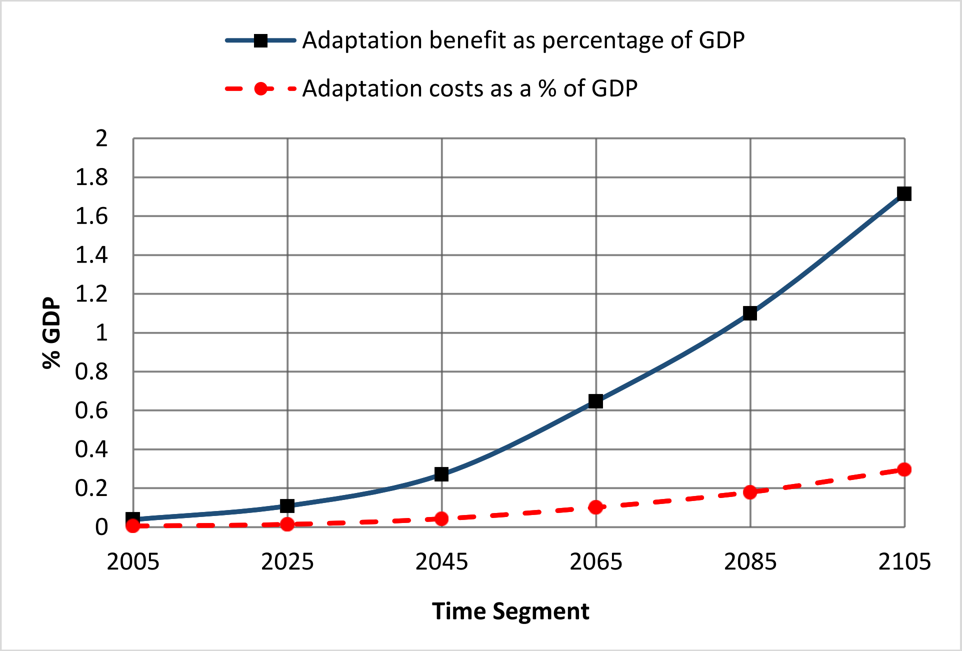


Figure 5.14: Comparison between the costs and benefits of adaptation

Figure 5.14 shows the comparison between costs and benefits of adaptation. It is evident that the benefits of adaptation are higher than the costs of adaptation for each time segment. Moreover, benefits of adaptation tends to increase at a higher rate than the rate of increase of the costs over time. It implies that the benefit over cost ratio will continue to increase over the time.

5.6.2 The Effects on Economic Outputs/Productions of Commodities

For all three scenarios, the value of output for each crop is now compared in order to determine whether adaptation policy is effective or not and to what extent. We consider both sector specific and aggregate level outputs to do this.

Climate change has a direct impact on the physical output particularly the agricultural output. If the temperature increases (for instance), it will directly affect the crop production. The production is negatively affected by the extent of the climate change damages. In our model, we simulate the base case (BCS), no adaptation (CINA) and climate change adaptation (CIAA) scenarios and measure their responsive economic outputs as showed in Table 5.5, 5.6 and 5.7 respectively.

Table 5.5: Sector Specific Outputs for BCS Scenario (in RM million)

Time segment/sectors	***2005***	***2025***	***2045***	***2065***	***2085***	***2105***
Paddy	871.015	902.587	935.579	970.048	1006.047	1043.657
Food Crops	904.889	910.735	917.3 91	924.864	933.148	942.3
Vegetables	367.06	382.894	399.409	416.604	434.347	452.999
Fruits	1136.565	1175.67	1216.988	1260.594	1306.563	1354.981
Rubber	4933.08	5124.66	5324.401	5532.646	5749.705	5976.089
Palm Oil	17691.2	18463.81	19268.85	20107.72	20981.83	21892.94
Livestock	4828.96	5031.419	5242.556	5462.741	5692.348	5931.826
Forestry and logging	6551.157	6718.793	6895.199	7080.669	7275.443	7480.058
Fishing	5955.641	6128.734	6312.591	6507.54	6713.924	6932.119
Other agriculture	4544.09	4758.287	4981.508	5214.149	5456.622	5709.365
Crude oil	77981.82	82161.22	86503.82	91017.37	95710.04	100589.9
Industrials	464622.6	482612.5	501391.3	520991.7	541444.8	562794.9
Transportation and communication	72409.42	75561.84	78856.54	82299.4	85896.64	89654.5
Financial Services	117049.5	121316.8	125799.7	130506.4	135445.3	140624.9
Services	409430.4	427605.9	446545.5	466283.3	486856	508296.8
Total	1189277	1238856	1290591	1344576	1400903	1459677

Table 5.6: Sector Specific Output for CINA Scenario (in RM million)

Time segment/sectors	***2005***	***2025***	***2045***	***2065***	***2085***	***2105***
Paddy	869.6601	899.6649	930.0871	959.7881	991.2587	1023.72
Food Crops	903.4814	907.7865	912.0059	915.082	919.4313	924.2994
Vegetables	366.489	381.6544	397.0645	412.1977	427.9624	444.3454
Fruits	1134.797	1171.864	1209.844	1247.261	1287.357	1329.097
Rubber	4925.406	5108.069	5293.147	5474.129	5665.188	5861.929
Palm Oil	17663.68	18404.03	19155.74	19895.05	20673.41	21474.72
Livestock	4821.448	5015.13	5211.782	5404.963	5608.674	5818.511
Forestry and logging	6540.966	6697.041	6854.724	7005.779	7168.499	7337.168
Fishing	5946.377	6108.892	6275.536	6438.712	6615.234	6799.696
Other agriculture	4537.021	4742.882	4952.267	5159.001	5376.413	5600.3
Crude oil	77860.51	81895.22	85996.04	90054.71	94303.16	98668.37
Industrials	463899.9	481050	498448.1	515481.3	533485.9	552043.9
Transportation and communication	72296.79	75317.21	78393.65	81428.95	84634.02	87941.84
Financial Services	116867.4	120924	125061.3	129126.1	133454.3	137938.5
Services	408793.5	426221.5	443924.3	461351.6	479699.5	498586.9
Total	1187427	1234845	1283016	1330355	1380310	1431793

Table 5.7: Sector Specific Outputs for CIAA Scenario (in RM million)

Time segment/sectors	*2005*	*2025*	*2045*	*2065*	*2085*	*2105*
Paddy	869.8358	900.1297	931.2286	962.4062	995.58	1030.269
Food Crops	903.6639	908.2555	913.1252	917.5782	923.4395	930.2122
Vegetables	366.5631	381.8516	397.5518	413.3221	429.828	447.188
Fruits	1135.026	1172.469	1211.329	1250.663	1292.969	1337.599
Rubber	4926.401	5110.708	5299.643	5489.061	5689.885	5899.428
Palm Oil	17667.25	18413.54	19179.25	19949.32	20763.53	21612.1
Livestock	4822.422	5017.721	5218.178	5419.707	5633.124	5855.733
Forestry and logging	6542.288	6700.501	6863.137	7024.889	7199.749	7384.104
Fishing	5947.578	6112.049	6283.238	6456.275	6644.072	6843.194
Other agriculture	4537.938	4745.333	4958.344	5173.073	5399.851	5636.126
Crude oil	77876.24	81937.53	86101.58	90300.36	94714.26	99299.56
Industrials	463993.6	481298.6	499059.8	516887.4	535811.5	555575.4
Transportation and communication	72311.39	75356.13	78489.86	81651.07	85002.97	88504.42
Financial Services	116891	120986.5	125214.8	129478.3	134036.1	138820.9
Services	408876.1	426441.8	444469.1	462610	481790.7	501776.4
total	1187667	1235483	1284590	1333983	1386328	1440953

Figure 5.15 shows the output values for each sector under different climatic conditions of BCS, CINA and CIAA scenarios. Economic output is highest for the BCS as this case assumes that growth trend will be unaffected by climate change impact. In comparison, outputs for CINA and CIAA are less than that of BCS but only by a small margin and therefore it is not quite visible in Figure 5.15, whereas the CIAA outputs are a little higher than that of CINA. The sectors are divided into four groups based on their output volumes i.e. i) less than 2,000, ii) between 2,000 to 10,000, iii) between 10,000 to 100,000 and iv) higher than 100,000 RM million.

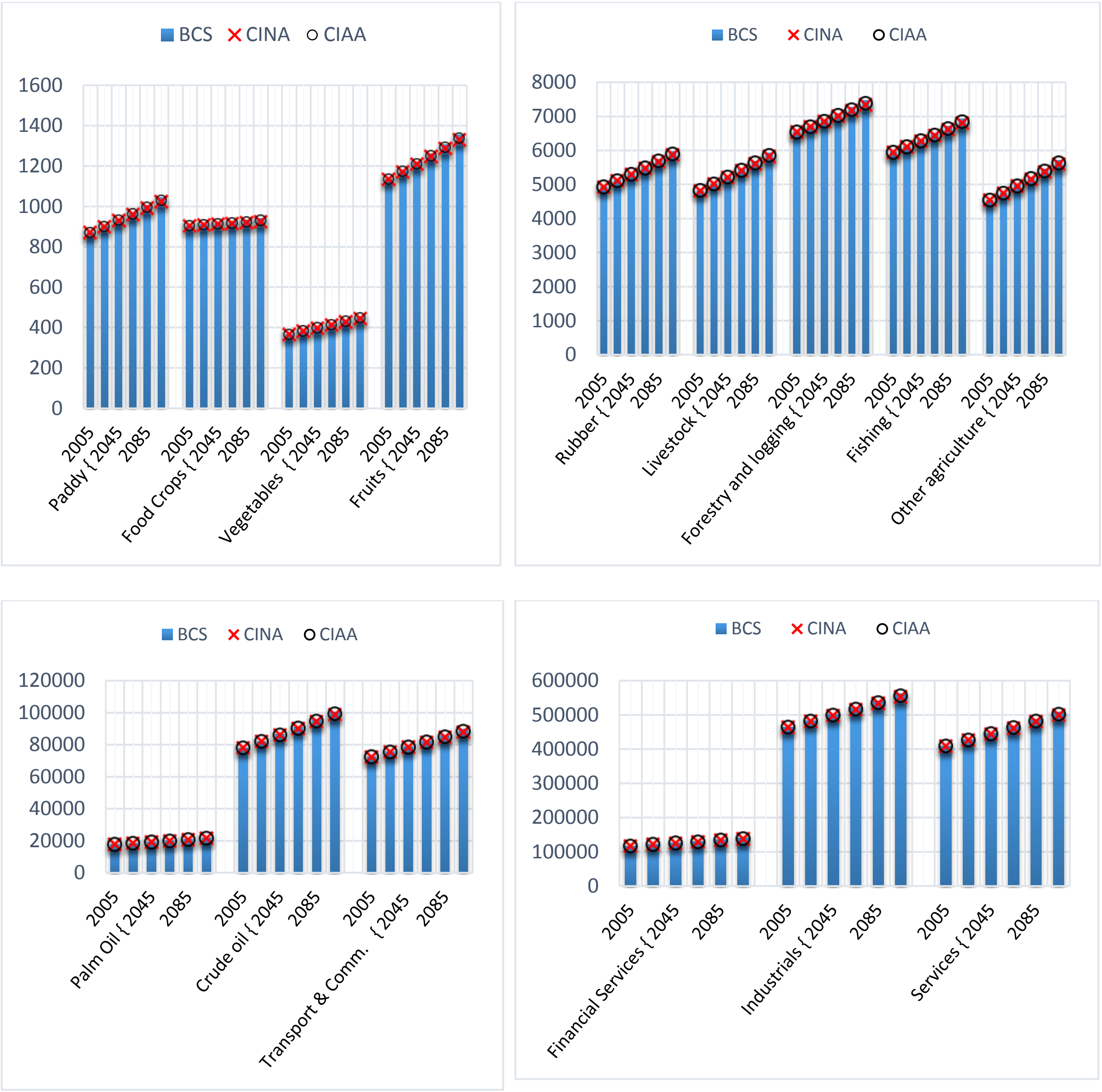


Figure 5.15: Comparison of sector specific outputs for BCS, CINA and CIAA scenarios (in RM million)

The estimated values show that with continued economic activities, the production of each sector tends to increase over time as expected. However, from Figure 5.15, it is evident that the rate of change for output values are not same for all sectors. For example, the output levels for food crops and palm oil sectors are nearly flat over the 100 year span while others show linear and consistent growth within this period. This happens because of the different elasticity of substitution values for individual sectors.

5.6.2.1 Climate change impact on output considering residual damages

Residual damages are calculated by subtracting the CINA, CIAA outputs from that of BCS scenario. The sector specific residual damages are tabulated in Tables 5.8 and 5.9 for CINA and CIAA scenarios respectively.

Table 5.8: Residual Damage Value of CINA Scenario (in RM million)

Time segment/sectors	***2005***	***2025***	***2045***	***2065***	***2085***	***2105***
Paddy	1.354897	2.922117	5.491854	10.25986	14.78826	19.93682
Food Crops	1.407589	2.948496	5.38509	9.781968	13.71669	18.00062
Vegetables	0.570976	1.239616	2.344533	4.406277	6.384629	8.653572
Fruits	1.76797	3.806221	7.143726	13.33287	19.20566	25.884
Rubber	7.673593	16.59104	31.25426	58.51689	84.51706	114.1603
Palm Oil	27.51933	59.7764	113.1082	212.6725	308.4198	418.2175
Livestock	7.51163	16.28917	30.77383	57.77753	83.67395	113.3148
Forestry and logging	10.19057	21.75203	40.47485	74.8898	106.9445	142.8904
Fishing	9.264225	19.84172	37.05494	68.82801	98.69048	132.4232
Other agriculture	7.068504	15.40491	29.24148	55.14826	80.20893	109.0651
Crude oil	121.3037	265.9962	507.7779	962.6594	1406.878	1921.554
Industrials	722.7381	1562.453	2943.169	5510.349	7958.899	10750.99
Transportation and communication	112.6356	244.6307	462.8883	870.4524	1262.627	1712.656
Financial Services	182.0749	392.7619	738.4451	1380.321	1990.96	2686.336
Services	636.8845	1384.37	2621.225	4931.718	7156.478	9709.918

Table 5.9: Residual Damage Value in CIAA Scenario (in RM million)

Time segment/sectors	*2005*	*2025*	*2045*	*2065*	*2085*	*2105*
Paddy	1.179223	2.457273	4.350383	7.641774	10.46699	13.38798
Food Crops	1.225083	2.479455	4.26581	7.285827	9.708539	12.08777
Vegetables	0.496944	1.04242	1.857227	3.281893	4.518977	5.811047
Fruits	1.538737	3.200735	5.658917	9.930616	13.59358	17.38162
Rubber	6.678645	13.95177	24.75813	43.58468	59.82034	76.66095
Palm Oil	23.95121	50.2673	89.59891	158.4032	218.2965	280.8414
Livestock	6.537683	13.69792	24.37755	43.03398	59.2236	76.09314
Forestry and logging	8.869277	18.29176	32.06224	55.77958	75.69423	95.95378
Fishing	8.063038	16.68534	29.35315	51.26463	69.85215	88.92485
Other agriculture	6.152012	12.95433	23.1637	41.07564	56.77109	73.23942
Crude oil	105.5756	223.6821	402.2373	717.0101	995.7741	1290.362
Industrials	629.0289	1313.902	2331.438	4104.23	5633.23	7219.502
Transportation and communication	98.03142	205.7154	366.6779	648.3323	893.6749	1150.083
Financial Services	158.4673	330.2822	584.9608	1028.094	1409.182	1803.928
Services	554.3069	1164.147	2076.408	3673.253	5065.285	6520.404

In other words, the productions of each sector tends to decrease by the amount of the residual damages. These damages are compared in Figure 5.16 for CINA and CIAA cases. It is clearly evident that for each sector, adaptation policy has reduced the residual damages compared to that of the CINA scenario. It is also evident that each sector projects damages commensurate to its ratio in the total production or output with the exception of palm oil sector which shows highest resilience to climate change related damages compared to its percentage contribution to the Malaysian economy.

