AN ECONOMIC ANALYSIS OF ANTHROPOGENIC CLIMATE CHANGE ON LOCAL RICE OUTPUT IN MALAYSIA

By
NICHOLAS HOE

MASTER OF ECONOMICS
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By
NICHOLAS HOE

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(Date)

Nama Pelajar : Nicholas Hoe
(Name of Student)

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Nama Penyelia/Penyelia-penyelia : Dr. Lee Wen Chiat
(Name of Supervisor/Supervisors)

Tandatangan

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ABSTRACT

Rice is an important staple food in Malaysia and represents a substantial household expenditure. Although the average rice consumption in Malaysian households has dropped due to preference change, total demand has increased. This can be attributed to the high population growth. Malaysian rice farmers have not been able to meet the country's demand. Hence, Malaysia imports large quantities of rice from neighbouring countries to supplement its rice stockpile. Malaysia, which imports about 40 percent of its rice, is the 10^{th} largest importer of rice in the world. This makes Malaysia susceptible to global rice crisis, similar to the one in 2008. To solve this problem, the government implemented policies to safeguard the country's food security and self-sufficiency levels. These efforts may be difficult in the future, as climate projections have shown that climate change will affect countries in the tropics most negatively with increased temperature and flooding due to anthropogenic carbon dioxide emissions. This study analysed the effect of anthropogenic carbon dioxide emissions on rice production in Malaysia during the period 1970-2013. The analysis incorporated the following variables: total local rice production, carbon dioxide emissions, precipitation, land used for paddy farming, total rice imports, and global average crude oil prices. The assessment of the impact of these determinants on rice production was achieved using the Vector Error Correction Model (VECM). The results indicated that in the long-run, climate changes will affect rice cultivation in the country, with carbon dioxide negatively affecting output, and increased rainfall positively affecting output. In the short-run, only precipitation and land showed effects on rice production. The significance of the error correction term also inferred that a long-run relationship exists. This study showed that climate variations in the future should be taken into consideration when formulating policies to ensure Malaysia's rice stockpile.

Keywords: rice production, climate change, temperature rise, precipitation, carbon dioxide emission.

ABSTRAK

Nasi adalah makanan ruji di Malaysia dan ia mewakili perbelanjaan isi rumah yang besar. Walaupun purata penggunaan beras isi rumah di Malaysia telah menurun disebabkan oleh perubahan keutamaan, namun begitu jumlah permintaan terhadap beras masih lagi meningkat. Hal ini boleh dikaitkan dengan kadar pertumbuhan penduduk yang tinggi. Justeru, para petani padi di Malaysia tidak dapat memenuhi permintaan negara yang semakin meningkat. Oleh itu, Malaysia mengimport beras dari negara jiran dengan kadar yang besar bagi tujuan untuk menambah stok beras di Malaysia . Malaysia mengimport kira-kira 40 peratus beras dari negara tersebut, dan ia adalah pengimport beras terbesar yang ke-10 di dunia. Hal seperti ini menjadikan Malaysia mudah terdedah kepada krisis beras global, seperti yang telah berlaku pada tahun 2008. Bagi menyelesaikan masalah ini, kerajaan melaksanakan dasar-dasar untuk menjaga tahap keselamatan makanan dan tahap pencapaian negara. Usaha ini mungkin sukar pada masa hadapan kerana unjuran iklim telah menunjukkan bahawa perubahan iklim akan mempengaruhi negara-negara di kawasan tropika. Apa yang paling negatif adalah dengan peningkatan suhu dan banjir akibat daripada pelepasan karbon dioksida antropogenik. Kajian ini akan menganalisis kesan pengeluaran karbon dioksida antropogenik terhadap pengeluaran beras di Malaysia dalam tempoh 1970-2013. Analisis ini akan menggabungkan beberapa pemboleh ubah, iaitu jumlah pengeluaran beras tempatan, pelepasan karbon dioksida, hujan, tanah yang digunakan untuk pertanian padi, jumlah import beras, dan purata harga minyak mentah global. Penilaian terhadap kesan penentu ini terhadap pengeluaran beras dicapai dengan menggunakan Model Pembetulan Kesalahan Vektor (VECM). Hasilkajian menunjukkan bahawa dalam jangka masa panjang, perubahan iklim akan memberi kesan terhadap penanaman padi di negara ini, manakala karbon dioksida memberi kesan negatif terhadap output, dan peningkatan hujan secara positif pula mempengaruhi output. Dalam jangka masa pendek, hanya hujan dan tanah sahaja yang menunjukkan kesan terhadap pengeluaran beras. Kepentingan istilah pembetulan ralat juga menyimpulkan bahawa hubungan jangka panjang adalah wujud. Kajian ini memperlihatkan bahawa variasi iklim pada masa hadapan harus diambil kira apabila merumuskan dasar-dasar untuk memastikan stok simpanan beras di Malaysia adalah mencukupi.

Kata Kunci: pengeluaran beras, perubahan iklim, kenaikan suhu, hujan, pelepasan karbon dioksida

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List of Abbreviations and Acronyms

AEZ	Agro-Ecological Zones
API	Application Program Interface
BLS	Basic Link System Model
CO2	Carbon dioxide
CRUTEMP	Climate Research Unit, Temperature
DOSM	Deparment of Statistics Malaysia
ESRL NOAA	Earth System Research Laboratory, National Oceanic and Atmospheric Organization
FELDA	Federal Land Development Authority
GCM	General Circulation Model
GISS	Goddard Institute of Space Studies
GTOP30	Global 30 Arc-second Elevation
IPCC	Intergovernmental Panel on Climate Change
MARA	Majlis Amanah Rakyat
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Organization
PPM	Parts per Million
USDA ERS	United States Department of Agriculture Economic Research Service
VECM	Vector Error Correction Model
WMO	World Meteorological Organization

CHAPTER ONE

INTRODUCTION

The agriculture sector is an important component in any country as it provides food and economic opportunities for the people. Due to its importance, various polices and budget allocation have been implemented to ensure it safekeeping. Although this has been the case, it has been projected that in the coming two decades, developing countries would be affected by crop production problems following changes in global temperatures and weather (Lobell, D. B., Burke, M. B., Tebaldi, C., Mastrandrea, M. D., Falcon, W. P., & Naylor, R. L. 2008). These climate changes stemming from anthropogenic activities such as mass deforestation, urbanization and vehicular pollution would cause adaption issues leading to food and economic problems in the country. Anthropogenic climate change in definition is "... a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods." (The United Nations Framework Convention on Climate Change, 21 March 1994). In the future, countries may experience food supply shortages, which in turn may cause price hikes.

Food security has recently been heavily debated and discussed among different parties and institutions around the world, as food and food prices is an important component in one's daily life. Various researches have shown that there has been a sharp increase in food and calorie demand comparatively to previous decades among the world's countries (Tscharntke, Clough, Wanger, Jackson, Motzke, Perfecto & Whitbread, 2012). Besides that, the growing anthropogenic activities around the world such as large-scale deforestation and urbanization have caused much change to our environment, which in turn also affected the crop-growing environments. With that in mind, more researchers have begun to include climate changes to explain food security (Cook, J., Oreskes, N., Doran, P. T., Anderegg, W. R., Verheggen, B., Maibach, E. W., ... & Nuccitelli, D. 2016). With growing population, growing food demand and varying food supply markets due to various climate induced factors; food scarcity has become an important issue. Thus, this research will look into how climate change will affect food production in Malaysia.

In 2016, there are approximately seven and half billion people in the world, and it is still increasing (Population Reference Bureau, 2016). For comparison, the population of the world has doubled in the span of less than 50 years (worldpopulationbalance.org). What this entails is that in a time span of about half a century, the world's inhabitants have multiplied by a factor of two fold. When looking at Malaysia, the same can be observed as well. According to the Department of Statistics in Malaysia, there are currently approximately 31.7 million people living in the country. Comparing with the estimates of the preceding year, there was a total increase of about 1.5 percent in Malaysia's population (Department of Statistics Malaysia, 2017).

With this strong growth in human population, a similar growth in food demand has also been observed, as food is a major necessity in the support of life. A paper written by David Tilman in 2011 on the growing demand on food highlighted that the demand for calories globally had risen considerably since the 1960's with projections of global food demand to further rise from the years 2005 to the year 2050. Although the increase in crop production technology was taken in to consideration, the rate of crop production may not be able to keep up with the rising demand in food. His results concluded that there would be an estimated increase of 100% to 110% in crop demand globally from the escalation of the worlds' population. Thus, growing population would lead to increasing demand of food, which would affect food prices and food security.

For the most part, food production has been greatly increased in the past few centuries with better farming techniques, superior irrigation methods and also improved agricultural management practices, leading some parties to feel the need to exclude attention in the this area of study. On the contrary though, many researchers have shown otherwise. Agricultural output has grown steadily although at a rate that may not be sufficient (Tilman, 2011). Climate changes to our agriculture environments may have significant impacts to the total output of crops. Among these factors are changes in the concentration of carbon dioxide in the atmosphere, changes in the duration of raining seasons, reduciton in land area suitable of agriculture and also global warming

With growing demand and varying supply trends, the price of food for consumers may see substantial changes. The fluctuation of food prices in the future may lead to problems of food securities. Food expenditure makes up a considerable portion of a consumers' income. For example, in Pakistan, the average household spends 47.7% of its income on food (FAO, 2014). The high ratio of income spent on food is due to Pakistan being affected droughts and other weather anomalies that destroy crops. As it will be discussed later in Chapter Two, increase in anthropogenic carbon emission will also lead to more frequent droughts and weather anomalies. Similar proportions of expenditure allocation can also be discerned in other developing countries such as Malaysia, Ukraine, Nigeria, Egypt and Cameroon with each country having to spend 18.9%, 37%, 39.5%, 42.7%, and 45.9% respectively on food. Comparatively, the average American household spends about $2273 on food per year, which amounts to about 6.6% of the total average household income (USDA 2012). Other developed countries such as the United Kingdom, Canada, Germany, South Korea and France spend an estimated 9.1%, 9.6%, 10.9%, 12.2% and 13.2% respectively. From these figures, a pattern can be seen, people in developing countries utilize a bigger portion of their total income for food compared to those used in developed countries. From the two groups of countries, it can be inferred that any increase in food price would affect developing countries more. This can be attributed to wealthier countries being able to shift the allocation of income during price shocks in the food market. Compared to developing countries, where during times of high food prices, allocating a bigger budget for food may prove difficult as food makes up a bigger portion of the income. This may result in household being able to afford less food. Thus, Malaysia being a developing country, during times of low food output and high prices, may likewise be adversely affected.

Society has done much in changing our environment to better suit our needs and to provide a better state of living to its residents. Every hour, resources are extracted and utilized and moulded to make items, objects and consumable products for consumption. Spurred by profits, firms and companies further intensify the rate of change in the natural environment. This ever-escalating change does bring its effects. Yearly, an estimated 36 million tonnes of carbon dioxide is emitted into the earth's atmosphere in the form of pollution through anthropogenic activities (Netherlands Environmental Assessment Agency, 2016). Besides carbon dioxide, carbon monoxide has also been a concern among parties are also another contributor of global warming. According to the Nasa Earth Observation, carbon monoxide in large quantities is able to indirectly affect global climate. Although this is true, the organization further explains that the pollutant is only available in trace amounts in the atmosphere and is unable to direct affect global temperatures through green house processes but instead plays an important role in atmospheric chemistry. Looking back at carbon dioxide, 65% of this pollution is brought about by industry, deforestation and agriculture (US Environmental Protection Agency, 2016). This exponential increase in greenhouse gasses has caused a change in climate by increasing the absorption of reflected solar radiation from the earth surface in the atmosphere. The build-up of these pollutants have caused an increased in temperature, increased in sea levels, and changes in precipitation levels. These changes in environments will bring negative effects to crops and agriculture yield in the future (Schlenker & Lobell, 2010). Thus, without mitigation, anthropogenic pollution, i.e. pollution caused by human activities, will affect the worlds' supply of food.