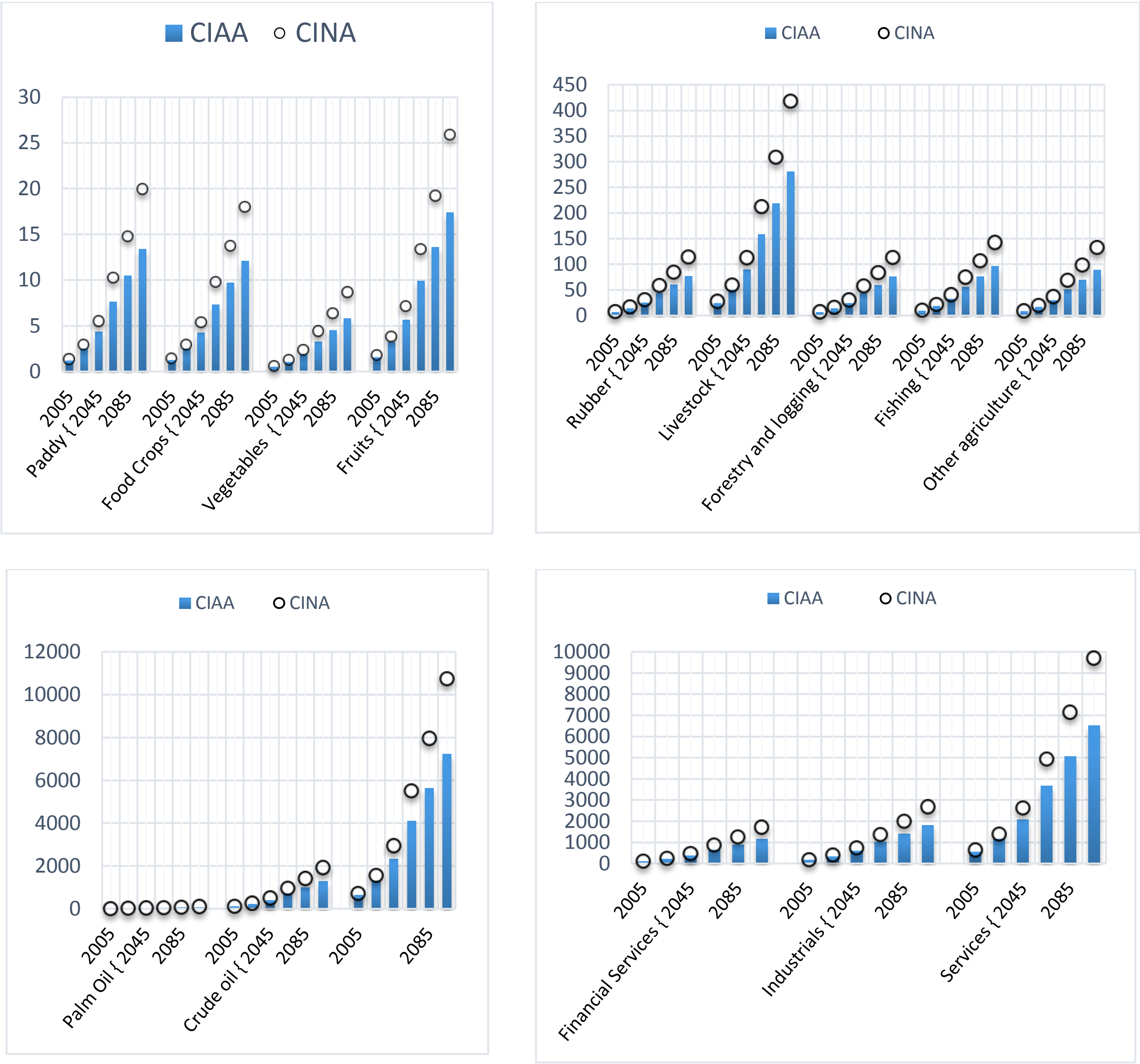


Figure 5.16: Comparison of residual damages for CINA and CIAA scenarios (in RM million)

5.6.2.2 Benefits of climate change adaptation

Taking into account of the optimum adaptation action, the simulation results show that CIAA residual damage is consistently lower i.e. the productions of each sector for CIAA are higher than that of CINA scenario. The results indicated that the adaptation policy is effective in terms of the outputs for each sector. It is further clarified in Table 5.10 which shows the difference between the production values of two scenarios (CINA and CIAA).

Table 5.10: Benefits of Climate Change Adaptation (in RM million)

Time segment/sectors	***2005***	***2025***	***2045***	***2065***	***2085***	***2105***
Paddy	0.175674	0.464844	1.141471	2.61809	4.321276	6.548847
Food Crops	0.182506	0.46904	1.11928	2.496141	4.008152	5.912842
Vegetables	0.074032	0.197195	0.487306	1.124384	1.865652	2.842525
Fruits	0.229232	0.605485	1.484809	3.402252	5.612083	8.502375
Rubber	0.994947	2.639267	6.496134	14.93221	24.69672	37.49938
Palm Oil	3.568118	9.509103	23.50931	54.2693	90.1233	137.3761
Livestock	0.973947	2.591247	6.396278	14.74354	24.45035	37.22164
Forestry and logging	1.321295	3.460267	8.412616	19.11022	31.25022	46.93664
Fishing	1.201186	3.156378	7.701794	17.56338	28.83833	43.49838
Other agriculture	0.916492	2.45058	6.077782	14.07261	23.43784	35.82572
Crude oil	15.72806	42.3141	105.5406	245.6493	411.1035	631.1921
Industrials	93.70921	248.5518	611.7318	1406.119	2325.669	3531.484
Transportation and communication	14.60417	38.91534	96.21039	222.1202	368.952	562.5734
Financial Services	23.60757	62.47973	153.4843	352.2274	581.7783	882.4075
Services	82.57755	220.2227	544.8162	1258.465	2091.193	3189.514

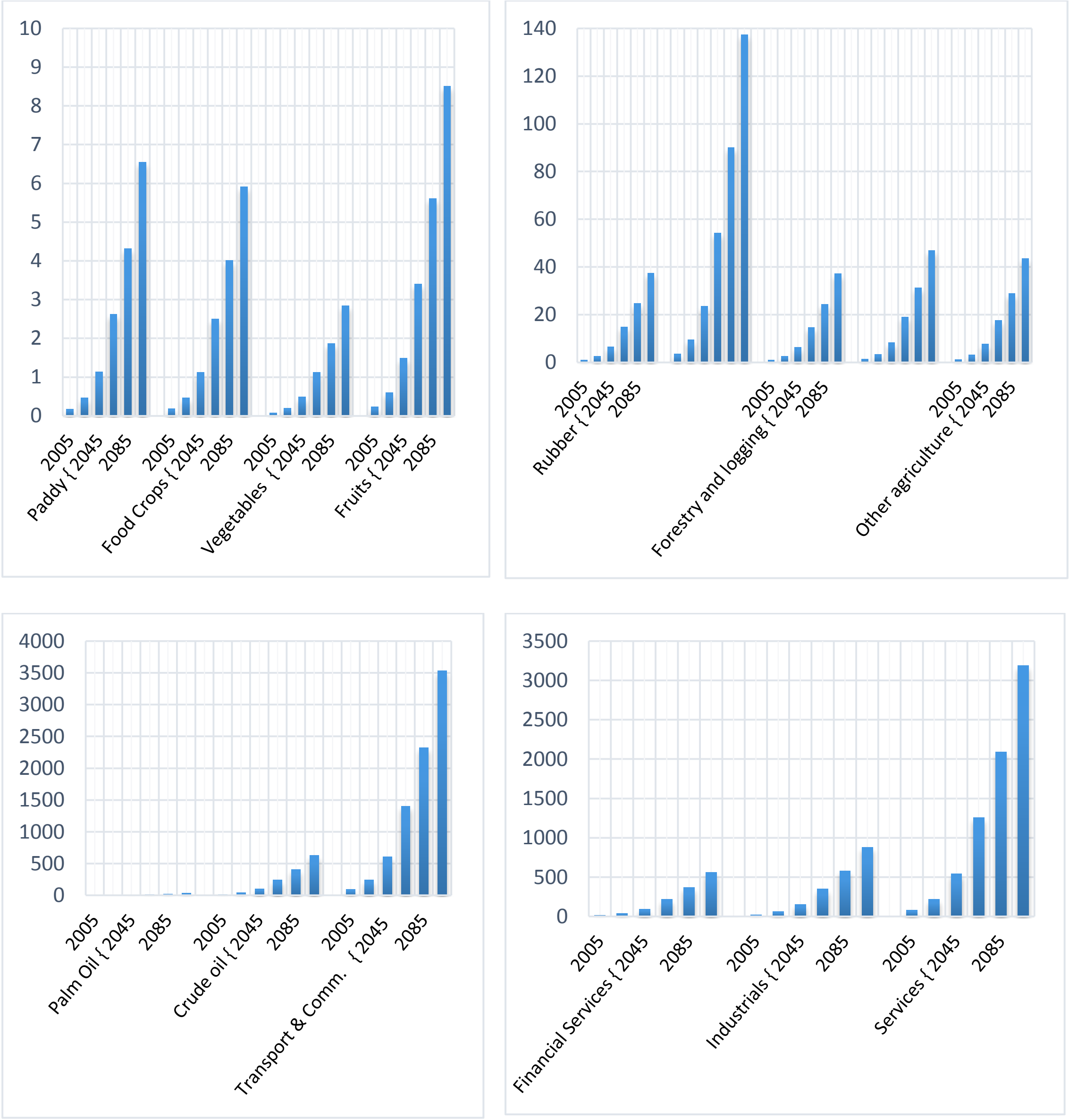


Figure 5.17: Benefits of climate change adaptation (in RM million)

5.6.2.3 Climate change effects on the overall agricultural sector

This study accumulated the production values of all agricultural subsectors to find out the benefits of adaptation for the overall agricultural sector. These values are tabulated in Table 5.11.

Table 5.11: Overall Agricultural Sector Outputs for Different Scenarios

(in RM million)

Time segment	***2005***	***2025***	***2045***	***2065***	***2085***	***2105***
BCS	47783.66	49597.59	51494.47	53477.58	55549.98	57716.33
CINA	47709.33	49437.02	51192.19	52911.96	54733.43	56613.79
CIAA	47718.97	49462.56	51255.02	53056.3	54972.03	56975.95

Figure 5.18 compares the overall productivity for the agricultural sector considering base case (BCS), climate impact without adaptation (CINA) and climate impact with adaptation (CIAA) scenarios. The CINA and CIAA outputs are obtained by subtracting the residual damages from BCS output.

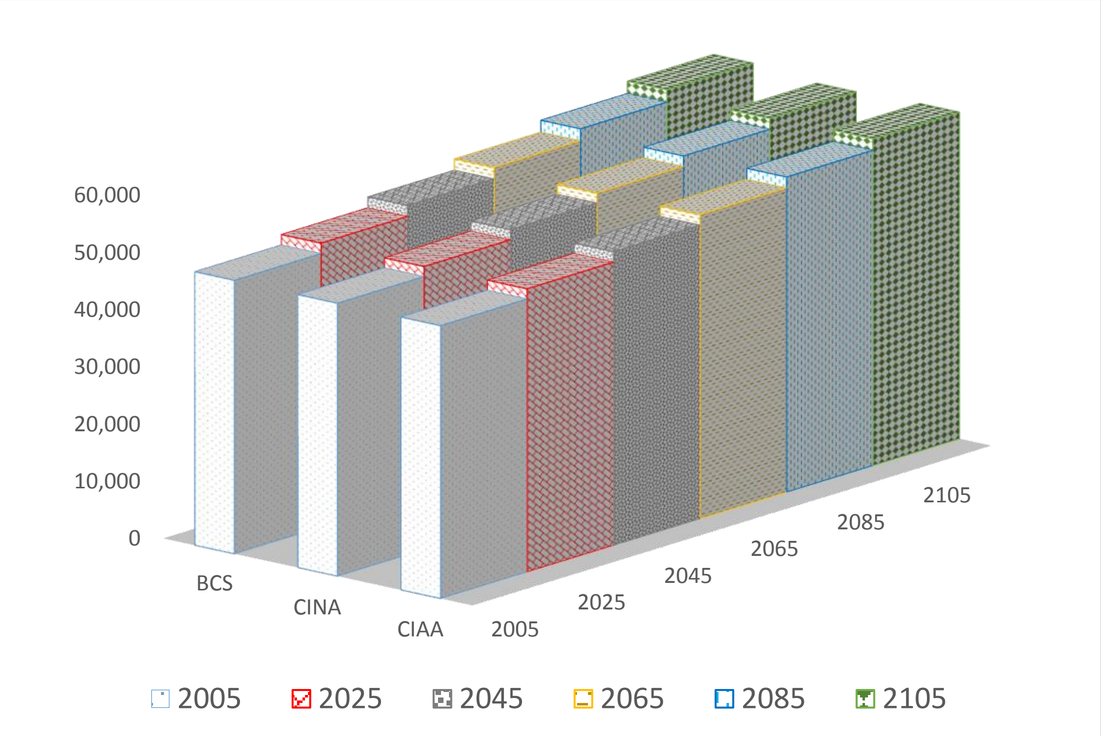


Figure 5.18: Comparison of agricultural sector outputs for BCS, CINA and CIAA cases (in RM million)

It is evident that with continued economic activities the production of each sector tends to increase over time for all three scenarios. As discussed before BCS output is fictitious as it does not consider any climate change projections. Therefore, it is also the highest. Comparing CINA and CIAA, we find that CIAA productions for the overall agricultural sector is higher than that of CINA. Hence, it can be concluded that the adaptation policy is effective in terms of the outputs for agricultural sector.

The difference between the production values of two scenarios (CINA and CIAA) shows the benefits of taking optimum adaptation action. Figure 5.19 shows the benefits of adaptation in terms of augmented production values. The positive values indicate that adaption is effective in terms of agricultural production, as the production without adaptation policy is less than the production with adaption policy. The results also highlight the fact that the benefits of adaptation policy increases over time.

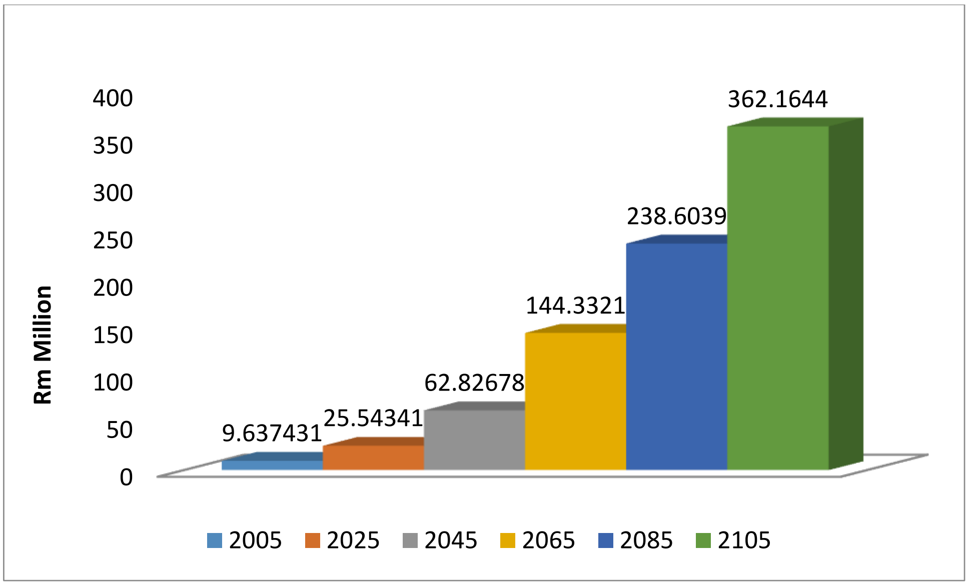


Figure 5.19: Benefits of adaptation for agricultural sector (in RM million)

Figure 5.20 shows the benefits of adaptation as percentage of the respective year real GDP while figure 5.21 shows the comparison between the costs and benefits of adaptation.

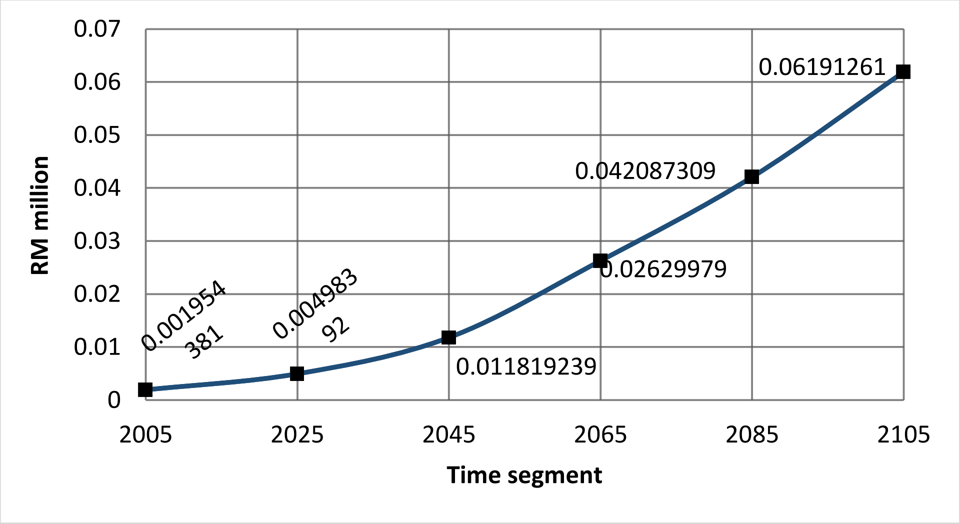


Figure 5.20: Benefits of adaptation for agriculture as % of RGDP

(in RM million)

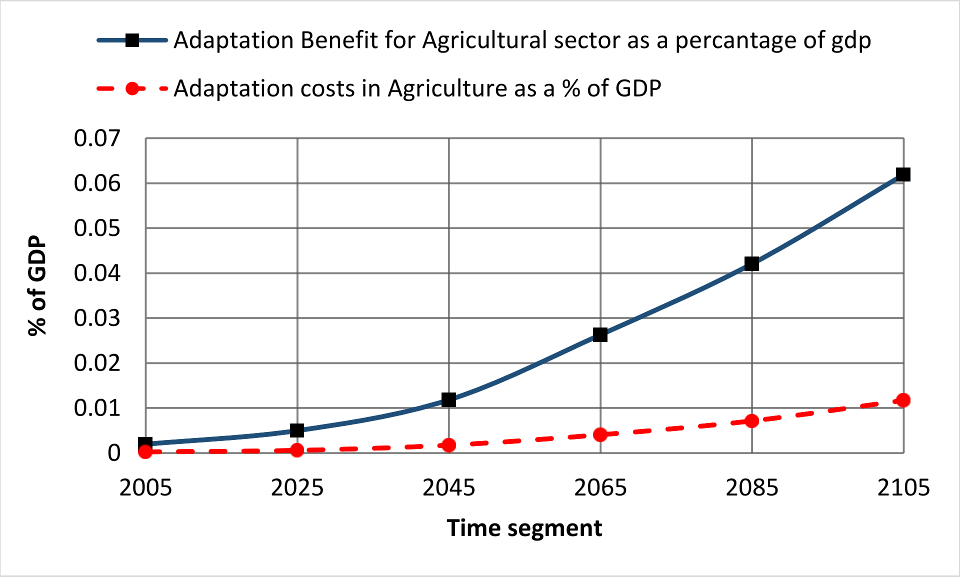


Figure 5.21: Costs and benefits of adaptation for the overall agricultural sector

(in RM million)

It is evident that the benefits of adaptation is higher than the costs of adaptation for each time segment. Moreover, benefits of adaptation tends to increase at a higher rate over time. This implies that the benefit over cost ratio would continue to increase by the way of time period.

5.6.3 The Effects on Government Expenditure

The government expenditure is a must to implement a public policy. Thus, to enforce adaptive actions, government has to bear the costs of adaptation. Which is ADPC (discussed earlier chapter).

Table 5.12 and Figure 5.22 show the estimated values of government expenditures before and after taking adaptation policy. In this scenario, there is no costs of adaptation was considered. The general trend for all cases show that with continued economic activities the government expenditure increases linearly over time. However, in case of CIAA, government expenditure is higher than that of no adaptation (BCS and CINA cases) by the amount of the costs of adaptation.

Table 5.12: Government Expenditure for BCS/CINA (AL=0.0) and CIAA (AL*) (in RM million)

Time segment	***2005***	***2025***	***2045***	***2065***	***2085***	***2105***
EG(AL=0.0)	68100.108	70455.33	72912.14	75474.95	78148.33	80936.99
EG(AL *)	68132.122	70531.277	73144.326	76035.197	79170.531	82671.628
Difference	32.014	75.947	232.186	560.247	1022.201	1734.638

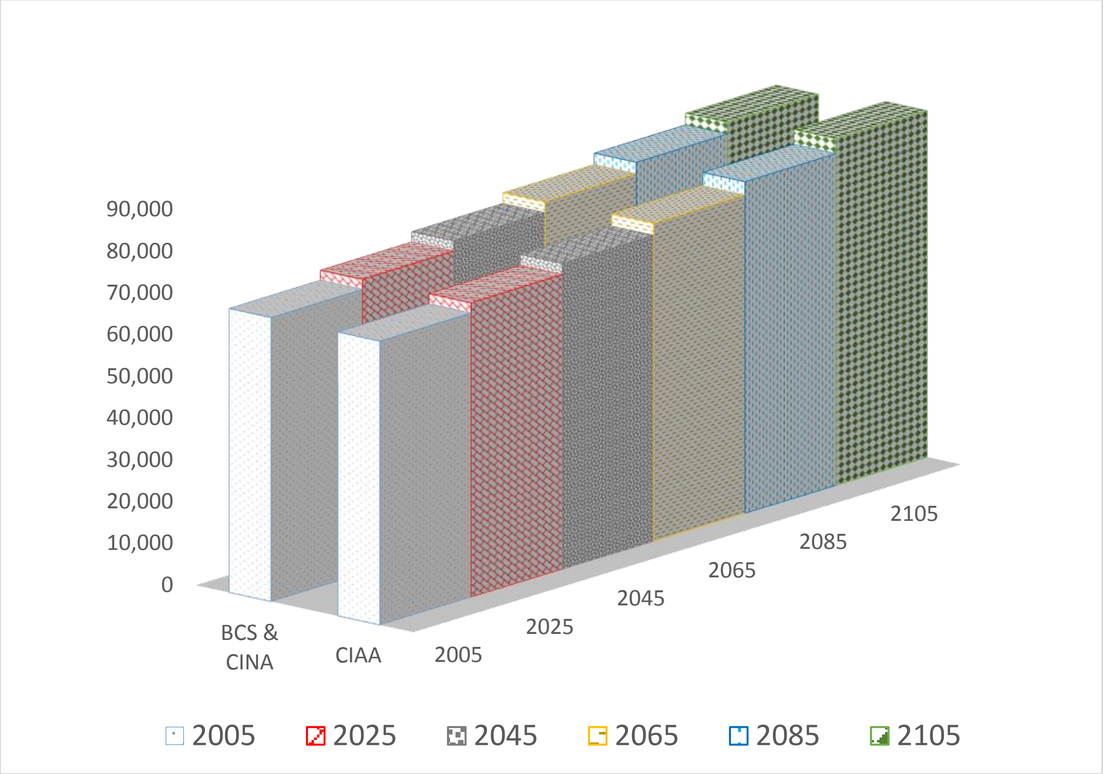


Figure 5.22: Comparison of government expenditures (in RM million)

5.7 Conclusion

From the above findings it is evident that the adaptation policy would be effective for Malaysia in terms of the costs and benefits. However, the next chapter will focus on a discussion of these findings and try to relate with other studies and theories relevant to the present study.

CHAPTER 6: DISCUSSION

6.1 Introduction

We addressed from the past literature that most of the climate change impacts/policy studies are either global or regional. However, the impacts and the costs of the climate change measures cannot be optimally determined on a global basis as the impact will vary from region to region; between countries or even within a country (Pearson et al., 2011). Therefore, it is necessary to assess the feasibility of the future adaptation plan on country basis to choose appropriate adaptation actions for a specific country. Also, the impacts of the climate change can be felt differently in each sector of an economy. Agriculture is considered to be one of the most vulnerable sector to climate change as it is directly dependent on weather conditions. This is also one of the most important sectors as it is significant for poverty elimination, food security and economic development. Considering the importance of this sector, we study here the impact of the climate change on this sector. The key questions that we try to answer are: Which level of adaptation is optimal for a tropical country like Malaysia? What will be the estimated cost of adaptation? How does this adaptation affect the agricultural sector in particular and on the economy as a whole to measure the overall impacts?

This chapter focuses on the interpretation of the results. Here, the results of this research are compared with the past studies to get a clearer understanding and validate the effectiveness of the adaption policy in Malaysia. The discussion is divided into three sections. Section 6.2 analyses the objective one, i.e. the optimum level of adaptation, Section 6.3 about the objective two, i.e. the costs of adaptation at its optimum level and Section 6.4 explains the objective three of this study i.e. whether adaptation policy is effective in terms of the associated costs and benefits.

6.2 Optimum Level of Adaption

This study shows that, with continued economic activities along with increased gross damage values, the optimum level of adaptation tends to increase over time. Without taking any mitigation policy, the country's economic activities continue to emit GHGs at a higher rate because of the expanding/growing economic activities and are supposed to accelerate the climate change negative impacts on the economy. As a result, the optimum level of adaptation increases over time.

The doubling of carbon dioxide (CO_2) emission compared to the pre-industrial age lead to a temperature increase by around 2.5 to 3°C. Following the literature (e. g. (Pearce et al., 1996)) benchmark damages of this temperature increase are assumed to cause around 1.3 to 2.5 percent damage in overall world income. The parameters of the climate impact model are calibrated to reflect this relationship (Tol & Fankhauser, 1998), p. 70). However, in our MCE model, we projected the values of CO_2 emission trend over a period of hundred years in six time segments, each with different emission level. Our results showed that with rising temperature, the damages for the climate change without any policy is estimated at the loss of RGDP by 5.7%. The loss due to the climate is higher for Malaysia than compared to the global average. This is because, some regions and countries are not so vulnerable to the climate change. Their damages are very low compared to the highly vulnerable countries like Bangladesh and moderately vulnerable countries like Malaysia.

The Dynamic Integrated Climate and Economy (DICE) and Regional Integrated Climate and Economy (RICE) models (Nordhaus, 1993b) analyses the climate change impacts at the global and regional levels not distinguishing sectors or economic and non-economic categories. DICE and related models are based on Cost-Benefit approach. They are used to calculate the optimal balance between greenhouse gas abatement and economic damages due to the climate change in order to maximise the inter-temporal welfare. DICE and RICE do not take adaptation as a decision variable into account while their extensions AD-DICE and AD-RICE do (K. C. De Bruin, Dellink, & Tol, 2009), (K. C. De Bruin et al., 2009). In these models adaptations decrease the potential damages due to climate change. This study followed AD-DICE and AD-RICE models with few variations. For example for Malaysia, we considered adaptation policy as the best policy in response to climate change and from our result we found that, the optimum level of adaptation is different for each time segment.

The adaptation cost function increases with the level of adaptation. The simulation results using AD-DICE model show that the adaptation costs for the first 15 percent of gross damage reduction can be avoided at very low costs. If additional adaptation measures (more than 15 percent) are considered, costs increase very rapidly. The calibrated model finds an optimal level of adaptation between 0.09 and 0.45 of the gross damages having an average of 0.33. It means that considering cost benefit aspects it is optimal to choose an adaptation level commensurate to the 33 percent of gross damages. Considering cost, it cannot be optimal to fully adapt to the climate change as adaptation costs are much higher for full adaptation. Neither is it the best solution to mitigate all future damages. For an optimal policy with minimum costs, considering both damages and implementation costs, a mixture of mitigation and adaptation policy has to be implemented (K. C. De Bruin et al., 2009), p. 70).

However, our study finds quite similar results to that of the AD-DICE and AD-RICE models. The results showed that optimum level of adaptation in between 0.13 to 0.34 over the next hundred years. For each time segment, we have found different optimum level depending on continued temperature change, emissions, economic growth, population growth, and so on. While our base models suggest that a combination of adaptation and mitigation policy is the most effective in terms of the reductions of climate change negative impacts, our study only focused on adaptation policy because for Malaysia, there is no quantitative restriction to take mitigation as a policy since it is a developing country and mitigation affects economic growth negatively i.e., any restriction on CO_2 emission can reduce the economic productions or can make it costly. Consequently, due to the competitive nature of the international trade, the country's economy would be negatively affected. Likewise, this policy of mitigation will not be effective without regional co-operation. In case the neighboring countries continue to produce emissions at a same rate, the concentration of the emission for Malaysia will be higher because of the externalities.

6.3 Costs of Adaptation

This study showed an increasing trend for the cost of adaptation over the hundred years. Growing economic activities as well as emissions would cause optimum level of adaptation to increase. Therefore, the costs of adaptation would also increase both for sector wise or overall economy considerations.

Nowadays, there are two main contextual approaches to view adaptation. According to Bosello, Carraro, and De Cian (2010), adaptation is a pro-active response that necessitates the investments on capital stocks of adaptation. For example, construction of dikes is to protect from the adverse effect of flood. On the other hand, K. C. De Bruin et al. (2009) described adaptation concepts as reactive response, which is to be effective within a very short gestation gap. Usually, this is applicable to agricultural sector, where adverse impacts of the climate change can be minimised by either altering crop variety or changing planting dates and harvesting time.

This study focused on reactive adaptation actions and studies the benefits and costs of adaptation. In case of the agricultural sector, reactive adaptation is particularly very important, especially for developing countries since this sector is a substantial source of national income for the developing countries. To balance most of climate impacts on agriculture, McCarl, Metting, and Rice (2007) figured out that 5 to 12 billion US$ have to be spent for adaptation per annum within the next twenty years. This highlights the fact that developing countries are exclusively vulnerable to the climate change and are expected to be at high risk without adequate financing for adaptation.

Similar studies for example, (N. H. Stern et al. 2006), found that, the costs of adaptation measures for the whole world would be as minimum as 4 billion US$ to a maximum of 37 billion US$ per year, whereas the world bank estimates (2007) that annual costs of adaptation may vary between 10 to 40 billion US$. In contrast, UNFCCC estimates (2007) show different results. According to their projection, annual costs of adaptation by 2030 would be in the range of 46 to 171 billion US$, and about 28 to 67 billion US$ will be needed for developing countries.

From this fact, a question can be raised straight away concerning the rational for financing for adaptation in Malaysia. The policy will be justified to be adopted according to the Hicks-Kaldor criterion (Hicks, 1939), if accumulated welfare gains is at least equivalent to or greater than the costs. According to Schenker and Stephan (2012), funding for adaptation policies by disbursements of 0.1% of the Gross Domestic Products (GDP) of industrialised regions' could turn out to be globally beneficial subject to the aggregation principle. Nevertheless, their findings showed that funding adaptations beyond welfare oriented funding levels is counterproductive. By applying the Bentham criteria, when sum of the regions' welfare is considered, the break-even level is relatively small (0.003%). A Nash welfare aggregation scheme, where individual welfare levels are multiplied with each other, would support a funding below 0.3%, following Rawls, even a funding of 1% of GDP would be justified where aggregate welfare corresponds to the loss of the most affected agent. This shows that depending on the social welfare function, funding of adaptations in the developing world could improve welfare levels improving and therefore is justified under the Hicks-Kaldor criterion. In 2011, the extension proposal for existing Kyoto Protocol to agree an international level for green-house gas abatement failed to reach consensus at the COP meeting in Durban, South Africa. This directed attention on adaptation, which consists of measures to reduce the follow up costs of the climate change. Assuming that all regions, including the least developed ones, have access to necessary resources for adapting optimally to the climate change, a maximum of 10% of the domestic GDP would be invested for adaptation for avoiding almost 40% of the climate change induced damages by the mid of the century. In numeric figure, this estimates show global adaptation expenditure to be more than 85 billion US$ by 2050. It is significantly higher than Stern's (2006) estimates but still within the limits of the range projected by World Bank (2007).

All these estimates are either global or regional. But the main concern is the lack of cooperation between countries as well as international organisations regarding responsibilities about funding prioritizing countries and sectors etc. Therefore, we consider in our study the case of full non-cooperation among countries and regions, with continued emission concentration by the country itself and without the spillover effect of other country's emission, how much would be the cost of adaptation for a tropical country like Malaysia.

Our study developed a dynamic computable general equilibrium model, in which impacts of climate change is influenced by temperature change only, to investigate the impacts of climate change adaptation policy with its associated costs, individually for overall the economy as well as for agricultural sector.

Thus from our model, we calculated costs of adaptation to be between .006 to .30 percent of the GDP for the next hundred years, while benefits are about .03 to 1.7 percent of the GDP, for Malaysia. The estimates are very similar to some earlier global estimates, for example, subject to the aggregation criteria, funding adaptation would be by spending 0.1% of the industrialised regions' GDP (Schenker & Stephan, 2012).

Specially, for the productions of vulnerable sectors, adaptation can promptly reduce the adverse impacts of the climate change, it would be expected that the maximum unfavorable sector (i.e. agriculture) could be benefitted most from funding adaptation. Our estimates found this proposition is valid and benefits far outweigh the costs in each time segment.

Specifically, the Hicks-Kaldor criterion is satisfied as the results showed that aggregate welfare increases for adaptation. Impacts of the climate change can be lessened by applying adaptation policies, having associated costs which are less than the benefits. Our estimates found that for each sector, adaptation is beneficial in terms of costs and benefits for adaptation. Even if Malaysian policymakers decide to take adaptation policy (primarily) only for a vulnerable sector like agriculture, it is still justified to invest into reactive adaptation in agriculture for example changing crop variety, planting dates etc.

In a study for the EU (European Union) by Hope et al. (1993), the results showed a benefit, cost ratios of at least 20:1 for an "aggressive adaptation package" involving of "coastal protection measures". Adaptation is frequently studied in an equilibrium context, though the costs of adaptation generally are likely to be a momentary phenomenon (e.g. resettlement costs for migration). Hence, adaptation is not a matter of a solitary adjustment/changing practices to a new climate condition, but it is a continuous adjustments procedure to a continuously varying climate. This is why, we have estimated that the optimum level of adaptation changes with changing climate change damages over the hundred years in six different time segments.

6.4 Impacts of the Climate Change with and without Adaptation

The general objective of this study was to investigate the impacts and costs of the climate change on the agricultural sector as well as on the overall economy with and without adaptation policy. Our results showed that, benefits of adaptation are higher than the costs of adaptation for each time segment. Moreover, benefits of adaptation tend to increase as a higher rate than the rate of increase for the associated costs over time. This implies that the benefit-cost ratio will continue to increase with the time period. The positive values for every sector indicated that, adaptation is effective in terms of sectorial production, as the production without adaptation policy is less than the production with adaption policy, for each of the 15 sectors. From the findings it is evident that the adaptation policy would be effective for Malaysia in terms of the costs and benefits.

Valuations of the economic/monetary costs of the climate change usually associates adaptation costs accompanied by residual costs to calculate an aggregate damage figure (with adaptation), without a strong distinction within these two (Pearce et al., 1996). Climate change costs usually concentrate on the equilibrium impacts of the climate change with a doubling of the pre-industrial CO_2 concentration level (K. C. De Bruin et al., 2009). The drawback of this concept is that the concentration level of CO_2 is expected to change continuously over time (Tol, Fankhauser, & Smith, 1998). Realizing this fact, this study considered the projected CO_2 emission concentration for different time segments for Malaysia (without mitigation policy), for the 100 years between 2005 and 2015.

In some, specifically previous impact studies, human behavior is presumed to remain virtually unchanged in response to the climate change. There is neither anticipatory nor autonomous adaptation S Fankhauser (1995). Without any adaptation policy, the impacts of the climate change on a usual society, is possibly very much connected to the so-called dumb farmer hypothesis. Nevertheless, this hypothesis of no adaptation has been used in numerous impact studies. Specifically, the studies on the impacts of climate change to estimate damage from extreme weather events, morbidity, hunger, health and so on. Ignoring adaptation is undoubtedly insufficient and may lead to an overestimation of the probable impact. To investigate the adaptation policy in reducing impacts, the value of the damages with adaptation policy and without adaptation policy can be compared. (e.g. (Rosenzweig & Parry, 1994).

Easterling III et al. (1993) estimated the impacts of the climate change with adaptation policy on the agricultural sector by using an arbitrary set of low-cost adaptation measures, for example, they considered an adaptation action such as an increased irrigation or change in planting date. Their results showed that adaptation could reduce the damages to the MINK (Missouri-Iowa-Nebraska-Kansas) region by 30 to 60% for the agricultural sector.