Linking the three aspects of exponential rise in human population, the fragility of certain nations and societies to the varying cost of food and our change and destruction of our environmental surroundings, we have a problem that is waiting to escalate to dangerous proportions. This unsustainability has also been predicted in the book titled "Limits to

Growth" by Meadows, Randers, and Meadows. The earth in recent years has experience drastic change in climate and weather following the intensification in human activities. Global temperature has drastically increased and weather has become more unpredictable (Cox et al., 2000). Crops and agriculture were able to previously experience growth in yield as environmental factors such as proper temperatures (climate), adequate rain and suitable spatial requirements, were more favourable for crop cultivation (Schlenker & Lobell, 2010). This has not recently been the case as the changing of the environment has hurt crop cultivation in countries around the world. Prevailing draughts that have hit California, that were previously unheard of, have caused the agricultural state to suffer reduction in crop out puts (ERS USDA, 2016). This has shown that global climate change is already underway. Similar weather anomalies have also hit Malaysia, whereby the country experienced severe droughts, affecting paddy cultivation (Perlis Irrigation and Drainage Department, 2016). Although some groups have cited the recent change in climate as due to natural cycles, other have shown that this is indeed human caused. This will be discussed in chapter two. In conclusion, although it is an on-going problem, policies and action to mitigate the effects have so far be few and in between by various governments (Gidden, 2009). Thus, it is important that the full effect of climate change on crop cultivation be studied and quantified to provide information and recommendations for mitigation.

1.8 Background of the study

Rice is the major staple food in Malaysia, making up the largest portion in food expenditure in an average household (Ishida et al., 2003). Due to its importance, the Malaysian government allocates incentives and subsidies to local farmers to increase production. With these efforts, production has increased from 1, 318, 000 tonnes in the year 1980 to 1, 820, 000 in the year 2016 (Department of Statistics Malaysia, www.dosm.gov.my, 2016). Although Malaysia has seen increase in rice production, demand has so far outweighed local output. Last year, Malaysia had a cumulative demand of 2, 825, 000 tonnes of rice (USDA, 2017). This puts local rice supply well below sufficiency to meet the populations' demand with a supply deficit of more than one million tonnes. To overcome this deficiency in rice supply, the Malaysian government has to import rice from neighbouring countries such as Thailand, Vietnam, Cambodia, Pakistan and India. Among these countries, Thailand and Vietnam are the top exporters of rice to Malaysia (USDA, 2017). Comparatively, Malaysia is also ranked ninth in total import of rice globally (Arandez-Tanchuling, 2008). Thus, rice is an important commodity for the Malaysian people, and the government relies heavily on imports to meet the high national demand.

The high dependency on rice imports has in the past, negatively affected Malaysia, such as in the case with the 2008 global rice and cereal crisis. The rice crisis, which was due to number of factors, namely constraints in trade by major exporters, the panic purchase of stock by importers, high crude oil prices, and a weakening dollar, caused rice prices to increase substantially (USDA, 2017). Together with a weak Malaysian currency, meeting the country's demand for rice proved costly for the Malaysian government, as rice was a controlled commodity in the country (Arandez-Tanchuling, 2011). Realizing that Malaysia is over dependent on rice imports, the Malaysian Government then prompted to increase rice sufficiency level to 90 percent by the year 2010 but was later repealed to 70 percent in the Tenth Malaysian Plan (2011 to 2015). Thus, being overly dependent on food imports can be detrimental, as any regional food crisis would affect the country's food security.

Due to the food crisis in 2008, the Malaysian Government instilled policies to increase self-sufficiency in rice production. The government's first action was banning the sale of locally produce rice overseas as local traders were stockpiling subsidized rice and subsequently exporting it (Arandez-Tanchuling, 2011). Besides, the government also implemented the Food Security Policy to increase sufficiency levels to 90 percent (Deviga, 2013). To achieve the target, the government allocated RM 1.73 billion in funding to local rice producers in the form of subsidies and incentives. The following year of 2009, the government further increased funding to RM 5.6 billion. In 2010, the self-sufficiency target was revised as output increase was insignificant. In the Tenth Malaysian Plan, a self-sufficiency target was pegged at a more reasonable 70 percent. Thus, it can be seen that the Malaysian government is intent on increasing self-sufficiency levels by increasing domestic rice production.

To increase self-sufficiency levels, the Malaysian Government has invested large sums of funding in to the Malaysian agricultural sector. Although this is a positive move to ensure the future of food security in the country, recent changes in global climate may adversely affect these efforts. In the past two hundred years, the average surface temperature of the earth has seen a steady increase (World Meteorological Organization, 2017). The Figure 1.1 below depicts this trend. The graph shows that global mean surface temperature for the past 200 years.

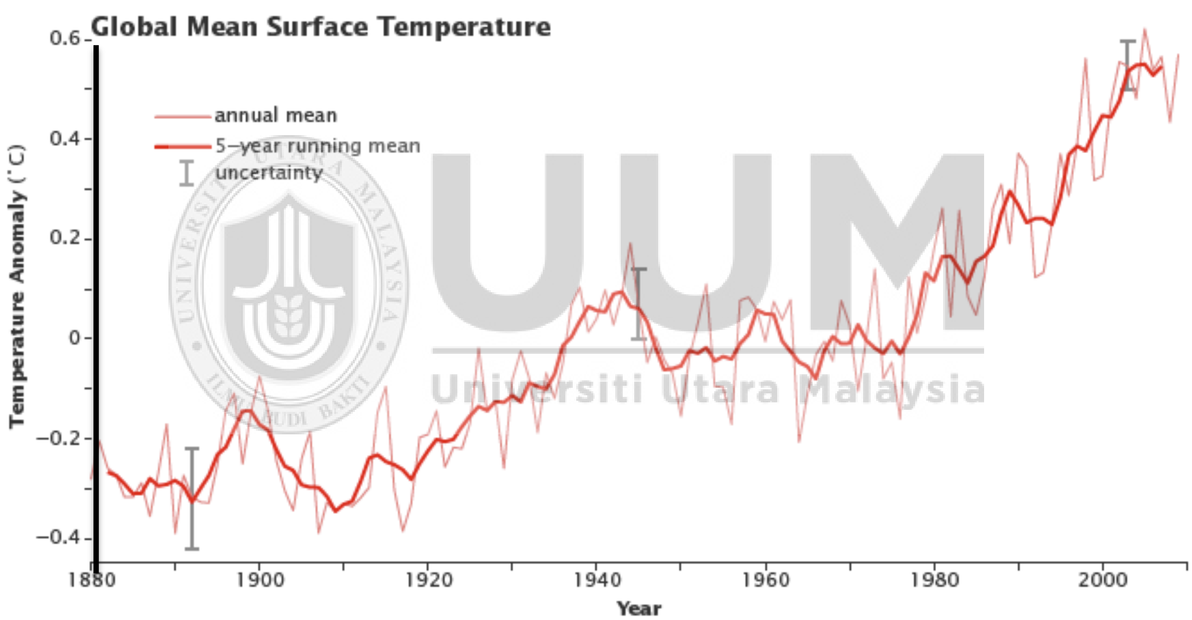

Figure 1.1

Global mean surface temperature in degree Celsius, 1880-2015

Source: World Meteorological Organization, 2014.

From Figure 1.1, starting in the mid-1800s, a huge spike can be seen in the late 19th century. After the adjustment of this spike, it can be observed that the advancing path truly takes an upward rise. According to the National Aeronautics and Space

Administration (NASA) in the United States, an increase of a figure between 0.6 to about 0.9 degrees Celsius has occurred in the past 100 years. The increase, largely due to the sudden spike in greenhouse gases such as carbon dioxide, CFC, water vapour, methane, nitrous oxide and ozone gas, were actively deposited into the atmosphere at the beginning of the industrial age (UW Atmospheric Science Department, 2013). Green house gasses caused the world surface temperature rise by preventing reflected solar radiation from the earth from leaving the atmosphere. This accumulation of radiation in the earth's atmosphere leads to temperature rise. According to NASA, the approximate increase of 38% of the carbon dioxide in the earths' atmosphere was only from the past 200 years alone, resulting from an increase in anthropogenic activities such as industry, deforestation, and automobile. This development can be seen more clearly using the figure 1.2 below.

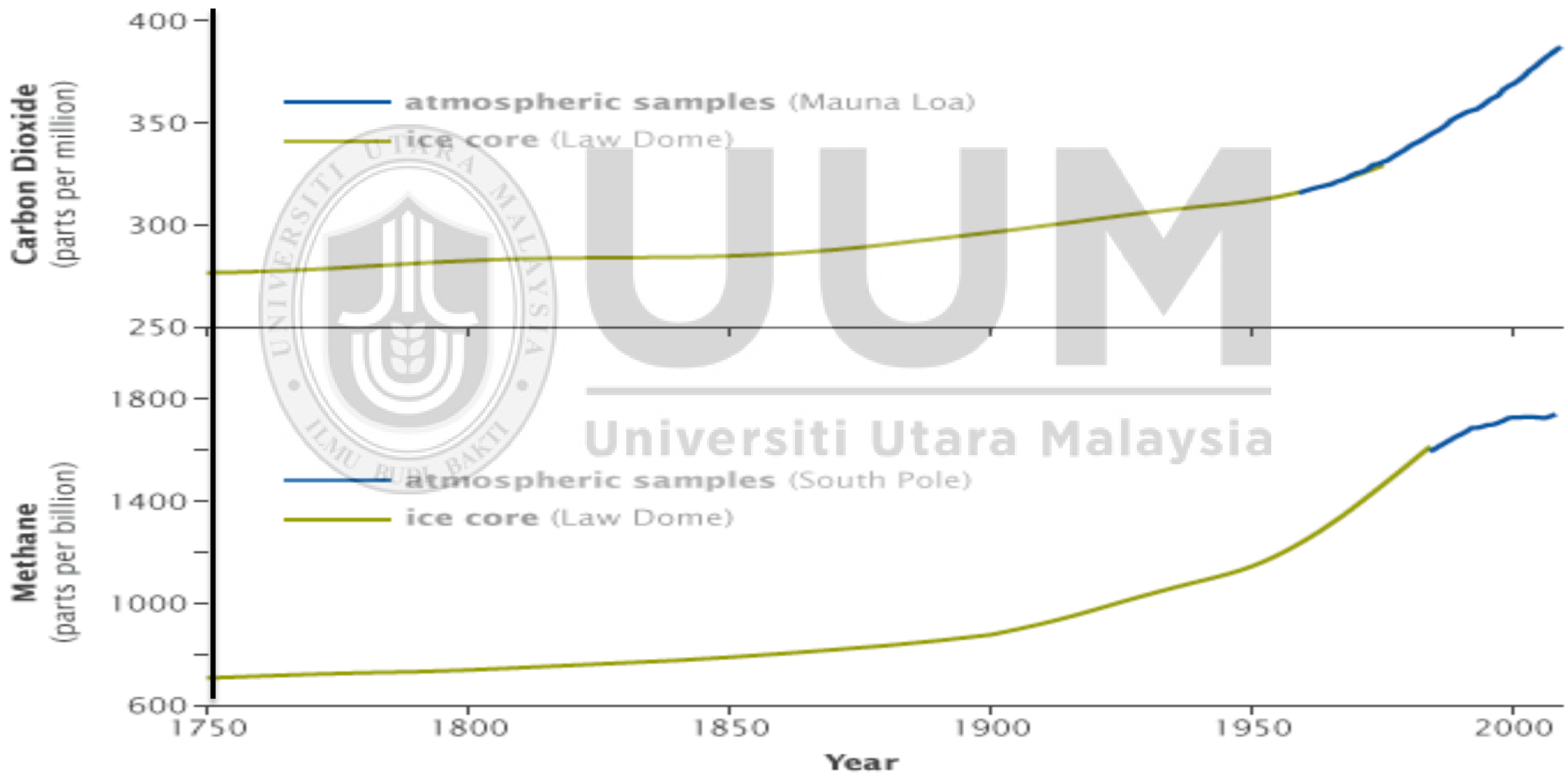

Figure 1.2
Global Carbon dioxide and methane concentrations, 1750-2015 (parts per million)
Source: National Aeronautics and Space Administration