Many other studies also showed similar results. Rosenzweig and Parry (1994) classified adaptation into three arbitrary levels. In scenario one (without adaptation scenario), farmers are assumed to be dumb and continue to act as they do at present, meaning, they completely ignore that climate has changed. In adaptation scenario two, a little adjustment in behavior as well as small investment of capital is allowed. At the final stage (adaptation scenario three), the study assumes large investments and adjustments are allowed. Results from the global study showed that, a change of 1.2% to 7.6% in cereal grains output/production (worldwide) without adaptation is related to 0 to 5% damage with adaptation policies. J Reilly (1994) estimates the similar study by using the Rosenzweig and Parry yield data, and their estimates showed that, without adaptation action, the loss of global welfare would be up to US$61.2 billion while with adaptation action, the loss of global welfare would remain same at US$37.6 billion. Thus adaptation policy is favorable.

The damage is a constant fraction of GDP; hence, damages grow linearly with GDP. This linear trend can be influenced by other factors shifting the amount of damages up or down. For example population growth affects the number of people concerned. Then income growth affects people's valuation of impact and this result in a change of tastes affecting valuation (K. C. De Bruin et al., 2009). Our study followed this fact and included Malaysian income and population data in the model to get different damage values for each time segment.

Provided that adaptation is applied as optimally, K. C. De Bruin et al. (2009) argue that with this implication the benefits of the adaptation policy would always be outweigh the costs. This kind of modelling belongs to the category of reactive adaptation. Our results also revealed the same proposition as showed in Figure 6.1 that shows the costs of climate change increases with mean temperature change. However, the costs of climate change without adaptation policy are higher than the costs with adaptation policy in place. The gap between dotted and dashed lines shows gross benefits of adaptation. This is the benefit without considering the costs of adaptation. The gap between solid and dotted lines indicates the net benefits of adaptation policy whereas the gap between the dot and dashed lines and the horizontal axis shows the

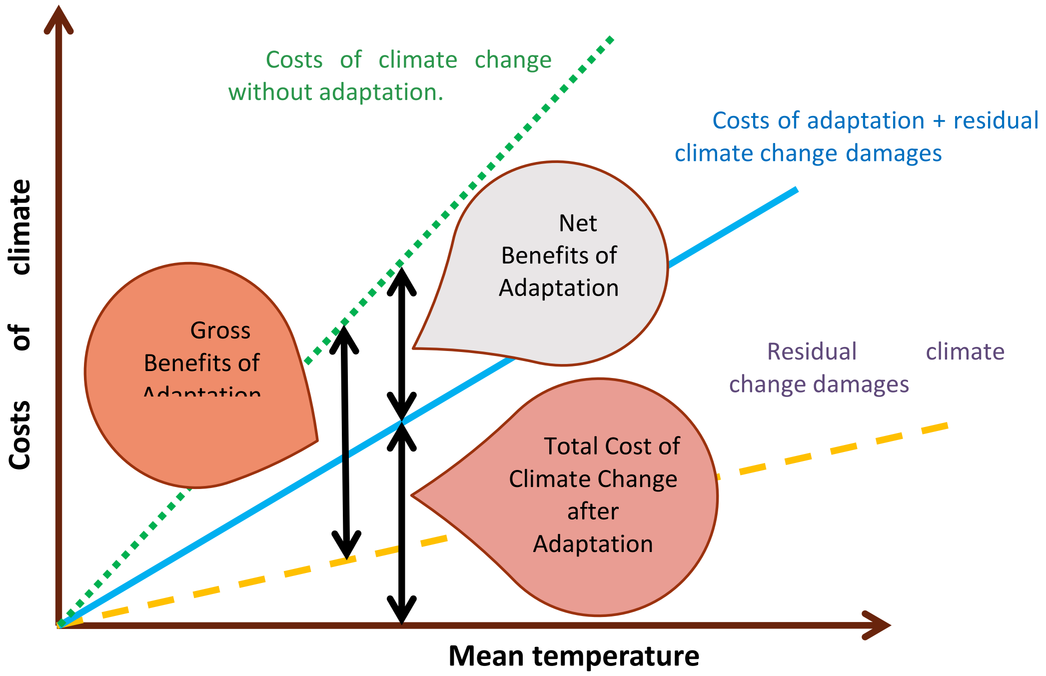


Figure 6.1: Costs of climate change with and without adaptation

total costs of climate change with adaptation (which is the sum of residual damage costs and costs of adaptation).

According to Tol et al. (1998), during the early period 2025-2034 the saving effect of an optimal adaptation and mitigation strategy compared to no action (with cost reduction of 3 percent) is very small, whereas the benefits of action increase strongly over time. The maximum benefits are possible in the period of year 2145- 2155. This finding is in-line with our study results which showed benefits of adaptation are 0.04% of RGDP in 2005 while it tends to increase to 1.7% of RGDP for the segment 2105.

Practically, wide-ranging modifications in management could offset all the losses. However, the gains would come, more likely from the developed countries. For the developing countries, there is insufficient resources, therefore, adaptation policy is assumed to be less effective and these countries would continue to suffer noteworthy losses of welfare (Tol et al., 1998). On the contrary, damages from climate impacts can be significantly reduced in developing countries when adaptation takes place (K. de Bruin, Dellink, & Agrawala, 2009), pp. 23-24. For example, Africa can reduce its gross damages by 35 percent with adaptation in the amount of 7 percent of gross damages. For Malaysia, our study found that, without investment into adaptation, climate change will cause remarkable losses in RGDP (almost 5.7% of RGDP). With adaptation policy, we can significantly reduce the loss which is the benefits of adaptation.

Our study found out that the benefits of adaptation is seven times higher than the costs of adaptation for each of the time segment. It implies that this policy is beneficial in terms of costs and benefits for every sector for Malaysia. Hope et al. (1993) developed a similar model named “The Policy Analysis for the Greenhouse Effect (PAGE) model". The model compares the no adaptation and aggressive adaptation cases. For no adaptation case, impacts are accepted as they occur and when they occur. The effect of aggressive adaptation is that the sectors face no damages from a 2°C rise of temperature until 2000. If temperature rise is more than 2°C, further implemented measures reduce the impacts of climate change by up to 90 percent compared to that of the no adaptation scenario. But adaptation should only be implemented if benefits are larger than the costs of adaptation. The estimated results show that the adaptation costs of 0.5 trillion Euro will avoid damages due to climate change impacts by 17.5 trillion Euro. Therefore, adaptation should be implemented to a large extent (Hope et al. (1993). However, our study established that, even a small temperature change (for example, 0.73°C by 2005) would contribute to accelerated damages due to climate change.

Numerous studies, specifically studies that are on agricultural impact, only assess/estimate the benefits of adaptation rather than costs and benefits. Nevertheless, considering a society which is fully adapted, impacts of climate change will be reduced, but the progression of attainment to this level would possibly be costly and achievement may be subject to the sufficient planning and appropriate policy measures (Tol et al., 1998). Distribution issues has been paid less attention in most of the studies, even though it is predictable that the benefits and costs of adaptation will supposed to be unevenly distributed among different sectors. In the case of government financed adaptation, distribution aspects can be taken care of through the adequate funding of measures. For autonomous adaptation along with other categories of individual adaptation measures, the choice of policy response is expected to be dependent on the distribution considerations.

This study focused on the entire economy by dividing it into fifteen different sectors among which ten sectors are only agricultural, as our special focus was on agricultural impact investigation. We have estimated the costs of climate change with and without adaptation action for each agricultural commodity separately. And the results showed that for every sector the benefit tend to be higher than the associated costs. Another similar study namely FUND, simulates damages due to climate change in key areas such as forestry, agriculture, energy consumption, water resources, ecosystems, sea-level rise, mortality and human health. Adaptation occurs in that model via the agricultural sector. A parameter denoted by the speed of adaptation lowers the impact of climate change on this sector. The adaptation costs are only modelled implicitly while explicit adjustment costs are missing (Warren et al., 2006), p. 48. Damages in the FUND model are in monetary units or in percentage loss of GDP (Tol, 1997), p. 157. For the period of 2000-2100 the results of FUND show that for the business as usual scenario at a global level a small benefit from climate change for a very moderate increase of about 0.5°C above 1990 levels. But for higher temperature increases, damages rise as global warming increases. For a 3°C rise in temperature, damages will amount to between 1.2 and 2.7 percent of the global GDP per year. For a 2°C rise the damages are still between 0.5 and 1.0 per cent. Compared to the results of the DICE model (0.5 percent loss for a 2°C rise in temperature), the damage estimates are very similar (Warren et al., 2006), p. 60. However, from our model, we found that with a 2°C rise of temperature would bring a damage of 2.4% of Malaysian RGDP.

In relation to the theories explained in the conceptual framework of the study, our findings show interesting similarity in relation to “The theory of transitions” (Blomström & Hettne, 1984) and “Action theory of adaptation” (Eisenack & Stecker, 2011) as discussed below.

Our study results are suitable to the “The Theory of Transitions (Blomström & Hettne, 1984)”, which identifies four stages for economic development i.e.

I. Pre-development: Before any development policy takes place, in our case before taking adaptation policy.
II. Take off: The immediate stage after taking the development policy. In our study it stands for the starting period of adapting the policy.
III. Acceleration: The stage when the economy is developing highly. Our findings in relation to this stage showed that the benefits of adaptation policy are strongly increasing over time.
IV. Stabilisation: This stage is the last stage of development process when the economy is stabilised. In our study, this stage refers to a fully adapted climatic condition.

“Action theory of adaptation” (Eisenack & Stecker, 2011) explains that adaptation is exercised by human actor and requires use of resources as means to achieve the intended goals. Our study assumed that actors would be the policymakers who would employ necessary resources to adapt suitable policy to reduce the negative impacts of the climatic change. To do this, it requires a monetary investment for costs of adapting to the appropriate level of action. From our findings, we have found that, the costs of adaptation policy would change over time with different optimum level of adaptation.

"Social ecological resilience theory" states that social and ecological factors are interlinked. From our study, we found that the adaptation decision influences the capabilities to adapt, which in turn reduces the vulnerabilities. For example, without adaptation action, climate change negative impacts are higher. This implies that, the environmental vulnerabilities are dependent on some human socio-economical actions. On the other hand, some adaptation decision is completely based on social responses such as change of crops to adopt with the changing environment. Thus climate change and some social aspects of human life on earth are closely linked to each other and change in one will continue to impact the other to eventually establish a social and ecological balance.

Hence the theories give reflections that benefits of adoption accrue over time with continuing necessary investment.

6.5 Summary

This chapter discussed our findings including answering the research questions outlined in Chapter One. The results clearly indicated that for Malaysia, climate change would bring negative impacts which can be reduced through adaptation policy. Our findings reveal that benefits are higher than the associated costs for every single time segment we considered in our simulation. In the next chapter, we conclude our study with some policy suggestions on adaptation for Malaysia.

CHAPTER 7: CONCLUSION

7.1 Introduction

This chapter concludes with policy recommendations based on the findings of this study. It clarifies strengths and weaknesses, and practical contribution of this study before suggesting further opportunities for future research. The overall purpose of this study was to analyse the impacts of climate change adaptation policy for Malaysia considering associated economic costs for the agricultural sector in particular and other sectors of the economy in general, and measure the macroeconomic impact (Gross Domestic Product - GDP variables).

The specific objectives of this study were, to investigate the optimal level of adaptation, to estimate the climate change adaptation cost for different time segments, and to examine the impacts of adaptation policy to climate change especially for agricultural sector and for the overall economy to establish whether the chosen adaptation policy for Malaysia is effective or not in terms of costs and benefits.

7.2 Overall Results

7.2.1 Summary of the Optimum Level of Adaptation

From our Malaysian model (MCE), we found that the estimated optimum adaptation level, i.e. equation (5.1), lies between 0.13 to 0.34 for the 2005 to 2105 period. With continued economic activities along with increasing gross damage values, the optimum level of adaptation is projected to increase over time without considering any mitigating policy. In 2005, if the adaptation policy were taken, the optimum level of adaptation would be 13% of the total damage. While in 2105, the optimum level of adaptation is estimated to be 34%.

7.2.2 Summary of the Costs of Adaptation

The results from the simulations showed costs of adaptation are a small percentage of the estimated real GDP. Interestingly, the results presented that the early action costs are as little as 0.65% for 2005, whereas if the adaptation is to be adopted late, the cost would increase as a percentage of GDP. Furthermore, the results established that, for the agricultural sector, the costs of adaptation is a very small percentage of GDP. However the increasing trend established that the early action costs are much lesser (0.0261% of GDP for 2005) than the later actions (1.1725% of GDP for 2105).

These values increase in a consistent manner i.e. linearly over the entire simulation period of hundred years from 2005 until 2105. However, the rate of change for each crop is not the same throughout the simulation period. For example, for the time segment 2005, the costs of adaptation for paddy was 23.446 thousand ringgits whereas, adaptation costs for food crops was 24.358 thousand ringgit. On the contrary, during the final time segment (2105), the costs of adaptation for paddy (1240.252 thousand ringgit) was higher than the costs of adaptation for food crops (1119.802 thousand ringgit).

7.2.3 Summary of the Climate Change Adaptation Policy Impacts

Climate change has a real effect on the production side of the economy as it has a direct impact on the physical output. If the temperature increases, it would directly affect crop production. Thus, the production is negatively affected due to climate change.

This study simulated three scenarios to investigate the impacts of adaptation policy with associated costs on the economy: 1) Base Case Scenario (BCS), 2) Climate Impact with No Adaptation (CINA) and 3) Climate Impact with Adaptation Actions (CIAA).

The study examined the impacts of adaptation policy on real GDP, productions of commodities, government expenditure etc.

In our model, at first we simulated the BCS which determined business as usual (i.e. as if climate change does not happen) values of the productions and therefore does not incur any adaptation cost. The estimated value showed that, with continued economic activities, the production of each sector tends to increase over time.

However, we observed that the BCS output for paddy was 871 million ringgit during 2005 and continued increasing to 1044 million ringgits during 2105. Whereas the value for food crops in the year 2005 was 904.889 and kept on increasing to the value of 942.9 in 2105. This may imply that the rate of change of the value of output is not the same for each sector. The aggregated level shows that, from 2005 to 2025, the output value increased by 4.16% (in 20 years) whereas from 2085 to 2105, the rate of increase was 4.19% (in 20 years). This indicates that without considering the impacts of climate change, output is increasing at an increasing rate.

The CINA scenario indicated the economic facts with the consideration of climate change monetary damage without adaptation policy. Considering the climate change monetary impact scenario, without taking any initiatives to reduce the negative impacts of climate change, the economy would make a monetary loss of real GDP for each time segment compared to BCS values.

Considering the optimum adaptation policy in the model, we found that the CIAA RGDP values increased compared to the CINA scenario as depicted in Table 5.15 and Figure 5.13.

The real GDP increase with the adaptation policy is the difference between RGDP with and without an adaptation policy which showed that a climate change adaptation policy is beneficial or effective in terms of the monetary value of real RGDP

The results from the simulation showed, in the case of CINA scenario, the productions of each sector decreases by the amount of the residual damages. Table 5.20 and sequential Figure 5.19 shows the output values of each sector after subtracting the residual damages.

Similarly, for the BCS scenario, the rate of change for each crop production differs overtime. For example, the output value of paddy increased by 3.45% (total in the first 20 years) and for the last 20 years, it increased at a decreasing rate (3.27%). However in comparison between paddy and food crops, the value of food crops increased 0.47% (total in the first 20 years) whereas in the last 20 years it increased by a higher rate (0.53%).

The aggregated output of CINA scenario showed that the output for the overall economy for each time segment is changing overtime. The aggregated level showed that, from 2005 to 2025, the output value increased by 3.9% (in the first 20 years) whereas from 2085 to 2105, the rate of increase was 3.7% (in the last 20 years). This indicates that considering the impacts of climate change without an adaption policy led to output that is increasing at a decreasing rate. In comparison, the rate of increase is lower compared to the BCS values. This indicates that the impacts of climate change without an adaption policy will significantly reduce the value of the aggregate output which over time and will have a greater impact on reducing the output value.

Taking into account the optimum adaptation action, the simulation results showed that after deducting the CIAA residual damage, the productions of each sector would be higher than CINA scenario output values. The results indicated that the adaptation policy is effective in terms of the outputs for each sector. The results showed the values of productions for each commodity with adaptation action.

The aggregated output of the CIAA scenario showed that the output for the overall economy for each time segment is changing overtime. The aggregated level showed that, from 2005 to 2025, the output value increased by 4.0% (in the first 20 years) whereas from 2085 to 2105, the rate of increase was 3.9% (in the last 20 years). This indicates that with consideration to climate change impacts with an adaption policy, the output is increasing. In comparison with the CINA scenario, output is increasing for each time segment (for example, in 2005-2025, the rate of change of CINA scenario was 3.9% but for the CIAA scenario it is 4.0%). This implies that the adaption policy is effective in terms of aggregate output value for each time segment.

From the results of the study, it is evident that the benefits of adaptation is higher than the costs of adaptation for each and every time segment. Moreover, benefits of adaptation intended to increase at a higher rate than the rate of increase of the costs overtime. This implies that the benefit cost ratio would continue to increase by way of time period. Therefore, the adaptation policy would be effective for Malaysia in terms of the costs and benefits.

7.3 Policy Implications

From the findings of the study, it could be suggested that an optimum adaptation policy should be implemented by the Malaysian policymakers. Primarily, they can focus on the agricultural sector to minimise the total costs of the adaptation policy through changing crop patterns, climate resilience crop variety, water management, food storage, and livestock practices etc.