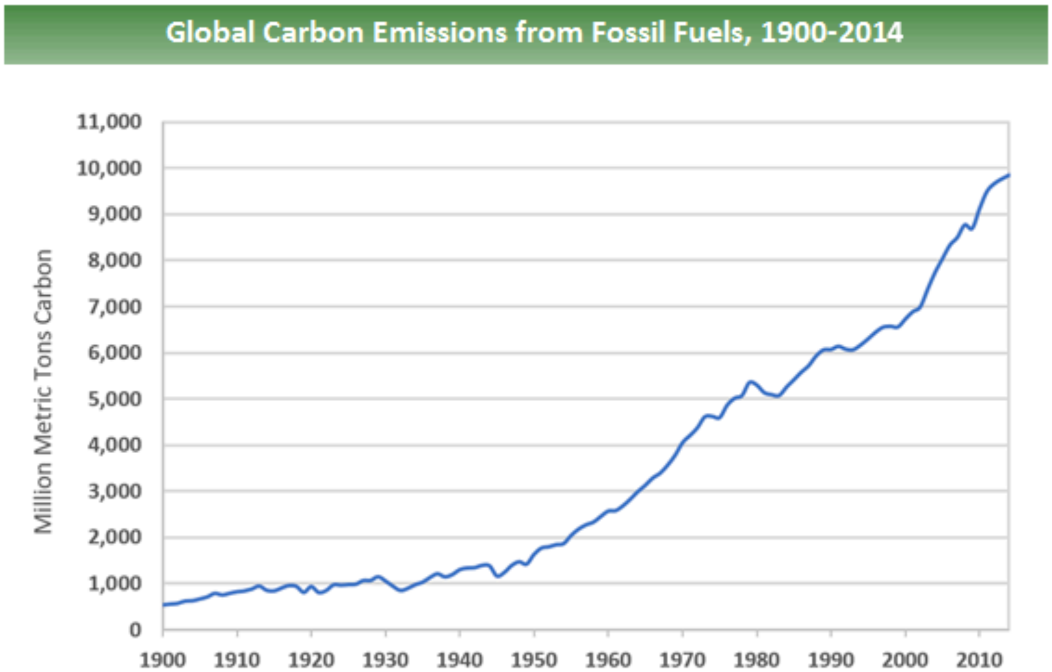

Figure 1.3
Global Carbon Dioxide Emissions from fossil fuels, 1900-2014
Source: Boden, T.A., Marland, G., and Andres, R.J. (2017). Global, Regional, and National Fossil-Fuel CO2Emissions. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A. doi 10.3334/CDIAC/00001_V2017.

The Figure 1.2 shows both the concentration carbon dioxide and methane in the earth's atmosphere. From the plot, it can be seen that during the pre-1800's, the concentration of both carbon dioxide and methane gasses in the atmosphere remained considerably flat for the most part. Starting from the industrial revolution (in the year 1760) onwards on the other hand, these concentrations began to experience a drastic upward shift. More specifically, before the industrial revolution, the earth's carbon dioxide levels in its' atmosphere wavered between 180ppm to 280ppm (ESRL NOAA, 2005). After the industrial revolution in the 19th century to the present day on the other hand, rates of deposition has increased a 100 folds with values surpassing 400 ppm. This yearly rise can been seen as detrimental to the environment as natural carbon sinks such as forests may not be able to cope in regulating carbon levels. In the long run, the effects may accumulate and affects the ability of countries to produce food. These levels are also higher than what natural levels should be. In Figure 1.3, analysis carbon dioxide emissions just from the 1900's onwards, it can be evidently seen that concentrations take an exponential path. Among the main contributors of increased atmospheric carbon dioxide are electricity production, industry, transportation, agriculture, commercial activities, and residential areas (IPCC 2013). Besides, carbon dioxide, similar exponential trends can be witnessed in other types of greenhouse gasses, with chlorofluorocarbons being the only exception due to the outcome of the implementation of the Montreal Protocol. Thus, on a whole, greenhouse gases are all increasing at an unnatural rate. More sustainable practices should be implemented to slow down the rise in airborne pollutants while looking after human welfare.

The rise of carbon dioxide in the atmosphere to such high levels will severely affect the natural environment required for crop cultivation and production of food. As carbon dioxide levels in the atmosphere rise from unsustainable practices, the global surface temperature will simultaneously rise (Hansen et al., 2010). Ever since the start of the industrial revolutions in the late 19th century, global temperatures have risen at a rate of 0.08 degrees Celsius every decade (NOAA 2016). During the late 1970's on the hand, rate of temperature rise from greenhouse gasses increased to 0.15 to 0.20 degrees Celsius every decade. Moreover, in this decade alone, 11 of the warmest years ever on record were observed (NOAA 2017). To properly observe this increasing temperature trend, a graph of the anomalies in temperature compared to the base period of 1951-1980 can be used. See Figure 1.4.

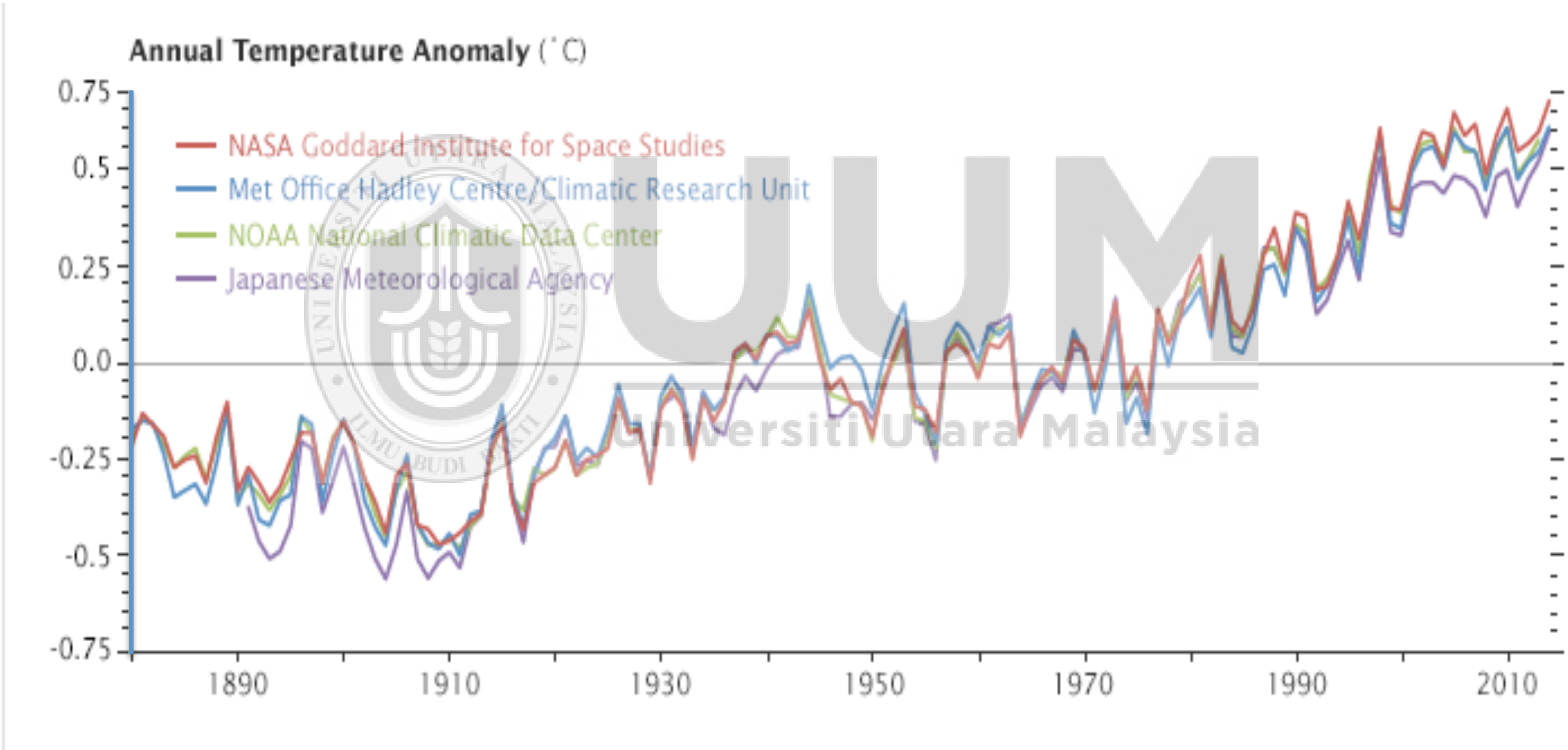

Figure 1.4

Annual temperature anomaly as compared to the time period 1951-1980 from NASA, CRU, NOAA, Japanese Meteorological Agency,1880-2014

Source: National Aeronautics and Space Administration

From figure 1.4, it can be observed that higher number of temperature anomalies have been experience in the past 30 year. Although the anomalies may seem miniscule, the value is significant as it takes a vast amount of heat to heat up the earth's oceans and lands to even a one degree change (Hansen et. al 2010). Thus human activities have changed the global natural environment, inviting harsher conditions for biological life such as crops and animals.

The change in temperature from the increase of anthropogenic carbon dioxide in the atmosphere may have detrimental effects on crop cultivation. If temperatures exceed the optimal level, crops may experience a decrease in total biomass and loss in crop yield (Asseng et al., 2004). Countries situated in the tropics are most prone to the negative effects of rising temperatures as compared to countries in the higher latitudes (Parry et. al 2004). Due to this, developed countries which are more commonly situated in the higher latitudes will stand to gain from climate change compared to developing countries, which are more commonly situated in lower latitudes. Countries situated in higher latitudes will stand to gain longer growing seasons from shorter winters while countries situated in the lower latitude will encounter harsher growing seasons. Situated in the tropics, Malaysia is expected to see decrease in crop yield from the rise in global temperature. As a result, efforts by the Malaysian government to increase self-sufficiency levels for rice production may see its target not met as rising temperatures will likely decrease total rice output. Therefore, it is important understand the full effects of the changing climate on Malaysia's rice production to ensure its food security.