However, in practice, Malaysian farmers confer little attention in planning for potential climate change impacts on both the individual and community levels. Generally, farmers cope with weather patterns on a short term basis and are sometimes able to adjust to potential risks and weather variability through best management practices, but climate change may pose new unpredictable risks for the future of Malaysia similar to rest of the world. This proposition is valid because from our study, we have found that impacts of climate change is projected to increase overtime which would ultimately reduce outputs of all the sectors of the economy. Hence, it is the government's responsibility to oversee the adaptation policy so that its benefits can be achieved collectively.

Every individual sector should have its own policy depending on its vulnerability to climate change. However, in Malaysia, "At present, no separate, specific policy exists for every economic sector that would address the effect of global warming and climate change on the individual sectors and their productivity." (Austin & Baharuddin, 2012). Furthermore, it is necessary to provide better and accurate information of probable climatic variations for designing efficient adaptive measures (MSTE, 2000). However, unfortunately in Malaysia, there exists a lack of information in this regard. Hence, it is apparent that for Malaysia the main obstacles are lack of knowledge of climate change impacts, limited conservation facilities, and political willingness, among others. There is one distinct and important challenge for Malaysia which is the continued uncertainty about how much climate change it will face. The perception is complex to understand. Current adaptation techniques may be practical in future circumstances but it is uncertain under extreme weather conditions. It is also unsure as what extent adaptation will reduce the vulnerability of Malaysia. Despite the uncertainties, rigorous effort is needed to facilitate decision making based on climate projections. Subsequently, for a range of climate change scenarios, a range of adaptation options and costs should be estimated. Taking into account these facts, our study has developed a country specific model for Malaysia to get the optimum level of adaptation with associated costs and benefits of the policy with different climate change scenarios over time. We have found different optimum levels of adaptation with different climate condition in different time segments. Our suggestion for the policymaker would be to implement this policy with necessary investments to improve the awareness and change the attitude of Malaysians towards adapting new policies.

Long-term climate change adaptations opportunities could be devastated by this lack of proper knowledge. Policymakers should take proper initiatives so that farmers could identify the risks on their farms associated with weather and climate events and subsequently implement a variety of anticipatory as well as reactive management strategies to manage climate risks. For Malaysia, there exists a lack of organisational involvement. To fill this gap, participation from each level of government through notification, harmonisation, and direction in regards to climate change adaptation is necessary. Besides, industries, producers, conservation organisations, social and personal level of organisations should share experiences to establish a common information source basis. Media can play a major role in overcoming the information gap and make the producers better informed on the adaptation methods which can change public perceptions and attitudes towards climate change.

To avoid rivalry, the government should be involved in the adaptation process when the benefactors (i.e. one who is adapting) and beneficiaries of adaptation (i.e. one who is benefitting from the adaptation) are different entities (public goods characteristics of adaptation). The government should ensure that the infrastructure, technology supplies and financial supports are evenly available to the farmers. Farm financial management and production practices should be modified to suit changed climate conditions.

Based on the best available information, it is necessary to assess the current and projected climate impacts with the adaptive capacity so that the vulnerability can be determined as shown in Figure 7.1. In addition, following the vulnerability assessment, we need to identify a target or set of targets, such as the protection of a specific crop production in a particular location. The outcome of vulnerability assessments will assist in deciding which crops should be priority conservation targets to ensure future food security. Prioritizing the guiding principles among available policies is the next step. Subsequent to that, choosing adaptation action with the consideration of different climate scenarios is required. In this framework, we try to combine “Hard” and “Soft” adaptation approaches simultaneously. Malaysia needs both infrastructural development (an example of “Hard” approach) as well as capacity building for policy implementation (an example of “Soft” approach).Once these crucial issues have been identified, the various management options among available adaptation specific alternatives should be evaluated.

Following this evaluation, we must build an institutional framework to assess the methodological practicability of potential solutions and the capability to respond, along with the economic, social and political factors. Implementations of proactive monitoring and management strategies are crucial for a project to be successful. The frequent review and updates of every step is critical to track the status of key indicators. Researchers should examine whether a specific adaptation option is viable for producers. Impacts are most felt at the local level and thus should be addressed at the local level. Successful adaptation will build resilience of the agricultural sector. Additionally, it will strengthen the capacity needed to force changes to adapt to climate change. In brief, potential solutions are: 1) disseminate proper information and guidance, 2) develop awareness programs, 3) empower rural communities in decision making, 4) precise vulnerability assessment, 5) decide priority conservation of crops to ensure food security, 6) choose appropriate adaptation options, 7) evaluation of management options, and 8) build a proper institutional framework to support all of the above.

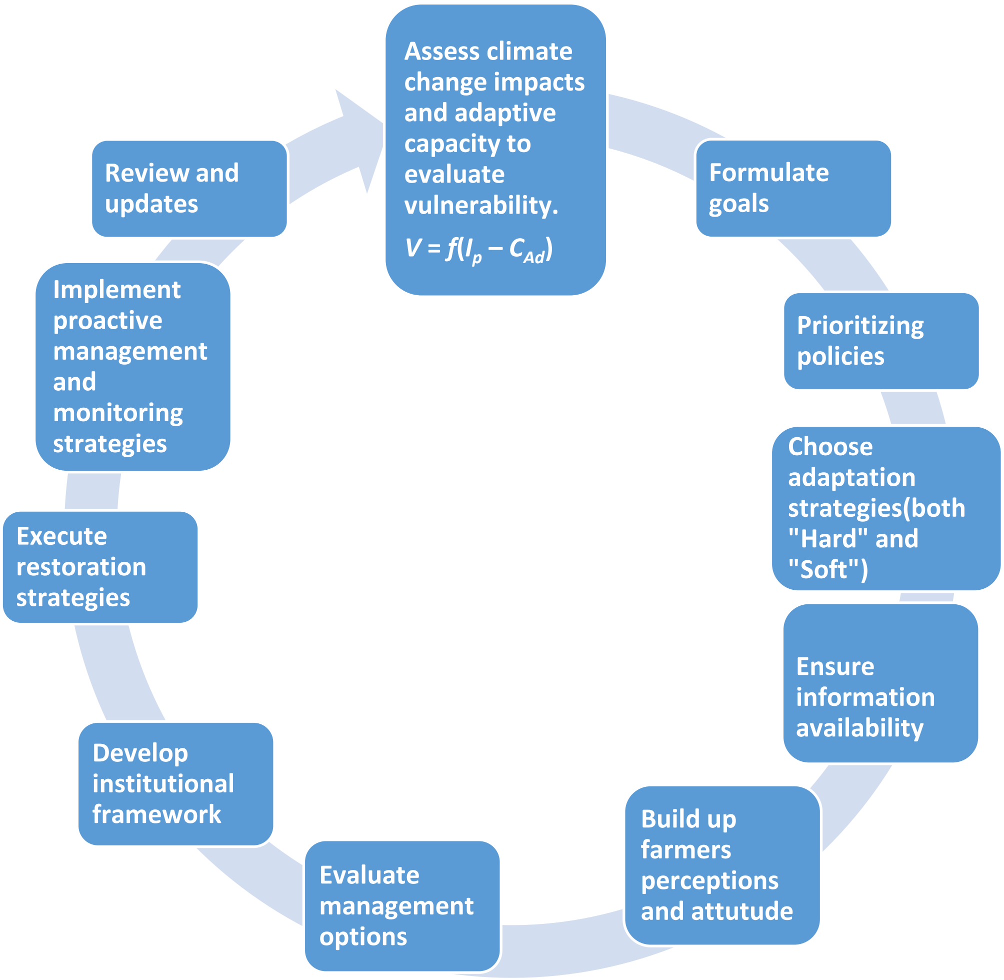


Figure 7.1: Framework for adaption strategies for agricultural sector of Malaysia

The idea of this framework comes from the concept of the Community-Driven Development (CDD) approach suggested by the World Bank. In this approach, communities as well as local government have decision making powers over investment and planning. This promotes awareness of the needs of the rural community and can lead to effectively provisioning for their basic needs. We do believe that in the climate change adaptation planning and implementation process, efficient results can be achieved if local communities are empowered to address suitable adaptation provisions for their particular area. In this case, the local government will provide all the necessary information and guidelines so that they can understand the climate risks and can take potential actions.

This study has shown that climate change has potential negative impacts on the agricultural sector in Malaysia. Particularly, the agricultural sector is inherently sensitive to climate variability that would pose significant future challenges. Malaysia needs to have a strong focus on effective early agricultural adaptation guidelines. Government and private sectors need to be working side by side to promote further adoption provisions, and adaptation strategies should be viewed as a long-term priority. The government can provide financial support for insurance at the beginning stage of implementation of adaptive actions, and private sectors needs to motivate farmers to change their attitudes and perceptions toward climate change. Gradually through providing proper education and information to raise awareness for adaptive management, the local stakeholder will contribute to adaptive management. It has to be noted that there is no single approach to climate change adaptation as appropriate way forward. Therefore, distinctive characteristics on the basis of topography, climatic conditions, and socioeconomic conditions needs to be researched for designing climate change adaptation strategies unique to each community. If the suggestions offered in this study are efficiently performed, the vulnerability to climate change can be significantly reduced which would enhance the socio-economic wellbeing of the communities.

7.4 Contribution

The study has revealed the macroeconomic effects of adaptation policies on the Malaysian economy. Specifically, this study will enhance the current knowledge by setting up a long-term national climate change adaptation policy framework for Malaysia in response to the Malaysian National Policy on Climate Change (2009). This study contributes to filling the research gap regarding the costs of adaptation for each crops within the agricultural sector. The study formed guidelines for policymakers to make macroeconomic decisions based on precise knowledge of the overall impacts of adaptive measures**.** Although the ultimate target groups are principally Malaysian policymakers, however, a wide range of people/organisations are expected to benefit from the scientific outcome of this research.

7.5 Limitations of the Study

Although CGE models are very useful for identifying economy wide impacts in response to a policy through a quantitative approach of estimation, there are some limits and weaknesses of this approach too. The main weakness of CGE models is the results from the calibration are implicitly linked to the assumptions of the model. Compared to other macro-econometric models, CGE models can be used only for simulation purposes, not for the forecasting. One more drawback of the general equilibrium analysis compared to sectoral models is that following the top-down approach, CGE models usually lack a detailed bottom-up representation of the production and supply side.

Specific to our modelling in this research, we acknowledge that we have been able to accommodate only temperature as a climate change variable. However, this is not a single parameter for climate change and there are other variable such as sea level rise and precipitation changes. The unavailability of exact data for these variables forced us to consider the temperature variable only. This is a fundamental limitation of earlier researches of this topic too, such as AD-DICE and AD-RICE models.

7.6 Further Research

Rigorous analysis on the net impacts of climate change on agriculture is yet to be performed on account of the uncertainty associated with the success of any adaptation action to handle climate change.

There are substantial limits and barriers to adaptation, including environmental, economic, informational, social, attitudinal and behavioural barriers that are not fully understood (EPA, 2013). Hence, understanding the limits and barriers to adaptation is crucial to support a sustainable and resilient agricultural sector (Stokes & Howden, 2010).

Further research can be focus on estimating vulnerability through the adaptive capacity of every sector separately.

REFERENCES

Abdullah, Abdul Rani. (1995). Environmental pollution in Malaysia: trends and prospects. *TRAC trends in analytical chemistry, 14*(5), 191-198.

Adams, Philip D, & Higgs, Peter J. (1990). Calibration of Computable General Equilibrium Models from Synthetic Benchmark Equilibrium Data Sets*. *Economic Record, 66*(2), 110-126.

Adams, Richard M, Hurd, Brian H, Lenhart, Stephanie, & Leary, Neil. (1998). Effects of global climate change on agriculture: an interpretative review. *Climate Research, 11*(1), 19-30.

Adams, Richard M, McCarl, Bruce A, & Mearns, Linda O. (2003). The effects of spatial scale of climate scenarios on economic assessments: An example from US agriculture *Issues in the Impacts of Climate Variability and Change on Agriculture* (pp. 131-148): Springer.

ADB-UNDP. (2011). *Economics of Climate Change for Malaysia*. Paper presented at the ECCM Inception Workshop, Putrajaya, Malaysia.

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

Adger, W Neil. (2000). Social and ecological resilience: are they related? *Progress in human geography, 24*(3), 347-364.

Adger, W Neil, Agrawala, Shardul, Mirza, M Monirul Qader, Conde, Cecilia, O'Brien, Karen, Pulhin, Juan, . . . Takahashi, Kiyoshi. (2007). Assessment of adaptation practices, options, constraints and capacity. *Climate change*, 717-743.

Adger, W Neil, Huq, Saleemul, Brown, Katrina, Conway, Declan, & Hulme, Mike. (2003). Adaptation to climate change in the developing world. *Progress in development studies, 3*(3), 179-195.

Agrawal, Arun, & Perrin, Nicolas. (2009). Climate adaptation, local institutions and rural livelihoods. *Adapting to climate change: thresholds, values, governance*, 350-367.

Agrawala, S, & Broad, K. (2002). Technology transfer perspectives on climate forecast applications. *Research in Science and Technology Studies, 13*, 45-69.

Agrawala, Shardul, & Cane, Mark A. (2002). Sustainability: lessons from climate variability and climate change. *Colum. J. Envtl. L., 27*, 309.

Al-Amin, Abul Quasem, Leal, Walter, de la Trinxeria, Josep Maria, Jaafar, Abdul Hamid, & Ghani, Zabawi Abdul. (2011). Assessing the Impacts of Climate Change in the Malaysian Agriculture Sector and its Influences in Investment Decision. *Middle-East Journal of Scientific Research, 7*(2), 225-234.

Alam, MM, Siwar, C, & Al-Amin, AQ. (2010). Climate change adaptation policy guidelines for agricultural sector in Malaysia. *Asian Journal of Environmental and Disaster Management, 2*(4), 463-469.

Arndt, Christian, & Volkert, Jürgen. (2011). The capability approach: a framework for official German poverty and wealth reports. *Journal of Human Development and Capabilities, 12*(3), 311-337.

Arrow, Kenneth J, & Debreu, Gerard. (1954). Existence of an equilibrium for a competitive economy. *Econometrica: Journal of the Econometric Society*, 265-290.

Austin, Okezie Chukwukere, & Baharuddin, Amir Hussin. (2012). Risk in Malaysian agriculture: The need for a strategic approach and a policy refocus. *Kajian Malaysia, 30*(1), 21-50.

Baharudin, MK. (2007). Climate Change–Its effects on the agricultural sector in Malaysia, National Seminar on Socio-Economic Impacts of Extreme Weather and Climate Change, QC903.2 M4NSSEIEW.

Bank, World. (2006). Economics of Adaptation to Climate Change. Washington, DC: World Bank.

Bates, B., Done , T , Gifford, R.M. , Howden, S.M. , Sutherst, R. , Warrick , R. , . . . Woodward, A. . (1997). Chapter 4 : Australasia. In R. E. Basher & B. A. Pittock (Eds.), *The Regional Impacts of Climate Change: An Assessment of Vulnerability*. Cambridge, England: IPCC.

Becken, Susanne. (2005). Harmonising climate change adaptation and mitigation: the case of tourist resorts in Fiji. *Global environmental change, 15*(4), 381-393.

Berrittella, Maria, Hoekstra, Arjen Y., Rehdanz, Katrin, Roson, Roberto, & Tol, Richard S. J. (2007). The economic impact of restricted water supply: A computable general equilibrium analysis. *Water Research, 41*(8), 1799-1813. doi: 10.1016/j.watres.2007.01.010

Bezabih, Mintewab, Chambwera, Muyeye, & Stage, Jesper. (2010). Climate Change, Total Factor Productivity, and the Tanzanian Economy: A Computable General Equilibrium Analysis.

Bezabih, Mintewab, Chambwera, Muyeye, & Stage, Jesper. (2011). Climate change and total factor productivity in the Tanzanian economy. *Climate Policy, 11*(6), 1289-1302.

Blomström, Magnus, & Hettne, Björn. (1984). *Development theory in transition: the dependency debate and beyond: Third World responses*: Zed books London.

Böhringer, Christoph, & Löschel, Andreas. (2006). Computable general equilibrium models for sustainability impact assessment: Status quo and prospects. *Ecological economics, 60*(1), 49-64.

Bosello, Francesco, Campagnolo, Lorenza, & Eboli, Fabio. (2013). Climate change and adaptation: the case of Nigerian agriculture.

Bosello, Francesco, Carraro, Carlo, & De Cian, Enrica. (2010). Climate policy and the optimal balance between mitigation, adaptation and unavoided damage. *Climate Change Economics, 1*(02), 71-92.

Broad, Kenneth, & Agrawala, Shardul. (2000). The Ethiopia food crisis--uses and limits of climate forecasts. *Science, 289*(5485), 1693-1694.

Brocker, Johannes. (2004). Computable general equilibrium analysis in transportation economics.

Burton, Ian, & Lim, Bo. (2005). Achieving adequate adaptation in agriculture *Increasing Climate Variability and Change* (pp. 191-200): Springer.

Burton, Russell R, & Smith, Arthur H. (1996). Adaptation to acceleration environments. *Comprehensive Physiology*.

Butt, Tanveer A, McCarl, Bruce A, Angerer, Jay, Dyke, Paul T, & Stuth, Jerry W. (2005). The economic and food security implications of climate change in Mali. *Climatic Change, 68*(3), 355-378.

Calzadilla, Alvaro, Rehdanz, Katrin, Betts, Richard, Falloon, Pete, Wiltshire, Andy, & Tol, Richard SJ. (2013). Climate change impacts on global agriculture. *Climatic change, 120*(1-2), 357-374.

Calzadilla, Alvaro, Zhu, Tingju, Rehdanz, Katrin, Tol, Richard SJ, & Ringler, Claudia. (2009). *Economywide impacts of climate change on agriculture in Sub-Saharan Africa*: International Food Policy Research Institute (IFPRI) and University of Hamburg.

Cane, Mark A, Zebiak, Stephen E, & Dolan, Sean C. (1986). Experimental forecasts of EL Nino. *Nature, 321*(6073), 827-832.

Carraro, Carlo, & Sgobbi, Alessandra. (2008). Climate change impacts and adaptation strategies in Italy: an economic assessment: Nota di lavoro//Fondazione Eni Enrico Mattei: CCMP, Climate change modelling and policy.

Chambwera, Muyeye, & Stage, Jesper. (2010). *Climate change adaptation in developing countries: issues and perspectives for economic analysis*: Iied.

Change, Climate. (2007). The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007, S. Solomon, D. Qin, M: Cambridge University Press, Cambridge, United King& dom and New York, NY, USA.

Chong, L. (2000). Assessment of the Impacts of Climate Change on Key Economic Sectors in Malaysia. *National Meteorological Service., 7*(2), 225-234.

Cline, William R. (1992). Economics of Global Warming, The. *Peterson Institute Press: All Books*.

Crimp, SJ, Stokes, CJ, Howden, SM, Moore, AD, Jacobs, B, Brown, PR, . . . Leith, P. (2010). Managing Murray–Darling Basin livestock systems in a variable and changing climate: challenges and opportunities. *The Rangeland Journal, 32*(3), 293-304.

Crutzen, Paul J, Golitsyn, Georgii S, & Mintzer, IM. (1992). Linkages between global warming, ozone depletion, acid deposition and other aspects of global environmental change. *Confronting climate change. Risks, implications and responses*.

D'Emden, Francis H, Llewellyn, Rick S, & Burton, Michael P. (2008). Factors influencing adoption of conservation tillage in Australian cropping regions*. *Australian Journal of Agricultural and Resource Economics, 52*(2), 169-182.

DARA. (2012). A Guide to the Cold Calculus of a Hot Planet: Climate Vulnerability Monitor. In M. McKinnon (Ed.), (2nd ed.). spain.

Darwin, Roy, Tsigas, Marinos E, Lewandrowski, Jan, & Raneses, Anton. (1995). World agriculture and climate change: Economic adaptations: United States Department of Agriculture, Economic Research Service.

Darwin, Roy, Tsigas, Marinos, Lewandrowski, Jan, & Raneses, Anton. (1996). Land use and cover in ecological economics. *Ecological Economics, 17*(3), 157-181. doi: 10.1016/S0921-8009(96)80004-8

De Bruin, Kelly C, Dellink, Rob B, & Tol, Richard SJ. (2009). AD-DICE: an implementation of adaptation in the DICE model. *Climatic Change, 95*(1-2), 63-81.

de Bruin, Kelly, Dellink, Rob, & Agrawala, Shardul. (2009). OECD Environment Working Papers No. 6.

Deke, Oliver, Hooss, Kurt Georg, Kasten, Christiane, Klepper, Gernot, & Springer, Katrin. (2001). Economic impact of climate change: simulations with a regionalized climate-economy model: Kiel Working Papers.

Dellink, Rob, Hofkes, Marjan, van Ierland, Ekko, & Verbruggen, Harmen. (2004). Dynamic modelling of pollution abatement in a CGE framework. *Economic Modelling, 21*(6), 965-989.

Deressa, Temesgen Tadesse. (2007). Measuring the economic impact of climate change on Ethiopian agriculture: Ricardian approach.

DFID, EC. (2002). UNDP and World Bank. 2002. *Linking Poverty Reduction and Environmental Management: Policy Challenges and Opportunities*.

Dilley, Maxx. (2000). Reducing vulnerability to climate variability in Southern Africa: The growing role of climate information. *Climatic Change, 45*(1), 63-73.

Dixon, Peter, & Rimmer, Mauren. (2002). Dynamic General Equilibrium Modelling for Forecasting and Policy. Contributions to Economic Analysis 256: Amsterdam: North-Holland Publishing Company.

Döll, Sebastian. (2009). Climate change impacts in computable general equilibrium models: An overview: HWWI Research Paper.

Dore, Mohammed HI, Burton, Ian, Dore, Mohammed, & under grant No, Fund. (2000). The Costs of Adaptation to Climate Change in Canada: A stratified estimate by sectors and regions. *Brock University Climate Change Laboratory, St. Catharines*.

Downing, Thomas E. (1991). Vulnerability to hunger in Africa: A climate change perspective. *Global Environmental Change, 1*(5), 365-380.

Eakin, Hallie. (2005). Institutional change, climate risk, and rural vulnerability: Cases from Central Mexico. *World Development, 33*(11), 1923-1938.

Easterling, David R, Evans, JL, Groisman, P Ya, Karl, TR, Kunkel, K E_, & Ambenje, P. (2000). Observed Variability and Trends in Extreme Climate Events: A Brief Review*. *Bulletin of the American Meteorological Society, 81*(3), 417-425.

Easterling III, William E, Crosson, Pierre R, Rosenberg, Norman J, McKenney, Mary S, Katz, Laura A, & Lemon, Kathleen M. (1993). Paper 2. Agricultural impacts of and responses to climate change in the Missouri-Iowa-Nebraska-Kansas (MINK) region. *Climatic Change, 24*(1-2), 23-61.

Easterling, William E. (1997). Why regional studies are needed in the development of full-scale integrated assessment modelling of global change processes. *Global Environmental Change, 7*(4), 337-356.

Easterling, William E, Hurd, Brian, & Smith, Joel. (2004). Coping with global climate change: the role of adaptation in the United States.

Edwards-Jones, G. (2006). Modelling farmer decision-making: concepts, progress and challenges. *Animal science*, *82*(6), 783-790.

Eisenack, Klaus, & Stecker, Rebecca. (2011). An Action Theory of Adaptation to Climate Change. *Earth System Governance Working Paper*(13).

EPA. (2013). Climate Change - Health, and Environmental Effects; Adaptation. Retrieved on 6 March 2013, Available at: http://whqlibdoc.who.int/hq/2000/WHO_SDE_OEH_00.4.pdf.

EPU. (2010). Tenth Malaysia Plan 2011-2015 *Putrajaya: Prime Minister Department*: Economic Planning Unit.

Eriksen, Siri, Aldunce, Paulina, Bahinipati, Chandra Sekhar, Martins, Rafael D'Almeida, Molefe, John Isaac, Nhemachena, Charles, . . . Sygna, Linda. (2011). When not every response to climate change is a good one: Identifying principles for sustainable adaptation. *Climate and Development*, *3*(1), 7-20.

Fankhauser, S. (1995). Protection versus retreat: the economic costs of sea-level rise. *Environment and Planning A, 27*(2), 299-319.

Fankhauser, Samuel, & Kverndokk, Snorre. (1996). The global warming game—Simulations of a CO< sub> 2</sub>-reduction agreement. *Resource and Energy Economics*, *18*(1), 83-102.

Fankhauser, Samuel, Smith, Joel B, & Tol, Richard SJ. (1999). Weathering climate change: some simple rules to guide adaptation decisions. *Ecological economics, 30*(1), 67-78.

Franco, G, & Sanstad, A. (2006). Climate Change and Electricity Demand in California. California Climate Change Center: CEC-500-2005-201-SF, February 2006.< www. energy. ca. gov/2005publications/CEC-500-2005-201/CEC-500-2005-201-SF. PDF.

Gebreegziabher, Zenebe, Stage, Jesper, Mekonnen, Alemu, & Alemu, Atlaw. (2011). Climate change and the Ethiopian economy: A computable general equilibrium analysis.

Glantz, Michael H. (2001). *Currents of change: impacts of El Niño and La Niña on climate and society*: Cambridge University Press.

Goklany, Indur M. (1995). Strategies to enhance adaptability: technological change, sustainable growth and free trade. *Climatic change, 30*(4), 427-449.

Greiner, Romy, & Gregg, Daniel. (2011). Farmers' intrinsic motivations, barriers to the adoption of conservation practices and effectiveness of policy instruments: Empirical evidence from northern Australia. *Land use policy, 28*(1), 257-265.

Gunning, Jan Willem, & Keyzer, Michiel A. (1993). *Applied general equilibrium models for policy analysis*: Tinbergen Institute.

Hamilton, Jacqueline M, Maddison, David J, & Tol, Richard SJ. (2005). The effects of climate change on international tourism.

Hassan, Rashid M. (2010). Implications of climate change for agricultural sector performance in Africa: policy challenges and research agenda. *Journal of African Economies, 19*(suppl 2), ii77-ii105.

Hawkins, Joyce, & Le Roux, Susan. (1986). *The Oxford reference dictionary*: Oxford University Press, USA.

Heath, Yuko, & Gifford, Robert. (2006). Free-market ideology and environmental degradation the case of belief in global climate change. *Environment and Behavior, 38*(1), 48-71.

Helms, Susan, Mendelsohn, Robert, & Neumann, Jim. (1996). The impact of climate change on agriculture. *Climatic Change, 33*(1), 1-6.

Hertel, Thomas W. (2002). Applied general equilibrium analysis of agricultural and resource policies. *Handbook of agricultural economics, 2*, 1373-1419.

Hicks, John R. (1939). The foundations of welfare economics. *The Economic Journal*, 696-712.

Hoffmann, Ary A, & Sgrò, Carla M. (2011). Climate change and evolutionary adaptation. *Nature, 470*(7335), 479-485.

Hope, Chris, Anderson, John, & Wenman, Paul. (1993). Policy analysis of the greenhouse effect: an application of the PAGE model. *Energy Policy, 21*(3), 327-338.

Howden, S Mark, Soussana, Jean-François, Tubiello, Francesco N, Chhetri, Netra, Dunlop, Michael, & Meinke, Holger. (2007). Adapting agriculture to climate change. *Proceedings of the National Academy of Sciences, 104*(50), 19691-19696.

Hunt, Alistair, & Watkiss, Paul. (2011). Climate change impacts and adaptation in cities: a review of the literature. *Climatic Change, 104*(1), 13-49.

Huq, Saleemul, & Konate, Mama. (2003). *Mainstreaming adaptation to climate change in least developed countries (LDCs)*: IIED.

Husaini, AS. (2007). Flood and drought management in Malaysia. *Kuala Lumpur: Department of Drainage and Irrigation Malaysia, Ministry of Natural Resources and Environment*.

IPCC. (2001). Climate Change : Impacts, Adaptation and Vulnerability. In IPCC (Ed.): Cambridge University Press.

Janssen, Marco A, Schoon, Michael L, Ke, Weimao, & Börner, Katy. (2006). Scholarly networks on resilience, vulnerability and adaptation within the human dimensions of global environmental change. *Global environmental change, 16*(3), 240-252.

Jorgenson, Dale W, & Wilcoxen, Peter J. (1993). Energy the environment, and economic growth. *Handbook of natural resource and energy economics, 3*, 1267-1349.

Juneng, Liew, Latif, Mohd Talib, & Tangang, Fredolin. (2011). Factors influencing the variations of PM10 aerosol dust in Klang Valley, Malaysia during the summer. *Atmospheric Environment, 45*(26), 4370-4378.

Kane, Sally, Reilly, John, & Tobey, James. (1992). An empirical study of the economic effects of climate change on world agriculture. *Climatic change, 21*(1), 17-35.

Kirkbride, Mary, & Grahn, Richard. (2008). Survival of the fittest: pastoralism and climate change in East Africa. *Oxfam Policy and Practice: Agriculture, Food and Land, 8*(3), 174-220.

Kirshen, P, Ruth, Matthias, Anderson, W, & Lakshmanan, TR. (2004). Infrastructure Systems, Services and Climate Change: Integrated Impacts and Response Strategies for the Boston Metropolitan Area. Climate’s Long-term Impacts on Metro Boston (CLIMB).

Klein, Richard JT, Nicholls, Robert J, & Thomalla, Frank. (2003). Resilience to natural hazards: How useful is this concept? *Global Environmental Change Part B: Environmental Hazards, 5*(1), 35-45.

Klein, Richard JT, & Tol, Richard SJ. (1997). Adaptation to climate change: Options and technologies. *Institute for Environmental Sciences, Vrije Universiteit, Amsterdam*.

Kurukulasuriya, Pradeep, & Mendelsohn, Robert. (2006). A Ricardian analysis of the impact of climate change on African cropland. *World Bank Research Policy Working Paper (forthcoming).*

Kurukulasuriya, Pradeep, & Mendelsohn, Robert O. (2008). How will climate change shift agro-ecological zones and impact African agriculture? *World Bank Policy Research Working Paper Series, Vol*.

Leary, Neil A. (1999). A framework for benefit-cost analysis of adaptation to climate change and climate variability. *Mitigation and adaptation strategies for global change, 4*(3-4), 307-318.

Lemos, Maria Carmen de Mello. (2003). A tale of two policies: the politics of climate forecasting and drought relief in Ceará, Brazil. *Policy Sciences, 36*(2), 101-123.

Liu, Jing, Arndt, Channing, & Hertel, Thomas W. (2004). Parameter estimation and measures of fit in a global, general equilibrium model. *Journal of Economic Integration, 19*(3), 626-649.

Manne, Alan, Mendelsohn, Robert, & Richels, Richard. (1995). MERGE: A model for evaluating regional and global effects of GHG reduction policies. *Energy Policy, 23*(1), 17-34. doi: 10.1016/0301-4215(95)90763-W

Mansur, Erin T, Mendelsohn, Robert, & Morrison, Wendy. (2005). A discrete-continuous choice model of climate change impacts on energy. *Social Science Research Network, Yale School of Management Working Paper No. ES-43, Yale University, New Haven, Conecticut*.

Matthews, Emily, Amann, Christof, Bringezu, Stefan, Hüttler, Walter, Ottke, Christian, Rodenburg, Eric, . . . Weisz, Helga. (2000). *The weight of nations-material outflows from industrial economies.* Paper presented at the World Resources Institute.

McCarl, Bruce A, Metting, F Blaine, & Rice, Charles. (2007). Soil carbon sequestration. *Climatic Change, 80*(1), 1-3.

McCarthy, James J. (2001). *Climate change 2001: impacts, adaptation, and vulnerability: contribution of Working Group II to the third assessment report of the Intergovernmental Panel on Climate Change*: Cambridge University Press.

Meinke, Holger, Howden, S Mark, Struik, Paul C, Nelson, Rohan, Rodriguez, Daniel, & Chapman, Scott C. (2009). Adaptation science for agriculture and natural resource management—urgency and theoretical basis. *Current Opinion in Environmental Sustainability, 1*(1), 69-76.

Mendelsohn, Robert. (2000). Efficient adaptation to climate change. *Climatic Change, 45*(3-4), 583-600.

Mendelsohn, Robert, & Dinar, Ariel. (1999). Climate change, agriculture, and developing countries: does adaptation matter? *The World Bank Research Observer, 14*(2), 277-293.

Mendelsohn, Robert, Dinar, Ariel, & Williams, Larry. (2006). The distributional impact of climate change on rich and poor countries. *Environment and Development Economics, 11*(02), 159-178.

Mendelsohn, Robert, Nordhaus, William D, & Shaw, Daigee. (1994). The impact of global warming on agriculture: a Ricardian analysis. *The American Economic Review*, 753-771.

Mizina, Svetlana V, Smith, Joel B, Gossen, Erwin, Spiecker, Karl F, & Witkowski, Stephen L. (1999). An evaluation of adaptation options for climate change impacts on agriculture in Kazakhstan. *Mitigation and Adaptation Strategies for Global Change, 4*(1), 25-41.

Morrison, Wendy N, & Mendelsohn, Robert. (1999). The impact of global warming on US energy expenditures (pp. 209-236): Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Moser, Susanne C, & Ekstrom, Julia A. (2010). A framework to diagnose barriers to climate change adaptation. *Proceedings of the National Academy of Sciences, 107*(51), 22026-22031.

MSTE. (2000): Ministry of Science, Technology and the Environment.

Nicholls, Robert J, Leatherman, Stephen P, Dennis, KC, & Volonte, CR. (1995). Impacts and responses to sea-level rise: qualitative and quantitative assessments. *Journal of Coastal Research*, 26-43.

Nicholls, Robert J, & Tol, Richard SJ. (2006). Impacts and responses to sea-level rise: a global analysis of the SRES scenarios over the twenty-first century. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 364*(1841), 1073-1095.

Njie, Momodou, Gomez, Bernard E, Hellmuth, Molly E, Callaway, John M, Jallow, Bubu P, & Droogers, Peter. (2006). *Making economic sense of adaptation in upland cereal production systems in The Gambia*.

NOAA. (1999). An experiment in the application of climate forecasts: NOAA-OGP activities related to the 1997-98 El Nino event *OGP/NOAA/US Department of Commerce*. Washington, DC, USA: National Oceanic and Atmospheric Administration

Nordhaus, WILLIAM D. (1992). The DICE Model. *Background Structure of a Dynamic Integrated Climate Economy*.

Nordhaus, William D. (1993a). Optimal greenhouse-gas reductions and tax policy in the" DICE" model. *The American Economic Review*, 313-317.

Nordhaus, William D. (1993b). Rolling the 'DICE': an optimal transition path for controlling greenhouse gases. *Resource and Energy Economics, 15*(1), 27-50.

Nordhaus, William D. (2007). A Review of the" Stern Review on the Economics of Climate Change". *Journal of Economic Literature*, 686-702.