The effect of climate change may negatively affect the Malaysian Governments' attempt achieve a 70 percent self-sufficiency. This may in turn cause the country to be more dependent on imports to meet the growing demand from the Malaysian population. A high dependency on imports may be risky in maintaining the country's food security in the long run as any rice crisis, as the one experienced in 2008, may reduce the country's rice supply. A reduction in total supply may cause food scarcity as well as increased prices, burdening the citizens of Malaysia, especially the low-income households. Although policies have been implemented to increase rice output in the wake of the 2008 world rice crisis, climate change may threaten the effectiveness of such policies. Thus, it is important that studies are undertaken to understand and quantify the full effects of climate changes on food production in Malaysia to ensure that early steps can be taken to guarantee food security in the country.

1.2 Problem statement

In the year 2008, the world experienced a complex food crisis, whereby the trading price of various cereal grains including rice surged considerably (Slayton, 2009). The spike in rice prices was the result of a mixture of factors, namely the surge in crude oil prices, restrictions in export by rice exporting countries, and shifts in investments opportunities in certain stock and commodity exchange markets. Due to the high prices, Malaysia, a net importer or rice, was hit hard. As a response, the government implemented policies to increase self-sufficiency of 70 percent. Although a positive move, recent effects of climate change may have derail these efforts as seen during the droughts that hit the country in the years 2014 and 2016. During the drought, paddy farmers in the country were unable to plant their crops as water supply in the irrigation dams were critically low. High temperatures also damaged crops that were planted in the country (Othman, 2016). Thus, the Malaysian agricultural sector had been affected by variations in weather and climate conditions. Besides that, changes to the climate are predicted to be more apparent in the coming decades due to an increase in green house gasses in the atmosphere from anthropogenic pollution. Anthropogenic pollution is the deposition of green house gasses into the atmosphere from human activities such as industrialization, deforestation, transportation, automobile, and agriculture. With this current trend, circulation models have predicted that in the coming decades, with increasing anthropogenic pollution, temperature is set to rise with increasing number of weather anomalies such as droughts and floods. It is also predicted that due to the climate change, crop output may decrease by 2.5% to 5% in the next decade (Parry, 2004). A reduction in rice output in the country will affect self-sufficiency levels and rice supply. This in turn will cause increase in food prices resulting in a higher cost of living. With increasing urbanization, the effect climate change will be more apparent, especially in terms of the agriculture environments. This will lead to changes in crop output and adversely affect self-sufficiency policies made by the Malaysian government. Variations in food output may affect supply and lead to future food price fluctuation.

Therefore, it is important to identify the magnitude of the effects of climate change on rice production, as this will allow better preparedness for future outcomes and also provide better information for the government in its efforts for self sufficiency in rice production. Besides, comparing the effects of the climate with the main factors of rice production such as land, imports, and oil price will similarly be beneficial as it can be used to allocate resources more effectively to tackle the problem of climate variability and its effects on the nations efforts in achieving higher self sufficiency in food production.

1.3 Research Questions

The research questions for this study are:

i) Do changes in carbon dioxide concentrations in the atmosphere affect rice production in the short-run and long-run?

ii) How do temperature and rainfall affect the country's rice production?

iii) How do these climate factors compare to other more conventional determinants of rice production especially import policies, area of available irrigated paddy land, and average crude oil prices.

1.4 Objectives of Study

The main objective of this research is to examine the relationship between the climate change and rice production.

The specific objectives of this study are:

1. To study the effects of surface temperature on rice production in Malaysia.

2. To study the effects of carbon dioxide on rice production in Malaysia.
3. To study the importance of climatic relative to the more conventional determinants of rice production in Malaysia.

1.5 Hypothesis

The following hypotheses are based on the problem statement and objectives of the study stated previously in the preceding sections.

i) Temperature increase will reduce rice output.

ii) Precipitation increase will positively affect rice production.

iii) Increased availability of agricultural land will positively affect rice output.

iv) Increased rice imports will negatively impact local rice production.

1.6 Significance of the Proposed Study

With the Malaysian government ramping up efforts in increasing the country's self sufficiency levels in terms of rice production and with the effects of carbon dioxide deposition gaining attention, an analysis on the effects of climate change on rice output (and ultimately on the self-sufficiency policies should be done). Up until recently, the scope of studies done on increasing food prices mostly encompass non-climatic factors such as energy prices, export policies, food demand, biofuel demand, currency rates, and the stockpile of foreign exchange. On the other hand, there is now a need for greater understanding in how the planet will be affected by increasing carbon dioxide pollution.

Thus, there is now a need to analyse the effects of climate on food production and price. The time for the inclusion of climatic factors affecting the economics of food production be made by the academic community to better understand the mechanism of climate change. Governmental bodies would also bebetter informed of the significance of the inclusion of climate in policy making. By obtaining and providing this analysis, farmers can better accommodate their varying income for improved finance management and also better farming strategies. The same can be said for household consumers. The study could bring to light the phenomena of increasing food prices and thus provide better practices when buying produce for households. Besides, the government would be guided by the findings to better allocate funding and budgets and to improve policies in the coming years as and when climate change may get worse. With this, better subsidies, better distribution of man power and scientific research can be carried out (such as looking to new ways to increase output and reducing the impact of the society's activities on the environment). Together, these reduce the burden on the people of Malaysia.

1.7 Outline of the Thesis

This thesis is organized into a number of chapters. Chapter Two will focus on the science of climate change and will discuss what is anthropogenic carbon dioxide pollution and how it affects our environment. It will also briefly touch on the other factors that affect food prices and output. Besides that it will also discuss the importance of rice to Malaysia and why it should be a marker on the effectiveness on the country's' food production.

Chapter Three will be allocated for laying out the research method for this dissertation. Chapter Four will be used to display the results of the regressions and Chapter 5 will be an analysis of the finding. Concluding statements will also be discussed in this chapter.

CHAPTER TWO

LITERATURE REVIEW

There have been many records on planet earth's past climate situations, some through direct means while others by indirect means such as the use of ice core samples that have provided somewhat accurate climate data of the earths' past. This chapter will serve to present the current climate situations with direct comparisons to past estimates as well as its projection for the future. Besides, our climate history will also be laid out, highlighting the significant turning points.

Firstly, the current historical climate situation of the planet will be reviewed and discussed. The reasoning behind this would be to facilitate better understanding on how climate cycles work and to better compare the current climate situation with the past to check on discrepancies and whether this is indeed normal or otherwise. This procedure will support the rationale to proceed with this study if profound differences are to be found. To achieve this, current concentration of greenhouse gasses will be compared to natural levels during the past 6.5 million years ago. This chapter will also look at data from the last 200 years, as this is when anthropogenic activities were carried out on a scale of importance. With these data aligned, we will then be able to judge how much changes have been due to anthropogenic activities which affected the earth. If this conclusion is reached, then it can be established that climate change is indeed not only a myth but also something incredibly abnormal in nature. Taking this into account, the study can then look into its' effects on food and ultimately food prices. (Most of the data will be taken from the Intergovernmental Panel on Climate Change, IPCC as this world body provides the most up to date and complete elaborations.)

Before going straight into the details of climate patterns past and present, it would be necessary to take into account other views and aspects to food price trends. This is crucial for the study, as it will ease the comparison between the non-climate factors to climate factors affecting food prices or if there are correlations between the two schools of thought. This section will be presented first as the climate aspects, being the bulk of the research, to allow better focus of the integral components for the research.

2.1 Non-Climatic Factors affecting Food Commodity Prices

Much of research has been done on the factors that affect the fluctuations of food prices spanning from well-rounded surveys carried out on the community to complex models on projections. A comprehensive compilation done by Trostle in 2008 for the United States Department of Agriculture (USDA) listed many drivers that affected food prices. Among these drivers were, biofuel feedstock, weather shocks, declining value of the US dollar currency during the good part of the 21st century, escalating energy prices, intensifying agriculture cost of production, growing foreign exchange holdings by key food producing countries, and recent policies undertaken by various countries to dampened their own food price inflation. These circumstances whether acting along or in simple and complex relationships with one another have been proven to be influential in food prices. The next section will discuss in greater detail each of the factors laid out above.

2.1.1 Biofuel Feedstock and the Price of Food Commodities

This section will discuss on how crude oil prices have affected food prices. High crude oil prices have shown to cause increase demand in corn for biofuel production purposes. This in turn has caused decreased supply in maize for food and thereby affects corn prices in the food sector.

A study conducted by Trostle (2008) discovered that the usage and demand for ethanol in the past 5 years (from the year 2002 to 2007) had seen sizeable increase and that this has amplified the usage of corn produced by the US to fuel the energy sector. These changes in the use of corn by the US had strong ramifications as the US was a large exporter of corn in the world market. Shortages began to transpire across the market, which ultimately lead to increases in overall price for corn. Although the study conducted by Trostle proved to be highly logical, another researcher found that biofuel demand had little or no effect on global food prices (Anjanovic, 2008). Anjanovic reasoned that although the use of biofuel had soared considerable and the use of agricultural produce had similarly increased for the use as biofuel feed stock, the aggregate production of corn output had also increased considerably. The same was recorded for other crops such as wheat, and other grains. Simultaneous growth on both supply and demand meant that prices would mostly remain unaffected by the shift of crop use from household consumption to the production of biofuel. Besides Anjanovic, similar studies on the effect of biofuel production on the changes of food commodity prices had also been carried out (Zilberman, Hochman, Rajagopal, Sexton and Timilsina 2012),. The results obtained by the study proved mixed. The evaluation was carried out by running simulations on time series data sets and then subsequently acquiring the significance of biofuel feedstock demand on food price. It was discovered that the influence of the shift of the use of crops output for biofuel production had varying effects on food prices. Prices of food were found to be less likely to fluctuate when biofuel crops were planted in land not allocated for food production. In other words, if crops used for energy production are grown in non-agricultural land (land not used for the production of food), there may be no biological competition among the crops. If the planting of biofuel feedstock crops were indeed done in or next to plots of land intended for food production, then we may actually see decrease yield in food output. This will ultimately lead to less supply in the market and thus the escalation food cost to households. One good example that demonstrated the non effect of the upswing of crop use for biofuel feedstock on the prices of food consumed by household is the production of sugarcane in the making of ethanol in Brazil (Zilberman et al., 2012). According to Zilberman et al., the planting and production of ethanol feed had inconsequential effect on the price of other crops as it was planted in land that was not intended for food agriculture. Thus there was no biological competition between the two crops for nutrients, space, water, sunlight, and other inputs. No competition between the two crops meant there was neither an decrease in the production of food crops nor the increase of prices as they would remained relatively steady (when comparing to the increase in biofuel feedstock production). Similar findings were also concluded in Nigeria, whereby the production of crops was sufficient for ethanol and food productions (Dick, 2014). This finding was the contradictory for the production of corn ethanol in the United States as it was found that the high demand and need of corn for the production of ethanol cause substantial variation in the world prices for corn as household food. The cause of this changed in price was due to the fact that corn played a principal role as a source of food for people around the world. This meant that the reduction of supply of corn for human consumption caused micro-shortages and eventually affected the world prices of corn. This was similarly concluded by Dogruer (2016) in his thesis titled " The demand and welfare analysis of vegetable oils, biofuel, sugar cane, and ethanol in Europe, Brazil and the US ". Looking further, according to a paper by Donald Mitchell for the World Bank Policy research, many studies conducted in this area have found that biofuel manufacturing was a foremost contributor to the variation in the prices of food. During a congress of Joint Economic Committees Conference held on May 1st 2008 , USDA lead economist, Dr. Joseph Glauber made a statement that a lot of the upsurge of maize and soybeans prices produced from farms was the result of the up swell of demand from the biofuel sector. First Deputy Managing Director of the IMF, John Lipsky (2008) also estimated that an immense 70% of the rise in corn prices was the by-product of the increase in biofuel production. Using mathematical simulations, 60 percent of the increase in the price of corn was that of the increase in ethanol production, which utilized corn in the years between 2006 and 2008 (Collins, 2008). In terms of long-term effects of the increase yield of ethanol and its growing demand of maize, Rosegrant, Zhu, Msangi, and Sulser (2008), calculated the effect on weighted cereal prices of the rapid rise of demand of maize for energy production to be about 30 percent in the years 2000 to 2007 using a general equilibrium model. In terms of the type of cereal, maize, wheat and rice were seen to rise by 39 percent, 22 percent, and 21 percent respectively in those years. Besides, it was also detailed that the American CPI increased by 20.4 percent entailing nominal price increase for corn, rice, and wheat for 47, 25, and 26 correspondingly. These values were the same as the values obtained by the World Bank's linkages model (van der Menbrugghe, 2006). Judging from statements made by the participants of the committee, there seems to definitely be a strong correlation between the upswing of corn demand stemming from the energy production and the prices of food.

From all these studies and statements by researchers and analysts, there were definitely varying opinions on the effect of ethanol and other biofuel production on the world food prices. Although there was no strong consensus among these researches, it is believe that the rise of biofuel production does have an effect on food price, both direct and indirectly.

To summarize, it thoroughly depends on the type of crop used for biofuel production and also the region that crop is produced. In some cases, high demand and conversion of use of biofuel from other energy sources have caused competition for land. As Zilberman found, when two crops compete for the same resources, total crop output from that specific plot would be significantly less and of lower quality. Thus incorporating crude oil prices into the model would be beneficial as it could be used as a comparison tool in determining how important climate factors are in determining food supply and resulting food prices.

2.1.2 Weather Shocks and Its' Relationship on Food Prices

Weather shocks, unsurprisingly also cause variation in food prices. Although at first glance, this may seem like a climate change factor to rising food prices, (weather anomalies caused by climate change will be discussed later) these weather anomalies are thought to occur not due to anthropogenic activities. In other words, these weather anomalies or natural disasters such as typhoons, floods, earthquakes and droughts among others are natural or random in nature. For the sake of comparison, this portion of the paper will focus only on weather anomalies that are not caused by climate change. According to Trostle (2008), droughts that occurred in 2006 and 2007 were anomalies that were not due to anthropogenic activities such as deforestation, industry, transportation, and urbanization in the past century. These droughts that ensued in various parts of Europe (mostly in Southern and Northern Europe), Africa and Australia had caused massive drops in agriculture output (Trostle, 2008). Abnormally cold weather had also affected a few areas in the U.S., which resulted in a large number of crops that were wiped out. All of those weather shocks have caused drops in wheat and grain production resulting in effect to the world food market. Lower crop outputs were not able to meet the growing demand of food by the mounting world population. As supply of these crops changed so rapidly and suddenly, the markets were not able to adapt and the low yields meant higher prices. These sudden high prices meant that households had little time to adapt. What is worse, John Quiggin from the University of Queensland believed that the recent droughts and the change in rainfall patterns that transpired in Australia were only the start and were the direct cause by the anthropogenic activities through the years. Since the climate takes a few periods of lag (or years) to adjust to the ever increasing volume of man-made greenhouse gasses being deposited into the atmosphere, the country will fully experience the severity of the effect of climate change in 15 to 45 years' time (Quiggin, 2010). By 2070, the country will experience 40 percent more occurrences of droughts and severe weather. Quiggin also elaborated on the past effects of drought on food prices. As it were, the country came across a 50 percent increase in lamb prices during the 2004 drought that triggered crops used as feeds for the livestock to dwindle in output. The same can be said for 2007 where locally produce fruits and vegetables saw a 33 percent and 43 percent increase in price respectively. Since Australia is an exporter of food such as grains, beef and milk powder, any decrease in output in the future from droughts will have stark effect on global prices (Quiggin, 2010). As a result, effects of weather shocks on crops in one country will likely to trickle to other communities in other parts of the world.

From these examples, sudden and abnormal changes in weather unquestionably do cause strong consequences on the food market and eventually its prices. It is the "sudden" trait of the severity that has the most negative impact on consumers. Due to the abruptness, households as an economic unit do not have the leisure to plan out consumption trend or change decisions for better allocation of funds for an efficient household. During these catastrophes, it will be low-income households that will be utmost affected. Having low income leads to having no room for adjustment. This will mostly definitely lead to malnourishment and poses the question of whether there will be a more prominent so call "social class nourishment".

Besides, the increase in weather shocks in the previous years may incite farmers to exit the agriculture sector and move into other business sectors (Blanc, 2011). Blanc attributed to the movement of farmers from the agriculture sector to other sectors to the anticipation by farmers of the worsening weather conditions in the following year. Participating in other economic activities was deemed safer as these farmers were already in poverty, and ensuring a steady income was prioritized. This change in economic activity may cause further decrease in locally produced food.

As advocated by Quiggin (2010), since the planet takes time adjusting to atmospheric changes, it may only now be experiencing the start of the effects of greenhouse gasses first deposited during the industrial revolution through anthropogenic activities. Not only will weather shocks be more frequent, they will also be bigger in magnitude. As shown by both Trostle (2008) and Quiggin (2010), abnormal weather patterns have detrimental effects on local and global food prices as well as food supply (whereby some low income families in Australia were affected). Thus, further studies should be done on the other aspects of global climate change (such as temperature change and sea level rise) on world food supply and food prices. In relation to this study, the importance shown in weather anomalies show the need to incorporate this factor when determining food output.

2.1.3 Increasing Cost of Energy, Agriculture Production Cost and World Food Prices

Farmers around the world mostly rely on cheap energy such as petroleum oil as it is easy to use (most machinery use petroleum or diesel, a by-product of crude oil processing), easy to transport, relatively high energy output and considerably cheaper than other sources of energy (Cho, 2006). According to Cho, oil prices were mostly low before the turn of the century, only rising early in the 21st century. Due to the increase in oil prices, individual farmers were force to increase the prices of their produce for the most of 2000 to 2006. Although Cho merely gathered news reports for his study, other researchers who carried out modelling of data also found similar results. Esmaeili and Shokoohi (2011), carried out the Scree test on the macroeconomics index (oil prices) and food prices. A Scree test is a technique for determining the number of factors to retain in a factor analysis. It was found that oil prices had an impact on food production index, which thus affected food prices. Thus, it was concluded that oil prices had an indirect effect on world food prices (Esmaeilli & Shokoohi, 2011). Besides Esmaeilli and Shokoohi, many other researchers also had similar findings. A group of researchers led by Sheng-Tung Cheng (2010) conducted research in the same field and the results were comparable. It was shown that the prices of grain were significantly influence by crude oil prices (Sheng-Tung Cheng, Hsiao-I Kuo & Chi-Chung Chen, 2010). One reason for the volatility in food prices is the changes in fertilizer prices. Shocks in crude oil prices have shown to affect fertilizer prices (McAleer, 2013). This in turn affected the resulting cost of food sold to suppliers by farmers.

As shown above, most researchers have found that crude oil prices have solid effects on world food prices such as grain and sugar. This supposition is mainly due in part to the reliance of farmers on petroleum to work farming machinery as petroleum is deemed a reliable and easily procured source of energy. Besides petroleum on the other hand, farmers do rely on other means of energy such as electricity for the production of agriculture produce. According to a report made by the US Climate Change Science Program (CCSP) in 2007, production and supply of various types of energy sources will likely decrease as climate change increase in severity. This is due to more intense weather affecting energy production, water shortages in hydropower producing areas, and the reduction in thermoelectric power generation efficiency from increase global temperatures (Schaeffer, R., Szklo, A. S., de Lucena, A. F. P., Borba, B. S. M. C., Nogueira, L. P. P., Fleming, F. P., … & Boulahya, M. S. 2012). For example in hydroelectric production, global warming could potentially alter water sources being fed into the turbines and thus affecting power generation. Thus, adverse climate changes may potentially have strong indirect effects on agriculture production cost besides direct affects through increase energy cost.

In relation to the study and proposed model, the cost of energy can be seen to affect food production and ultimately food price. Combining with the discussion in the previous section on crude oil prices and its effect on food production, the inclusion of petroleum prices would be a useful comparison tool to determine the importance of climate factors in predicting crop output.

2.2 The current climate change situation due to Anthropogenic activities

This section will look particularly at the theories behind climate change and whether there is indeed a "change". This will cover the types and severity of the change by comparing previous natural cycles such as past ice ages, the snowball theories, natural carbon cycles, among others with current climate characteristics. That being said, this chapter will also look at the rate of pollution and environmental change in our surroundings. Among the signals of climate change that will be covered in this chapter are carbon dioxide concentration in the atmosphere, temperature rise, increase in ultra violet rays, weather shocks such as drought and prolonged monsoon. Individually, we will be able to break down the changing climate into blocks that can be easily explained and quantified. Together, these aspects will give us a better holistic picture of the current situation.

Most of the data on the shifting climate will be taken from the Fourth Assessment Report done by the Intergovernmental Panel on Climate Change. Founded by the United Nations Environmental Program and the World Meteorological Organization, the body provides exact, detailed and comprehensive datasets on the worlds' climate on various aspects. The data collected are from diverse backgrounds and countries providing an unabridged picture analysis. A comprehensive look at the situation will be invaluable, as it will add scale and severity to the change, besides proving if the change in climate is a global phenomenon or a collection of isolated cases. If the former is true, the effects of the global food market would be worse.

2.2.1 Change in Greenhouse gases.

According to a report made by the Intergovernmental Panel on Climate Change (IPCC) in 2007 titled the Fourth Assessment Repot, carbon dioxide has risen considerably since 1750. This has mostly been attributed to the industrial revolution and the increased use of petroleum products as well as other fossil fuels such as coal(during the start of this revolution). The industrial revolution marked the start of increasing manufacturing processes, business and increased work force. With the textile sector seeing rapid growth, it was one of the first sectors to verge into industrial production and use of coal (Landes, 1960). Seeing increasing yields at lower cost, it was only a matter of time that the rest of the manufacturing sector converged using industrialize techniques. The progression of the industrial revolution in Britain, Europe, North America and later the rest of the world, sky rocketed the expulsion of carbon dioxide into the atmosphere. For example, it was recorded that the carbon dioxide concentrations had risen by 35 percent since the start of the industrial age. This equated to a rise from 280 ppm3 at the start of the industrial age to 379ppm3 in 2005 (IPCC, 2007). Besides industry, agriculture also contributes a larger percent of carbon dioxide pollution into the atmosphere (Wolken, 2009; Nkongolo, 2010; Sedorovich, 2008). It is estimated that agriculture contributed to 49% of all carbon emissions. These emissions come from enteric fermentation from livestock (a digestive process in which carbohydrate are broken down), manure decomposition, and soil dentrification (Johnson, J. M. F., Franzluebbers, A. J., Weyers, S. L., & Reicosky, D. C. 2007). The remainder of the emissions are from deforestation, urbanization and transportation.

A valued increase of 35% percent based solely on anthropogenic activities is a worrisome predicament but there are other parties that argue otherwise. The are researchers that argue and believe whole heartedly the ideology of natural carbon cycles and that the planet is simply on the upsurge of that carbon dioxide cycle. An analyst by the name of Leiserowitz (2006) from Yale University in his paper on the common perception of climate change problems at different levels of society revealed that the general perception of climate change can be divided in two. One group supports the general unease of the matter while the other exhibited cynicism and scepticism. The latter group having thoughts and opinions that the rising carbon dioxide concentration in the atmosphere is due to natural cycles and the increasing trend would not pose any complications to human health. Although in his paper, titled ”Global Warming in The American Mind: The Roles of Affect, Imagery, and Worldviews in Risk Perception, Policy Preferences and Behaviour” **,** stated that the majority of the American public do see climate change as a global problem stemming from human activities and only a small number (in relation to the latter group) who think otherwise, the group does still exist.

Now, it may seem plausible to count out man-made causes for the shifting of the climate because of increase carbon dioxide in the air, but another aspect should also be analysed, the rate of increase of carbon dioxide. Although there seems to be an upward inclination of carbon dioxide that is in line with the natural cycle of carbon dioxide variations in the planet’s atmosphere, but rate of this upswing is what is upsetting. Based on readings sourced from the National Oceanic and Atmospheric Administration at the U.S

Department of Commerce (NOAA), the rate of increase of carbon dioxide has accelerated to 2.1ppm(parts per million) per year during the last decade compared to 0.7 ppm per year in the 1950's. Comparing these two values, in 60 years, the rate of deposition of carbon dioxide into the air has tripled. More staggering is the rate today is about 100 times the rate during the last ice age. A rate of 100 times that of the last ice age would suggest that what the planet is experiencing at the current moment is a cycle situation that is not natural. In another sense, the world population has surpassed Mother Nature at carbon dioxide deposition to a very large degree. At this stage it may be hard to blame natural causes. Beside, deforestation has also been a contributor to green house gasses. During the 90's and early 20th century, deforestation accounted for 25 percent of all anthropogenic green house emissions. This was a result of logging and land conversion to urban and agricultural land (Houghton, 2004). Reduction in forest area also lead to decreased carbon sinks, lowering the absorption of carbon dioxide. Transportation on the other also contributed to increased green house gasses. Petroleum based fuel used in cars, trucks, ships, trains, and aeroplanes contributed 27 percent in green house gasses (Ribeiro Kahn, S., Kobayashi, S., Beuthe, M., Gasca, J., Greene, D., Lee, D. S., & Wit, R. (2007)

From the plot below of the concentration of carbon dioxide in the atmosphere, the past ten thousand years have seen numbers that were significantly constant. After the year 1960 on the other hand, it can be seen that the sharp increase resembles an exponential graph plot (the hockey stick representation). Thus, carbon dioxide is really on the rise and it is doing it in an alarming fashion.

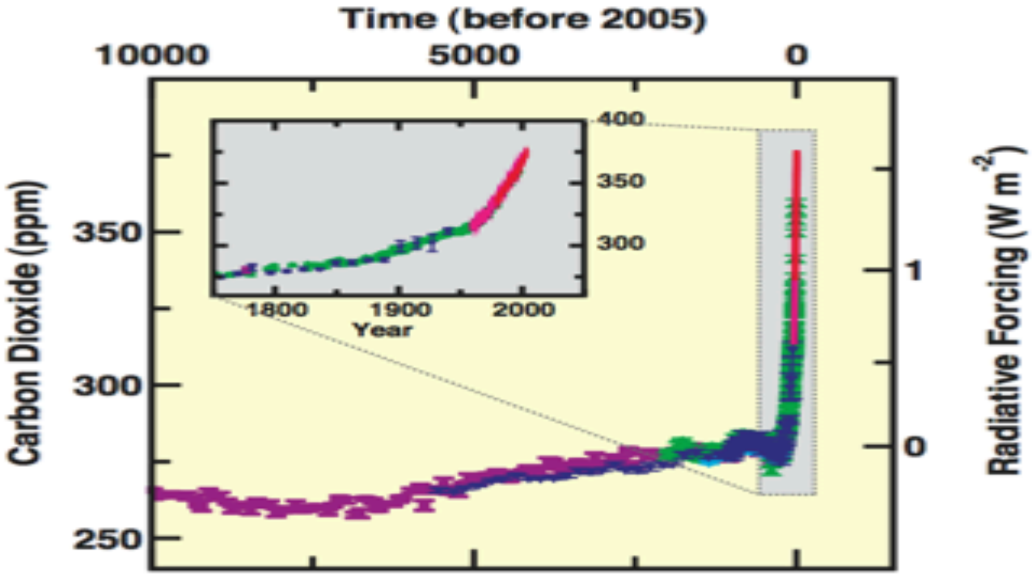

Figure 2.1 *Historic Carbon Dioxide Concentrations in the Earths' Atmosphere 10 Thousand Years Before the Year 2005 (ppm)*
Source: IPCC Fourth Assessment Report.

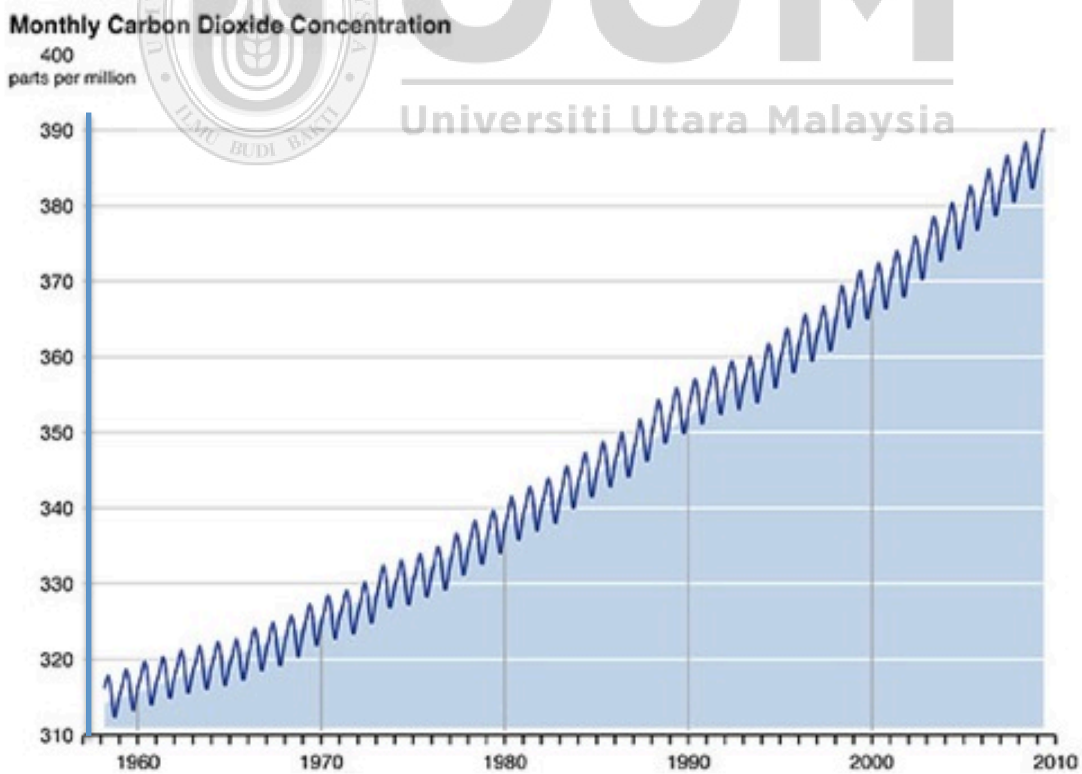

Figure 2.2 *Monthly Global Atmospheric Carbon Dioxide Concentration, 1955-2010 (ppm)*

Source: Earth System Research Laboratory, National Oceanic and Atmospheric Administration, U.S.

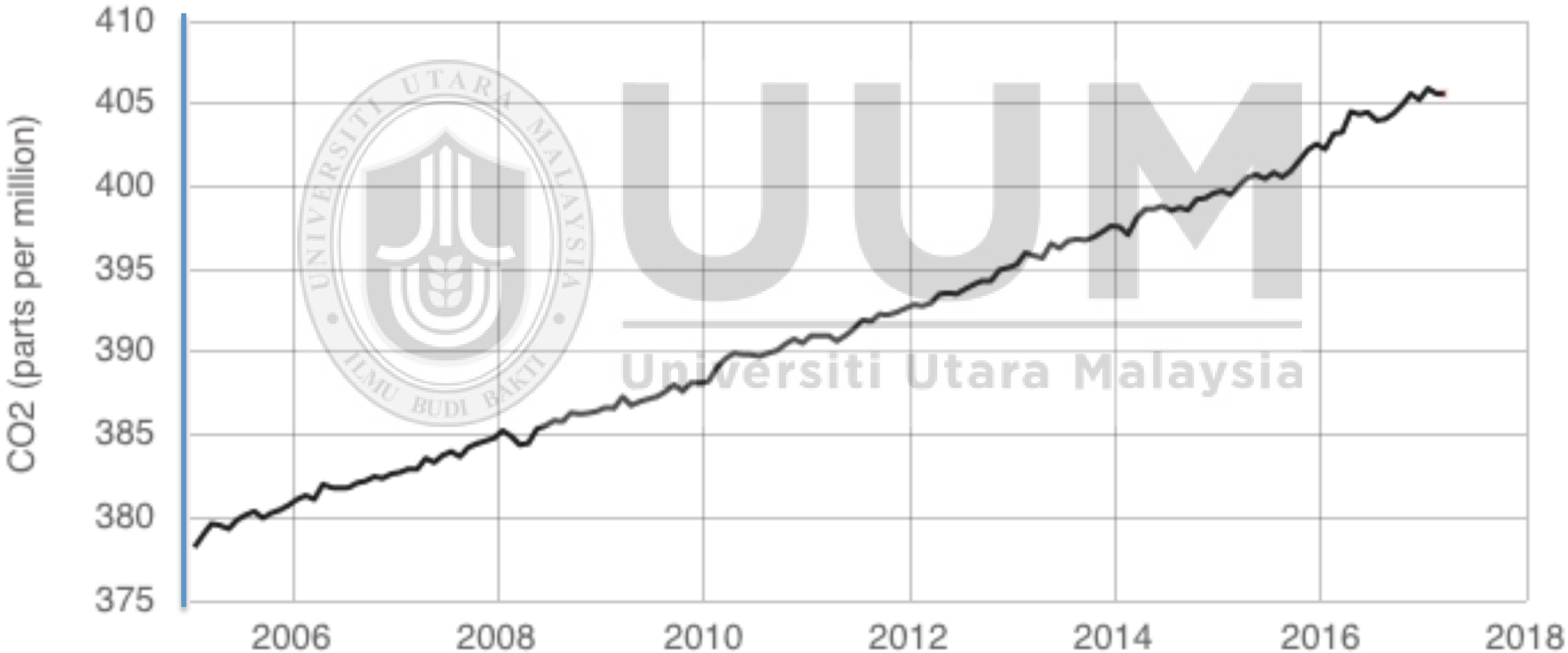

Figure 2.3 *Global Atmospheric Carbon Dioxide, 2005-2016 (ppm)*
Source: National Atmospheric and Oceanic Administration, U.S.