Nordhaus, William D, & Yang, Zili. (1996). A regional dynamic general-equilibrium model of alternative climate-change strategies. *The American Economic Review*, 741-765.

NRE. (2008). Report on national Capacity Needs Self-Assessment for Global Environmental Management and National Capacity Action Plan. Malaysia: Ministry of Natural Resources and Environment, Government of Malaysia.

NRE. (2009). National Policy on Climate Change. Malaysia: The Ministry of Natural Resources and Environment.

NRE. (2010). Climatic Changes-Government Policy-Malaysia. I. Malaysia. Kementerian Sumber Asli dan Alam Sekitar. II. Judul: National policy on climate change. Malaysia: Ministry of Natural Resources and Environment.

NRE. (2011). Malaysia Second National Communication to the UNFCCC. Malaysia: Minstry of Natural Resources and Environment.

O'Brien, Karen, & Vogel, Coleen. (2003). *Coping with climate variability: the use of seasonal climate forecasts in Southern Africa*: Ashgate Publishing Ltd.

O'Ryan, Raúl, De Miguel, Carlos J, Miller, Sebastian, & Munasinghe, Mohan. (2005). Computable general equilibrium model analysis of economywide cross effects of social and environmental policies in Chile. *Ecological Economics, 54*(4), 447-472.

OCCIAR. (2011). *Climate Change Impacts and Adaptation: A Literature Review of the Canadian Agriculture Sector, Available at: http://www.climateontario.ca/*

Ospina, ANGELICA VALERIA, & Heeks, Richard. (2010). Unveiling the Links between ICTs & Climate Change in Developing Countries: A Scoping Study. *International Development Research Centre, 2*, 2009-2010.

Ostrom, Elinor. (2014). A polycentric approach for coping with climate change. *Ann. Econ. Finance, 15*, 71-108.

Ott, Hermann E, Sterk, Wolfgang, & Watanabe, Rie. (2008). The Bali roadmap: new horizons for global climate policy. *Climate Policy, 8*(1), 91-95.

Oxfam. (2007). Adapting to Climate Change: What's Needed in Poor Countries, and Who should Pay *Oxfam Briefing Paper* Oxford: Oxfam.

Pacala, Stephen W, Hurtt, George C, Baker, David, Peylin, Philippe, Houghton, Richard A, Birdsey, Richard A, . . . Ciais, Philippe. (2001). Consistent land-and atmosphere-based US carbon sink estimates. *Science, 292*(5525), 2316-2320.

Pachauri, RK, & Reisinger, A. (2007). IPCC fourth assessment report. *IPCC, Geneva*.

Pannell, David J, Marshall, Graham R, Barr, Neil, Curtis, Allan, Vanclay, Frank, & Wilkinson, Roger. (2006). Understanding and promoting adoption of conservation practices by rural landholders. *Animal Production Science, 46*(11), 1407-1424.

Patt, Anthony, & Gwata, Chiedza. (2002). Effective seasonal climate forecast applications: examining constraints for subsistence farmers in Zimbabwe. *Global Environmental Change, 12*(3), 185-195.

Pearce, David. (2003). The social cost of carbon and its policy implications. *Oxford review of economic policy, 19*(3), 362-384.

Pearce, David, Cline, William R, Achanta, Amrita N, Fankhauser, Samuel, Pachauri, Rajendra K, Tol, Richard SJ, & Vellinga, Pier. (1996). The social costs of climate change: greenhouse damage and the benefits of control. *Climate change 1995: Economic and social dimensions of climate change*, 179-224.

Pearson, Leonie J, Nelsonc, Rohan, Crimp, Steve, & Langridge, Jenny. (2011). Interpretive review of conceptual frameworks and research models that inform

Australia’s agricultural vulnerability to climate change. *Environmental Modelling & Software, 26*(2), 113-123.

Pereira, J.J., & Subramniam, M. (Eds). (2007). Rapporteur Report for the National Seminar on Socio-Economic Impacts of Extreme Weather and Climate Change. Putrajaya, Malaysia: Ministry of Science, Technology and Innovation.

Pfaff, Alexander SP. (1999). What drives deforestation in the Brazilian Amazon?: evidence from satellite and socioeconomic data. *Journal of Environmental Economics and Management, 37*(1), 26-43.

Pyatt, Graham, & Round, Jeffery I. (1985). Social accounting matrices: A basis for planning.

Reid, Hannah, & MacGregor, Hannah ReidLinda SahlénJesper StageJames. (2007). *The economic impact of climate change in Namibia: how climate change will affect the contribution of Namibia's natural resources to its economy* (Vol. 7): IIED.

Reilly, J. (1994). Crops and Climate Change. *Nature, 367*(6459), 118-119.

Reilly, John, Hohmann, Neil, & Kane, Sally. (1994). Climate change and agricultural trade: who benefits, who loses? *Global Environmental Change, 4*(1), 24-36.

Reilly, John, Sarofim, Marcus, Paltsev, Sergey, & Prinn, Ronald. (2006). The Role of Non-CO_3 GHGs in Climate Policy: Analysis Using the MIT IGSM. *The Energy Journal*, 503-520.

Reilly, John, Tubiello, F, McCarl, B, Abler, D, Darwin, R, Fuglie, K, . . . Jones, J. (2003). US agriculture and climate change: new results. *Climatic Change, 57*(1-2), 43-67.

Relnert, Kenneth A, & Roland-Holst, David W. (1997). Social accounting matrices. *Applied methods for trade policy analysis: A handbook, 94*.

Robinson, Sherman, Burfisher, Mary E, Hinojosa-Ojeda, Raul, & Thierfelder, Karen E. (1993). Agricultural policies and migration in a US-Mexico free trade area: A computable general equilibrium analysis. *Journal of Policy Modeling, 15*(5), 673-701.

Rosenthal, Donald H, Gruenspecht, Howard K, & Moran, Emily A. (1995). Effects of global warming on energy use for space heating and cooling in the United States. *The Energy Journal*, 77-96.

Rosenzweig, Cynthia, & Parry, Martin L. (1994). Potential impact of climate change on world food supply. *Nature, 367*(6459), 133-138.

Roy, Marlene, & Venema, Henry David. (2002). Reducing risk and vulnerability to climate change in India: the capabilities approach. *Gender & Development, 10*(2), 78-83.

Sailor, David J, & Pavlova, AA. (2003). Air conditioning market saturation and long-term response of residential cooling energy demand to climate change. *Energy, 28*(9), 941-951.

Sánchez, Marco, & Vos, Rob. (2007). Informative note on elasticities and calibration of MAMS. *Development Policy and Analysis Division, Department of Economic and Social Affairs, New York.*

Schelling, Thomas C. (1992). Some economics of global warming. *The American Economic Review*, 1-14.

Schenker, Oliver, & Stephan, Gunter. (2012). International trade and the adaptation to climate change and variability: Discussion Papers, Department of Economics, Universität Bern.

Schneider, Stephen H, Easterling, William E, & Mearns, Linda O. (2000). Adaptation: Sensitivity to natural variability, agent assumptions and dynamic climate changes. *Climatic Change, 45*(1), 203-221.

Sen, Amartya. (1999). *Commodities and Capabilities*: Oxford University Press.

Shaw, Roderick W. (2000). *Climate change: impacts, adaptation and networking.* Paper presented at the Proceedings of a Workshop at Mount Allison University, Sackville, New Brunswick.

Shoven, John B. (1992). *Applying general equilibrium*: Cambridge university press.

Shoven, John B, & Whalley, John. (1984). Applied general-equilibrium models of taxation and international trade: an introduction and survey. *Journal of Economic Literature*, 1007-1051.

Smit, Barry, & Skinner, Mark W. (2002). Adaptation options in agriculture to climate change: a typology. *Mitigation and adaptation strategies for global change, 7*(1), 85-114.

Smit, Barry, & Wandel, Johanna. (2006). Adaptation, adaptive capacity and vulnerability. *Global environmental change, 16*(3), 282-292.

Smith, Barry, Burton, Ian, Klein, Richard JT, & Wandel, Johanna. (2000). An anatomy of adaptation to climate change and variability. *Climatic change, 45*(1), 223-251.

Smith, Joel B. (1996). Using a decision matrix to assess climate change adaptation options *Adapting to Climate Change* (pp. 68-79): Springer.

Smith, Joel B, Rahman, Atiqur, Mirza, Monisul Q, Kenny, Gavin J, Sims, Graham C, & Warrick, Richard A. (1998). *Considering Adaptation to Climate change in the sustainable development of Bangladesh*: South Asia Region, World Bank.

Smith, Joel B, Schellnhuber, Hans-Joachim, Mirza, M Monirul Qader, Fankhauser, S, Leemans, R, Lin, Erda, . . . Rosenzweig, C. (2001). Vulnerability to climate change and reasons for concern: a synthesis. *Climate change*, 913-967.

Sohngen, Brent, & Mendelsohn, Robert. (1998). Valuing the impact of large-scale ecological change in a market: The effect of climate change on US timber. *American Economic Review*, 686-710.

Solomon, Susan. (2007). *Climate change 2007-the physical science basis: Working group I contribution to the fourth assessment report of the IPCC* (Vol. 4): Cambridge University Press.

Sperling, Frank, & Szekely, Francisco. (2005). *Disaster risk management in a changing climate*: Vulnerability and Adaptation Resource Group.

Stern, Nicholas Herbert, Britain, Great, & Treasury, HM. (2006). *Stern Review: The economics of climate change* (Vol. 30): HM treasury London.

Stokes, Chris, & Howden, Mark. (2010). *Adapting agriculture to climate change: preparing Australian agriculture, forestry and fisheries for the future, Publisher: CSIRO PUBLISHING , ISBN: 9780643095953*: Csiro.

Stuczyiński, T, Demidowicz, G, Deputat, T, Górski, T, Krasowicz, S, & Kuś, J. (2000). Adaptation scenarios of agriculture in Poland to future climate changes. *Environmental Monitoring and Assessment, 61*(1), 133-144.

Sue Wing, Ian, & Eckaus, Richard S. (2007). The implications of the historical decline in US energy intensity for long-run CO2 emission projections. *Energy Policy, 35*(11), 5267-5286. doi: 10.1016/j.enpol.2006.01.035

Tangang, FT, Juneng, L, & Ahmad, S. (2007). Trend and interannual variability of temperature in Malaysia: 1961–2002. *Theoretical and Applied Climatology, 89*(3-4), 127-141.

Thomas, David SG, & Twyman, Chasca. (2005). Equity and justice in climate change adaptation amongst natural-resource-dependent societies. *Global Environmental Change, 15*(2), 115-124.

Thomas, David SG, Twyman, Chasca, Osbahr, Henny, & Hewitson, Bruce. (2007). Adaptation to climate change and variability: farmer responses to intra-seasonal precipitation trends in South Africa. *Climatic change, 83*(3), 301-322.

Tobey, James, Reilly, John, & Kane, Sally. (1992). Economic implications of global climate change for world agriculture. *Journal of Agricultural and Resource Economics*, 195-204.

Tol, Richard SJ. (1997). On the optimal control of carbon dioxide emissions: an application of FUND. *Environmental Modeling & Assessment, 2*(3), 151-163.

Tol, Richard SJ. (2002a). Estimates of the damage costs of climate change, Part II. Dynamic estimates. *Environmental and Resource Economics, 21*(2), 135-160.

Tol, Richard SJ. (2002b). Estimates of the damage costs of climate change. Part 1: Benchmark estimates. *Environmental and resource Economics, 21*(1), 47-73.

Tol, Richard SJ. (2008). The social cost of carbon: trends, outliers and catastrophes. *Economics: The Open-Access, Open-Assessment E-Journal, 2*(2008-25), 1-22.

Tol, Richard SJ, & Fankhauser, Samuel. (1998). On the representation of impact in integrated assessment models of climate change. *Environmental Modeling & Assessment, 3*(1-2), 63-74.

Tol, Richard SJ, Fankhauser, Samuel, & Smith, Joel B. (1998). The scope for adaptation to climate change: what can we learn from the impact literature? *Global Environmental Change, 8*(2), 109-123.

Tol, Richard SJ, Van Der Grijp, Nicolien, Olsthoorn, Alexander A, & Van Der Werff, Peter E. (2003). Adapting to climate: a case study on riverine flood risks in the Netherlands. *Risk Analysis, 23*(3), 575-583.

Toman, Michael. (2006). Values in the economics of climate change. *Environmental Values, 15*(3), 365-379.

UNDP. (2007). Human Development Report 2007/08. New York: United Nations Development Programme

UNEP. (2006). The Emissions Gap Report Nairobi: United Nations Environment Programme (UNEP).

UNFCCC. (2007). Investment and Financial Flows to Address Climate Change. Bonn: Climate Change Secretariat.

USAID. (2010). Regional Policy and Action Planning for Climate Change Adaptation in the Coral Triangle Countries. Jakarta, Indonesia: The Coral Triangle Initiative on Coral Reefs, Fisheries and Food Security.

Walz, R, & Schleich, J. (2009). The economics of climate policy: macroeconomic effects, structural adjustments, and technical change. *Physica/Springer, Heidelberg*.

Warren, Rachel, Hope, Chris, Mastrandrea, Michael, Tol, Richard, Adger, Neil, & Lorenzoni, Irene. (2006). Spotlighting impacts functions in integrated assessment. *Tyndall Centre on Climate Change Working Paper, 91*.

West, Guy R. (1995). Comparison of input–output, input–output+ econometric and computable general equilibrium impact models at the regional level. *Economic Systems Research, 7*(2), 209-227.

Wilbanks, Thomas J, & Kates, Robert W. (2010). Beyond adapting to climate change: embedding adaptation in responses to multiple threats and stresses. *Annals of the Association of American Geographers, 100*(4), 719-728.

Winters, Paul, Murgai, Rinku, Sadoulet, Elisabeth, de Janvry, Alain, & Frisvold, George. (1998). Economic and welfare impacts of climate change on developing countries. *Environmental and Resource Economics, 12*(1), 1-24.

Yohe, Gary W, & Schlesinger, Michael E. (1998). Sea-level change: the expected economic cost of protection or abandonment in the United States. *Climatic Change, 38*(4), 447-472.

Zhang, Xiao-guang, & Verikios, George. (2006). *Armington Parameter Estimation for a Computable General Equilbrium Model: A Database Consistent Approach*: University of Western Australia, Economics.

Zhang, Zhongxiang. (1998). Macro-economic and sectoral effects of carbon taxes: a general equilibrium analysis for China. *Economic Systems Research, 10*(2), 135-159.

Ziervogel, Gina. (2004). Targeting seasonal climate forecasts for integration into household level decisions: the case of smallholder farmers in Lesotho. *The Geographical Journal, 170*(1), 6-21.

APPENDICES

Appendix A: Summary of the Literature Review

A1: Effects and Vulnerability to Climate Change and Concepts of Adaptation

Research Center/ Author	Focus	Findings
UNFCCC(2006), UNDP(2005), IPCC(2001), R. R. Burton and Smith (1996)	Concepts of Adaptation and Its Characteristics	Adaptation may be anticipatory(proactive) or reactive based on timing, autonomous or planned depending on the degree of spontaneity, private or public depending on their characteristics.
Samuel Fankhauser et al. (1999), Klein and Tol (1997)	Effects of Climate change and adaptation options	The intuitively optimal current adaptation policy may improve the no-regret measures given the long time-span and greater uncertainty of climate change.
IPCC (2007), IPCC-TAR (McCarthy, 2001)	Vulnerability, Adaptive capacity, Impacts and Adaptation Options	Social, economic and political forces has effective role to minimise local vulnerabilities. Therefore, adaptation issues need to address the role of local initiatives for development relative to transformations of global geo-political economic systems.
Shardul Agrawala and Cane (2002) , J. B. Smith et al. (2001) Goklany (1995)	Impacts of climate variability on Economic development	Climate itself is a resource that affects the productivity of several other critical resources comprising food, forests, fisheries, and water resources. Therefore it has a profound impact on the economy and on economic developments.

A2: Adaptation options, level, costs, benefit and efficiency

Ref.	**Focus**	**Findings**
UNFCCC (2007)	Cost and investment for protecting society and economy from climate change	Current levels of investment are considered far from adequate and lead to high vulnerability to climate change at present, including losses, the latter being termed as current “adaptation deficit”. This partly explains why climate change impacts are expected to be greatest in low and middle-income countries. Some impacts are unavoidable irrespective of funding availability as the action technologies are not available.
OECD (2008)	Cost and Benefits of Adaptation	Relative climate variability (without adaptation) is actually climate change total damage. On the other hand, Relative climate variability (with adaptation) is the imposed cost of climate change including adaptation costs. Therefore, net benefits of adaptation are relative to adaptive gain with and without adaptation.
IPCC (2007) , W. E. Easterling, Hurd, and Smith (2004)	Effectiveness of specific adaptation with cost and benefit	The costs and benefits of the adaptation choices cannot be estimated with satisfactory accuracy for the majority of the choices as there are lack of information, missing data or poor reliability. As location, circumstances and exact phasing of the measures influence costs and benefits, detailed studies in so-called hotspot areas are indispensable.
Huq and Konate (2003)	Cost calculation in developing countries	The economic costs of future adaptations can be derived by investigating the differences between the economic losses associated with scenarios of technology acceptance and dissemination. Among these policies, a key concern is the determination of successful adaptations for the developing countries where the risk and physical vulnerability are highest. However, there will always be winners and losers, even where successful examples from indigenous strategies for resource management to large-scale infrastructure and irrigation are identified.
Stern et al. (2006), IPCC (2007)	Damage calculation in global context	The benefits of robust and initial actions far outweigh the economic costs of not taking any actions. If no action is taken, the overall costs and risks of climate change will be equivalent to losing at least 5%-20% of global GDP each year, now and for future. In contrast, the costs of action – decreasing greenhouse gas emissions to avoid the worst effects of climate change can be restricted to around 1% of global GDP each year.