There is definitely a natural carbon dioxide progression that the earth undergoes that has been proven. At the same time, anthropogenic activities such as deforestation, urbanization, industry, transport, and automobile are also outpacing this natural rhythm. We are at a level of carbon dioxide concentration that is meant for many tenths of thousands of years in the future to reach but this value was only attained in a mere 50 years due to unsustainable urbanizations. Thus, to slow down this accelerated progression, more sustainable practices should be adopted by countries such as safeguarding our forest and trees, and controlled industrial progression, planned urbanization and perhaps careful use of petroleum based fuels.

On a side note, it should be stated here that all the carbon dioxide molecules deposited into the atmosphere is in the form of gas (ESRL). This is due to the properties of carbon dioxide not having a liquid state below a 5.1 standard atmosphere value.

It has been established in the previous paragraph that we are on an upswing in carbon dioxide concentration in the atmosphere. In addition we have also shown with the hockey stick representation that a considerable amount of carbon dioxide has been deposited in the atmosphere that is outside of the natural cycle, stemming from the sudden outburst of anthropogenic industrial activity in the last two centuries. Adding these two ‘positive’ contributions in terms of volume of carbon dioxide, the earth is presently experiencing a sort of double effect of escalating carbon dioxide. This connotes that in the future, the aggregate carbon dioxide in the earth’s atmosphere would be a large, if mitigation is not carried out and countries and industries proceed at the present rate. Hence, carbon dioxide in our atmosphere has already had its increase and is projected to increase further with its affects will only come sooner and more unembellished.

A similar situation can also be seen for nitrous oxide, another detrimental greenhouse gas. An upward trend was recorded similar to carbon dioxide. The only difference being that its ascent is less exponential.

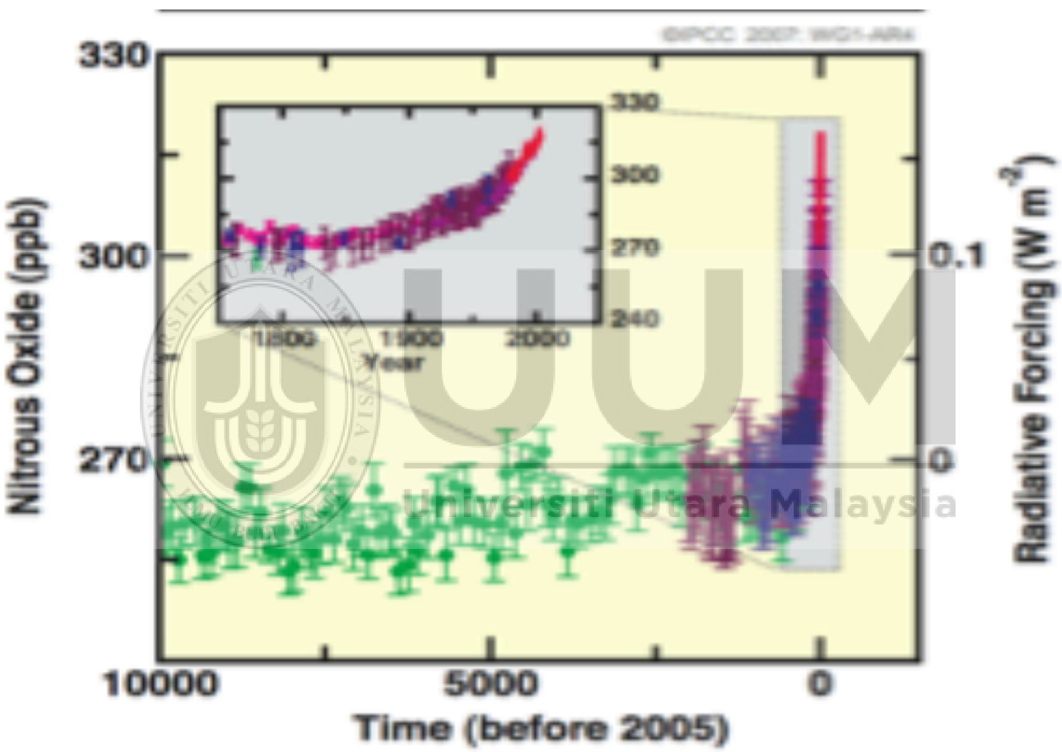

Figure 2.4 *Global Average Atmospheric Nitrous Oxide For the Past 10 Thousand Years, (ppm)*
Source IPCC Fourth Assessment Report

The rise in these greenhouse gases can be attributed to the rapid increase in farming and other anthropogenic activities such as deforestation, transportation and automobiles, and urbanization (Vitousek et al., 1997). According to Vitousek and his team, up to half of the worlds' surface land is used for anthropogenic practices such as farming, industry, and housing. In other words, 50% of the planets' acreage is used solely for the purpose of mankind's' utility highlighting our unsustainable circumstance. With this, the greenhouse gasses released by these activities have been building up. What is more is that these levels of carbon dioxide released by these areas are more than any natural terrestrial sources. These high levels add up causing the exponential increase in greenhouse gasses seen today.

This increase is seen as a problem because these values are outside of what is considered the norm. These values are considerably higher than what is considered the normal range in the past 650,000 years (IPCC, 2007). Since these are new territories that our global society is facing, studies should be done on what effects these unnatural circumstances would bring and how these changing times will affect agriculture and food production. With proper and early analysis, early steps can be taken to mitigate these effects to reduce and reverse the change of climate that appears to not be stoppable anytime soon.

In relation to this analysis, the unnatural rise in green house gasses as shown may have implications of rice output within a country. As will be shown in a later portion of this chapter, excess carbon dioxide in the atmosphere has varying effects on crops, that is through a fertilization effect and climate change. It is thus important to determine what these increases in green house gasses have on rice production in the country and how it will affect the nations policies on achieving a higher sustainability in rice production.

2.2.2 Albedo Versus Carbon Dioxide

With increases in populations, comes the need to support it. The advancement of agriculture techniques and technology can only go so far as to increase output to accommodate the increasing demand. To alleviate this, more forest and virgin jungle have been cleared to make way for agriculture activity. To date, a large number of 46 to 58 thousand square miles of virgin forest had been cleared every year for the development of agriculture and urbanization (World Wildlife Fund). This unsustainable rate has caused ramifications with the amplitude of climate change similar to that caused by other anthropogenic carbon dioxide increase (Chase, 2007).

There have been certain factions of researchers and politicians who think that albedo can counteract the effects of carbon dioxide concentration increase and its ultimate effects on changing our climate. In definition, albedo is the ratio of irradiance reflected compared to the irradiance absorbed by a surface (Coakley, 2003). According to Matthews, a researcher in the field of climate in his paper titled "Natural and Anthropogenic Climate Change: Incorporating Historical Land Cover Change, Vegetation Dynamics and the Global Carbon Cycle" found in his models that there is indeed albedo affects that results in global cooling affects. An overall cooling of -0.06c to -0.22c was estimated from the cutting of trees and conversion of forest and jungle land to crop and housing land. The increase of albedo, where albedo is measured on a scale between zero and one, was caused by the lighter shade of colour of crops lands compared to dense jungle (Barnes, 2010).

Although surface albedo is able to reflect some radiation back away from the earth, it is not able to counter the effect brought on by increase greenhouse gasses in the atmosphere. According to Akbari, Matthews and Seto (2012), the albedo effects are significantly less than the warming effects of anthropogenic greenhouse gasses. According to models, albedo cooling from the lightening of the surface of the environment is not as impactful as compared to polluting activities such as cutting down trees for farming, industry and housing (Akbari et al., 2012). Since this study analysed data for the past 300 years, the significance of land cover change and its consequences on albedo is only significant during the first 200 years of those 300. From the 300 years of data on land cover change and climate, it was found that only the years leading up to the industrial revolution had the change in land cover cause significant climate variability in the form of albedo. This leads to the conclusion that anthropogenic activities have a greater effect on climate and land cover change is of second importance. Akbari et al. also concluded in saying that the warming and cooling at the turn of the century is well simulated by the collective effects of anthropogenic activities whereas climate change before the twentieth century is a mixture of both. Akbari et al., goes on to say that the amount of carbon dioxide released into the air by the falling and the burning of the forest trees, transportation, urbanization and industrialization, posed a greater threat to the warming of the earth than the albedo effect of doing so. Thus, land cover change on a whole is deemed detrimental to the environment. This only cements the fact that climate change of a warming kind is indeed under way. Its effects on our way of life would require a deeper analysis to assist in the preparation of the inevitable.

In relation to this dissertation, with other studies suggesting that surface albedo wil not counteract the effects of greenhouse gasses, it is important that temperature data is incorporated when studying crop output. This will allow estimations on how increase greenhouse gasses will affect the governments' policies to achieve a higher rice output sufficiency in the future.

2.2.3 Changing and Rising Global Temperature

The abrupt increase in anthropogenic caused greenhouse gas has in turn instigated a change in the global average temperature of the earth (IPCC, 2007; Kang, 2010). Surface, ocean and atmospheric temperature have all seen an increase in the past two decades according to the 2007 IPCC report. In the past two decades, eleven of the 12 warmest years have been recorded since the 1800's. . Overall, the earth temperature has increased by about 0.76°C in the past 50 years. What this shows is that our "hot" days are more frequent and this trend can be traced to the start of the industrial revolution. In other words, warmer days are imminent and already present. Moreover, based on data from the Fourth Assessment Report, radiative forcing from the higher concentration of greenhouse gasses is +2.30 Wm^{-2}. This is a worrying number due to the radiative forcing being the largest that world has seen in the past 10, 000 years (IPCC, 2007). Radiative forcing is the capacity of a contaminant or additional forcing agents to upsets the energy balance and therefore resulting in the change of the climate (co2offsetresearch.org). When more solar radiation is received than reflected back into space, a high radiative force can be said to exist.

Besides greenhouse gasses, other contaminants called aerosols have the opposite effects compared to its counter parts. Aerosols such as sulphate, organic carbon, black carbon nitrate, and dust have also been actively deposited in to the planet's atmosphere. The rates at which these gases are dispersed in to the air have also been snowballing since the dawn of the industrial revolution of the 1800's. Due to this, there has been some perception that the intense deposition of the contaminants should help alleviate the effects of global warming to some extent. Although plausible, the opposite is true as the cooling effects of aerosols are significantly much lower than the radiative forcing from greenhouse gasses. From the Fourth Assessment Report, aerosols deposited through anthropogenic activities only contribute about -0.5 Wm^{-2} of a cooling affect. Radiative forcing of greenhouse gasses currently in the atmosphere on the other hand is +2.3 Wm^{-2}. Comparing these two values, it can be seen that the radiateve forcing of green house gasses is more than the forcing contributed by the aerosols. In other words, the cooling effect of aerosols is insufficient to counter the warming effect of green house gasses. In other words, the world and its people will most definitely feel the full brunt of its activities in the years to come.

In the arena of climate change debate, there stand two distinct groups presently. One side strongly believes that the recent increase in temperature is just the earth following a natural 1000-year cycle of temperature fluctuations. One notable researcher who believed this was the case was researcher Dr. Craig Loehle and his paper titled "Correction to: A

2000-year Global Temperature Reconstruction Based on Non-Tree Ring Proxies", published in 2008. The paper talked about how the classical hockey shaped graph depicting the change of temperature over the years was flawed as it used tree ring data to show the temperature change. Loehle proved this was inconsistent and used other methods to peer into earth's climatic past. Among the methods used were borehole temperature measurements, pollen remains, oxygen isotopes, diatoms and reconstructed sea surface temperature. What Loehle concluded was that temperatures were likely to not rise anymore and that previous temperatures of the past 200 years were relatively constant. Although Loehle did find an upward trend starting from around the 1800's, he attributed it to the natural fluctuation of the planets' temperature. The 1800's just merely stood at the turning point of the natural temperature cycle and thus justified the recent warming of temperature. Although Loehle provided some accurate representation of the change in our earth's temperature, one thing that was not take into account was the historical natural carbon dioxide concentration in the past as compared to today. According to Petit, Jouzel, Raynaud, Barkov, Barnola, Basile, and Delmotte (1999), the carbon dioxide concentration had been following a natural fluctuating cycle every 100,000 to 150,000 years and this can be attributed to the natural fluctuating temperature found by Loehle. But in the past 50 years, the concentration of carbon dioxide has been at its highest in the past 650,000 years. This can be seen in the graph plot below. Besides, there have been studies that have shown that carbon dioxide does not determine temperature but the reverse is true that carbon dioxide is determined by temperature (Mytty, 2013).

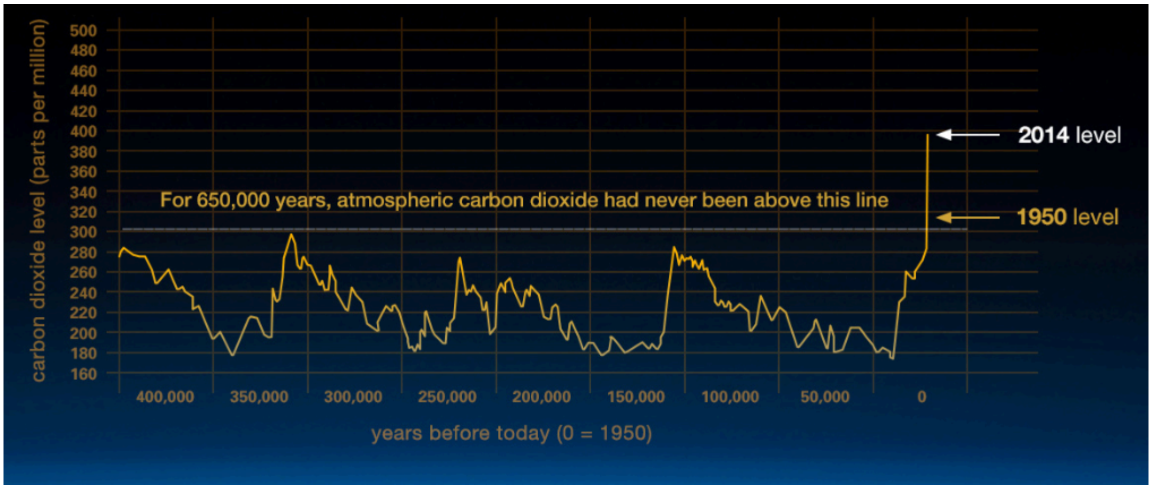

Figure 2.5 *Historical Global Atmospheric Carbon Dioxide Levels for the past 400, 000 Years, (ppm)*
Source: Vostok ice core data/J.R. Petit et al.; NOAA Mauna Loa CO2 record.

As it can be seen, the current situation is considerably above the normal carbon dioxide fluctuation cycle. Comparing this to Loehle's representation of temperature variation, greenhouse gases such as carbon dioxide have an immense influence on global average temperature and this was mutually echoed by researcher Svante Arrhenius. Moreover natural causes of temperature rise due to natural carbon cycles cannot be accepted without taking into account the recent deposition of carbon dioxide by human activities, especially in the past 200 years which was not present in the past.

From Loehle's representation of the planets' past temperatures and correspondingly taking into consideration the recent exponential increase of anthropogenic activities, we can say that climate change is happening. This is something of great concern that requires deep analysis to prepare society for the glaring changes that are approaching. Since our earth's climate will vary greatly in the coming years, the world's food production may vary immensely as well. Climate change is happening and future food output forecast should be carried out to better prepare the world.

In relation to this study, the preceding discussions showed that the rise in temperature was shown to be man-made. Due to this, it is important that a temperature variable be included in determining future crop output. Temperature has varying affects on crops, both detrimental and beneficial depending on the area. These effects in turn would affect food output and food availability. Predicting the affects of temperature on crop output will be important, as it would enable better understanding on how the changing environments would affect current agricultural policies.

2.3 The effects of climate, its extremes and abnormities on the production of food

2.3.1 Carbon Dioxide, Temperature rise and the Effects on Crop Yield

The exponential growth of the worlds' population will bring with it intensifying anthropogenic activities (Zhou, 2009). From the previous sections and data from the IPCC, increasing anthropogenic activities will eventually lead to growing deposition of carbon dioxide in the earth's atmosphere. This has been agreed by many researchers and activist alike including world leaders. Although we are already experiencing the effects of our unchecked anthropogenic activities, it has only been recently that countries and governments are starting to incorporate these effects when dealing with policies.

The increase in temperature across the many varied latitudes of the world have convincing effects on the biomes across the globe (Morison et. Lawlor, 1999). Upon reviewing multiple experiments on the effects of increasing atmospheric and land temperature on the productivity of crops, varied results have been found. The main cause for the wide-range of results is the initial latitude where the experiment was conducted. Countries situated in different latitudes will experience different natural climates. In other words, the type of climate plays a very important role in determining whether temperature increase is beneficial or the contrary. This difference is due to different climates having different growing season. A study conducted by Rustad and her colleagues titled "A Meta-analysis of Soil Respiration, Net Nitrogen Mineralization, and Above Ground Plant Growth to Experimental Ecosystem Warming" showed that under experimental environments, various incremental increases in temperature showed predictable growth in soil respiration, nitrogen mineralization, and aboveground plant growth. The outcome of increased soil respiration and nitrogen mineralization was due to the warm temperatures promoting more intense microbial activity in the soil. The increase in microbial activity such as litter decomposition and the conversion of organic matter into nitrogen has resulted in the deposition of more minerals and nutrients that promote plant productivity. It is for this reason that an increase in aboveground plant growth and yield was observed in the final result. Since the study was done using data that was taken from 32 different ecosystem experiments around the world, the team was able to compare the result between different categories of climate from tundra climates to tropical environments. Compiling all the data sets, increased surface plant mass were more prevalent in testing sites situated in colder latitudes, particularly in the tundra countries whereby the climate consisted of low precipitation. Overall there was an average increase of 19 percent in the 20 sites that provided data. This was different in developing countries. According to an article by Cnythia Rosenzweig and Martin L. Parry (1994), titled “Potential Impact of Climate Change on World Food Supply”, there would be minimal to moderate negative impact on crop cultivation in developing countries as compared to developed ones. This was based on projections from the International Panel on Climate Change. Developed countries saw positive increase in crop output as they had better access to fertilization, better agriculture technology and also that most developed countries were situated in colder latitudes thus prolonging growing seasons with increased temperatures. The article also states that since most of the developing countries were situated in warmer climates, any increase to temperature would cause unsuitable environments for crop cultivation. Cereal prices thus faced potential increase in developing countries, as more imports are needed. Besides increasing prices, increased risk of malnutrition and hunger were also a potential outcome in these countries due to the adverse effects of climate change.

With that in mind, since climate temperature has been projected to rise and to cause adverse effects in countries situated in the tropics, it would be important to estimate these effects. It would be useful to analyse how temperature affects rice output in Malaysia and how these effects will influence the governments’ efforts in increasing rise sufficiency. With better understanding of how different temperature affects rice output, the country can better prepare itself in regulating rice supply as well as rice prices.

2.4 The Shift of Food Prices and its Relation to Climate Change

This section of the chapter will focus towards studies that were carried out on the relationship on food commodity prices and climate change. This will cover historical aspects and highlighting spikes and anomalies that were presented about the progression of food prices.

During the 2008, the world experienced a rice price crisis as the price of rice surged considerably during the year. According to The Food and Agriculture Policy Research Institute (FAPRI), the world saw a spike in rice mainly due to various rice exporting countries restricting exports due bad market predictions. The main reason for these trade restrictions was largely due to governments fearing the surge of other food and commodity prices would eventually affect rice (Dawe and Slayton, 2010). Rising oil prices in 2004, biofuel tariffs, weak US dollar, and weather anomalies caused maize and other cereals to rise in price. This lead to concern in rice producing and exporting countries, prompting governments to restrict rice export in an effort to protect themselves (Dorosh, Paul A.; Rashid, Shahidur, IFPRI 2012). As a substantial amount of rice was in stockpiles instead of being exported, prices increased further. This rise in price nearly affected Malaysia as the country had to considerably consume its' own rice stockpile. After the crisis, the Malaysian government decided to take measured in increasing the country's level of self sufficiency in rice. The next paragraph will discuss the projections of how climate change will affect crop output and how this will relate to the Malaysian Governments efforts in increasing self –sufficiency.

A few notable studies have found relatively significant increase in food prices in conjunction with the predicted doubling of carbon dioxide in the next 50 years by the IPCC. Fischer, Shah, and van Velthuizen (2002), found that using the HadCM3 general circulation model developed by the Hadley Centre for Climate Prediction and Research, cereal price were slated to increase by a hearty value of 2 percent to 20 percent. The HadCM3 being a model where the atmospheric and oceanic components of the planet are divided into fixed sized grids different only between the two types, one of oceanic component and once of atmospheric component. By apportioning set areas of the planet, the effects on crop output from weather and climate responses from given emission scenarios by the International Panel on Climate Change in specific grids could be projected. Looking further; the same conclusions were also reached using the Basic Linked System. Using the said referencing model, increases in prices were similarly projected for the next half of the century. For instance, using the A2 emission scenario by the IPCC, food prices were anticipated to grow to an overwhelming 270 percent from the reference prices of 1990 (Fischer et. al, 2002). In fact, almost all emission scenarios using the BLS modelling scheme showed expansion in world cereal prices. The only scenario where by decrease in prices were observed was the B2 emission scenario. The main contributor of the decrease in prices was attributed to the predicted slow growth of the world's population in the scenario. What really strikes the chord is the fact that the increase in prices can be seen in all crop outputs and not only cereal alone.

Thus, in relation to this analysis, climate projections have predicted that crop output may see a decline in growth over the coming decades. This would hamper the efforts of the

Malaysian government in ensuring a higher self-sufficiency level for rice in the country. Due to this, it will be useful in analysing how these factors affect rice output over time so as to better prepare the country.

2.4.1 Paddy as Malaysia's Most Important Food Crop

Rice is one of Malaysia's staple foods with current local production being insufficient to satisfy local demand (Vegedasalam, 2013). Although, the amount of rice consumed per capita has dropped over the years, from 109 kg in 1980 to 92 kg in 2009, total demand due to population has been increasing. Rice consumption in the country is expected to increase from 2.75 million tons in 2016 to 2.8 million tonnes in 2017 (USDA). According to Vegedasalam, this constant rise can be attributed to the country's growing population.