A3: Empirical Techniques /Models

Ref.	Focus	Techniques
Hamilton et al. (2005)	Impacts of climate change on tourism (Global)	DICE (Dynamic Integrated Climate and Economy) model which consider adaptation as an implicit variable in the model.
Tol and Fankhauser (1998)	Dynamic Estimates of the Damage Costs of Climate Change (Global)	DICE
Hope et al. (1993)	Economic and non-economic damages and eight world regions.	PAGE (Policy Analysis from Greenhouse Effect). The model includes uncertainty by incorporating parameters from a random sample and repeated runs.
Manne et al. (1995)	Global and Regional impacts of GHGs emissions.	MERGE (Model for Evaluating Regional and Global Effects) of greenhouse gas reduction policies. This model considers market and non-market damages and find out the optimum mitigation level.
Tol (2008)	Global and Regional Damage cost.	FUND (Climate Framework for Uncertainty, Negotiation and Distribution) model is based on the DICE model, but it contains a regional specification like AD-RICE.
Nordhaus (1992), (1996)	Global and regional impacts of climate change on the economy.	DICE (Dynamic Integrated Climate and Economy) and RICE (Regional Integrated Climate and Economy) which consider adaptation as an Implicit variable in the model.

A4: Selected Empirical Works of Economic Effects of Climate Change on Agriculture

Name	Topic	Methodology	Conclusion
Reid and MacGregor (2007)	The economic effect of climate change in Namibia	Looked at the impacts of climate change on agriculture and fisheries, used a CGE model to model potential general equilibrium impacts. On assumption of no adaptation	Climate change will cause a fall in GDP of around 1-6% (£35- £100 million), if no action is taken.
Bezabih, Chambwera, and Stage (2010)	The economic effects of climate change induced adjustments on the Tanzanian economy	Used a countrywide dynamic CGE model (an extension of the IFPRI model) to model the effects of climate change on agriculture and the feedbacks between agriculture and other sectors, under two scenarios. Total Factor Productivity and climate change and no-climate change scenarios.	Until 2030 Climate change impact will be little on agricultural productivity after which it will be more. By substituting factors, the overall impacts can be restricted significantly, suggesting a need for independent adaptation and strategies to strengthen the overall economy, instead of direct adaptation strategies.
Kurukulasuriya and Mendelsohn (2006)	The impacts of climate change on net revenue per hectare across Africa (based on 11 country studies)	Ricardian method making use of crop response simulation modelling. Applied regression to conclude how diverse climatic variables impact net revenue per ha, then observed at impacts of two types of climate change scenarios.	Impacts vary noticeably depending on scenario, e.g., sectoral gains of $97 billion p.a. under one model, and losses of $48 billion p.a. by 2100 under another. Dry-land farming is likely to be affected most negatively.
Sue Wing and Eckaus (2007)	The impact of climate change on agriculture through the 2080s for over 100 countries	Combined the Ricardian and crop procedure model methodologies, applying large amount of geographical and climatic detail for more than 100 countries and regions. He chooses a ‘consensus’, rather than looking at a wide range of values.	Global agricultural productivity will decline by about 3% by 2080 with carbon fertilisation, or by about 16% if carbon fertilisation does not occur. The effects would be uneven, with developing countries enduring the disproportionate losses.
Calzadilla *et al.* *(2009)*	Economy-wide impacts of climate change on agriculture in sub-Saharan Africa	Used a partial equilibrium model with a water simulation model (IMPACT), and a general equilibrium model, including water resources (GTAP-W), to look at the impact of climate change under two adaptation scenarios (doubling irrigated areas and increasing crop production by 25%), compared to a baseline of no specific adaptation.	Without adaptation, climate change will cause a 1.6% fall in food production, with heavy losses in sugar cane (10.6%) and wheat (24.1%). An increase in agricultural productivity achieves better outcomes than an expansion of irrigated areas. Both scenarios lead to lower world food prices
Calzadilla et al. (2013)	Potential impacts of climate change and CO_2	Used a new version of the computable general equilibrium GTAP-W model,	Global food production is expected to fall by around 0.5% in the 2020s and 2.3%

	fertilisation on global agriculture	which implements water as an explicit factor of production for irrigated agriculture. Assessed how climate change, modeled under two climate change scenarios, affects water availability and thereby worldwide agricultural production in two time periods (the 2020s and the 2050s). They use six scenarios, including CO_2 fertilisation and distinguishing between rain-fed and irrigated land.	in the 2050s. Higher market values are expected for all crops, and in particular cereals, grains, sugar cane, sugar beet and wheat (between 39-43% depending on scenario). Countries are affected by changes in competitiveness as well as by regional climate change.
K. C. De Bruin et al. (2009)	Climate change costs as % of output	Explicitly includes adaptation in an Integrated Assessment Model (Nordhaus and Boyer's 2000 DICE model), which sees net damages as the total of the residual damages and the protection costs. They considered four scenarios of different balances between adaptation and mitigation.	Both mitigation and adaptation can decrease the effects of climate change; adaptation by (on average) 33%. Adaptation is the main climate change cost-reducer until 2100, then mitigation becomes more important.
Deressa (2007)	The economic impact of climate change on Ethiopian agriculture	Ricardian approach that captured farmers' adaptations examined data from 11 of the country's 18 agro-ecological zones and surveys 1000 farmers. They regressed net revenue against climate, household and soil variables, carried out a bordering impact valuation of growing temperature and precipitation, and scrutinised the effects of unchanging climate scenarios on net revenue per hectare.	Increasing temperature and reducing precipitation are both damaging to Ethiopian agriculture
Kurukulasuriya and Mendelsohn (2008)	The impacts of climate change on agriculture in Africa	Develops an Agro-Ecological Zone (AEZ) model. Calculate the average percent cropland and the average crop net revenue for each AEZ. Assessed how cropland and crop net revenue will change under two climate change scenarios, as the farms shift between zones	Cropland changes little under either climate scenario, but crop revenue ranges from a loss of 14 percent in the mild climate scenario to 30 percent in the harsher climate scenario. The central region of Africa is hurt the most.

Appendix B

B1: Values of adaptation coefficient

	β_1	β_2	β_3	γ_1	γ_2
MI	-	0.00587	1.49	0.216	3.97

Source: de Bruin, Kelly C.; Dellink, Rob B.; Tol, Richard S.J. (2009)

Where, β_s are the Parameters of damage function and γ_s are parameters of adaptation cost functions. Specifically, β_2 indicates Damage coefficient quadratic term, β_3 shows Damage exponent, γ_1 is the intercept adaptation cost function, γ_2 indicates exponent of adaptation cost function.

B2: ELASTICITY (C,*) Value of elasticity of substitution for each sector from GTAP data base.

SEC1-C	5.1
SEC2-C	2.9
SEC3-C	3.8
SEC4-C	3.8
SEC5-C	1.5
SEC6-C	1.4
SEC7-C	2.3
SEC8-C	1.5
SEC9-C	2.4
SEC10-C	2.9
SEC11-C	4.9
SEC12-C	4.0
SEC13-C	1.5
SEC14-C	0.9
SEC15-C	0.9

B3: LIST OF VARIABLES

EG (T)	government expenditures
EXR (T)	exchange rate (dom. currency per unit of for. currency)
FSAV (T)	foreign savings (foreign currency)
IADJ	investment adjustment factor
MPS (H)	marginal (and average) propensity to save for household h
PA (A, T)	price of activity a
PD(C, T)	domestic price of domestic output c
PE (C, T)	export price for c (domestic currency)

PM (C, T)	import price for c (domestic currency)
PQ (C, T)	composite commodity price for c
PVA (A, T)	value-added price for activity a
PX (C, T)	producer price for commodity c
QA (A, T)	level of activity a
QD(C, T)	quantity sold domestically of domestic output c
QE(C, T)	quantity of exports for commodity c
QF (F, A, T)	quantity demanded of factor f from activity a
*K (T)	capital
*L (T)	Level of population and labor
QFS (F, T)	supply of factor f
QH (C, H, T)	quantity consumed of commodity c by household h
QINT (C, A, T)	quantity of commodity c as intermediate input to activity a
QINV (C, T)	quantity of investment demand for commodity c
QM (C, T)	quantity of imports of commodity c
QQ (C, T)	quantity of goods supplied domestically (composite supply)
QX (C, T)	quantity of domestic output of commodity c
RGDP (T)	REAL GDP
*QG (C, T)	government demand for commodity c
WALRAS (T)	dummy variable (zero at equilibrium)
WF (F, T)	average price of factor f
WFDIST (F, A, T)	wage distortion factor for factor f in activity a
YF (H, F, T)	transfer of income to household h from factor f
YG (T)	government revenue
YH (H, T)	income of household h
CPI (T)	CONSUMER PRICE INDEX
RGDP (T)	REAL GDP
GD (T)	GROSS DAMAGE
RD (T)	RESIDUAL DAMAGE
ND (T)	NET DAMAGE
*DT (T)	CHANGE IN MALAYSIA mean temperature compared to a base year
MIU (T)	Emissions control rate GHGs
FORC (T)	Radiative forcing in watts per m2
*TATM0 (T)	atmospheric temp change (C) from 1900
TATM (T)	Temperature changes of atmosphere in degrees C
TOCEAN (T)	Temperature of lower oceans degrees C
MAT (T)	Carbon concentration in atmosphere GtC
MATAV (T)	Average concentrations
MU (T)	Carbon concentration in shallow oceans Gtc
ML (T)	Carbon concentration in lower oceans GtC
E (T)	CO_2-equivalent emissions GtC (BILLIONS OF TONS OF CO_2)
ADPC (T)	adaptation cost
CONS (T)	consumption (net)
NQ (A, T)	net output with climate damage

B4: PARAMETERS

TIME (T)	Current Period
AL	Adaptation Level
Ad (A)	Efficiency parameter in the production funtion for AC OF A
Alpha (F, A)	Share of value-added to factor f in activity a
Aq (C)	Armington function shift parameter for commodity c
At (C)	CET function shift parameter for commodity c
Beta (C, H)	Share of household consumption spending on commodity c
cpi0	Consumer price index
cwts(C)	Weight of commodity c in the CPI
deltaq(C)	Armington function share parameter for commodity c
deltat(C)	CET function share parameter for commodity c
ica(C,A)	Qnty of c as intermediate input per unit of activity a
pwe(C)	Export price for c (foreign currency)
pwm(C)	Import price for c (foreign currency)
qg(C)	Government demand for commodity c
qinvbar(C)	Base-year qnty of investment demand for commodity c
rhoq(C)	Armington function exponent for commodity c
rhot(C)	CET function exponent for commodity c
shry(H,F)	Share for household h in the income of factor f
te(C)	Export subsidy rate for commodity c
theta(A,C)	Yield of output c per unit of activity a
tm(C)	Import tariff rate for commodity c
tq(C)	Rate of sales tax for commodity c
tr(I,IP)	Transfer from institution ip to institution i
ty(H)	Rate of income tax for household h
yfrepat(F)	Factor income to ROW (ROW CAP)
ygi	Government investment income (GOV SI)
gsav	Govt savings (SI GOV)
irepat	Investment surplus to ROW (ROW SI)
cost1(t)	Cost function for abatement
ALFA1	VARIABLE A1
ALFA2	VARIABLE A2
ALFA3	VARIABLE A3
LAM	Climate model parameter
L (T)	Level of population and labor
K (T)	CAPITAL

B5: SCALARS

G	GDP growth Rate (From the World Bank data)	/0.0431/
A1	Damage intercept	/0.00011/
A2	Damage coeff quadratic term	/0.00587/
A3	Damage exponent	/1.49000/
C1	Climate-equation coefficient for upper level	/0.2200 /
C3	Transfer coeffic upper to lower stratum	/0.3000 /
C4	Transfer coeffic for lower level	/0.0500 /
TATM0	2000 atmospheric temp change (C) from 1900	/0.73/
TOCEAN0	2000 lower strat. temp change (C) from 1900	/0.0068/
COST10	Intercept control cost function	/0.045/
COST2	Exponent of control cost function	/2.15/
T2XCO2	Equilibrium temp impact of CO2 doubling oC	/ 3 /
FCO22X	Estimated forcings of equilibrium co2 doubling	/3.8 /
FEX0	Estimate of 2000 forcings of non-CO2 GHG	/ -0.06 /
FEX1	Estimate of 2100 forcings of non-CO2 GHG	/ 0.30 /
MAT2000	Concentration in atmosphere 2005 (GtC)	/808.9 /
MU2000	Concentration in upper strata 2005 (GtC)	/1255 /
ML2000	Concentration in lower strata 2005 (GtC)	/18365 /
b11	Carbon cycle transition matrix	/0.810712 /
b12	Carbon cycle transition matrix	/0.189288 /
b21	Carbon cycle transition matrix	/0.097213 /
b22	Carbon cycle transition matrix	/0.852787 /
b23	Carbon cycle transition matrix	/0.05 /
b32	Carbon cycle transition matrix	/0.003119 /
*GAMMA1		/0.216/
*GAMMA2		/3.97/

(all the scalar data are exogenously taken from, AD-DICE and AD-RICE model)

AC global set (SAM accounts and other items)

SEC1-A	Paddy
SEC2-A	Food Crops
SEC3-A	Vegetables
SEC4-A	Fruits
SEC5-A	Rubber
SEC6-A	Oil Palm
SEC7-A	Livestock
SEC8-A	Forestry and logging
SEC9-A	Fishing
SEC10-A	Other Agriculture
SEC11-A	Crude Oil & Natural Gas & Mining and Quarrying
SEC12-A	Industrials
SEC13-A	Transportation & Communication
SEC14-A	Financial services
SEC15-A	Services
LAB	
CAP	
HOH	Label for ALL private consumption
COM	Label for enterprise

GOV	government
S-I	Savings-investments
YTAX	tax income
STAX	sale tax
TAR	tariff
ROW	rest of the world
TOTAL	total account in SAM /

B6: EMISSION DATA

Date	Value of CO_2 emissions (kt)	Date	Value of CO_2 emissions (kt)
12/31/2010	216,804	12/31/1989	49,882
12/31/2009	203,882	12/31/1988	42,724
12/31/2008	213,221	12/31/1987	40,762
12/31/2007	205,308	12/31/1986	39,985
12/31/2006	170,648	12/31/1985	36,237
12/31/2005	177,373	12/31/1984	34,697
12/31/2004	167,333	12/31/1983	37,972
12/31/2003	160,266	12/31/1982	30,572
12/31/2002	135,129	12/31/1981	30,825
12/31/2001	136,717	12/31/1980	27,998
12/31/2000	126,603	12/31/1979	27,279
12/31/1999	107,934	12/31/1978	23,238
12/31/1998	114,187	12/31/1977	22,611
12/31/1997	124,821	12/31/1976	23,894
12/31/1996	125,375	12/31/1975	19,446
12/31/1995	121,132	12/31/1974	19,050
12/31/1994	94,011	12/31/1973	17,514
12/31/1993	91,723	12/31/1972	17,913
12/31/1992	75,298	12/31/1971	16,678
12/31/1991	68,591	12/31/1970	14,602
12/31/1990	56,593		

Source: World Bank

Retrieved 10/1/2014
Frequency: annual
Validate (http://api.worldbank.org/countries/MYS/indicators/EN.ATM.CO2E.KT?per_page=1000) Permalink (http://www.quandl.com/WORLDBANK/MYS_EN_ATM_CO2E_KT)
Description: Carbon dioxide emissions.

B7: PROJECTED EMISSIONS

Year	Predicted	year	Predicted	year	Predicted	year	Predicted	year	Predicted
2010	216,804	2030	311,753	2050	448,285	2070	644,611	2090	926,917
2011	220,777	2031	317,467	2051	456,501	2071	656,424	2091	943,905
2012	224,824	2032	323,285	2052	464,867	2072	668,455	2092	961,203
2013	228,944	2033	329,209	2053	473,386	2073	680,705	2093	978,819
2014	233,140	2034	335,243	2054	482,062	2074	693,180	2094	996,758
2015	237,412	2035	341,387	2055	490,897	2075	705,884	2095	1,015,025
2016	241,763	2036	347,643	2056	499,893	2076	718,821	2096	1,033,627
2017	246,194	2037	354,014	2057	509,055	2077	731,994	2097	1,052,570
2018	250,706	2038	360,502	2058	518,384	2078	745,409	2098	1,071,861
2019	255,301	2039	367,109	2059	527,884	2079	759,070	2099	1,091,504
2020	259,979	2040	373,837	2060	537,559	2080	772,982	2100	1,111,508
2021	264,744	2041	380,688	2061	547,410	2081	787,148	2101	1,131,878
2022	269,596	2042	387,665	2062	557,443	2082	801,574	2102	1,152,622
2023	274,537	2043	394,770	2063	567,659	2083	816,264	2103	1,173,746
2024	279,568	2044	402,005	2064	578,062	2084	831,224	2104	1,195,257
2025	284,692	2045	409,372	2065	588,656	2085	846,457	2105	1,217,162
2026	289,909	2046	416,875	2066	599,444	2086	861,970		
2027	295,222	2047	424,515	2067	610,430	2087	877,767		
2028	300,633	2048	432,295	2068	621,617	2088	893,854		
2029	306,142	2049	440,217	2069	633,010	2089	910,236		

B8: EMISSION SCENARIOS

According to IPCC SRES, “A1. The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B) (where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end-use technologies).

A2. The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.

B1. The B1 storyline and scenario family describes a convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.

B2. The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the A1 and B1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels."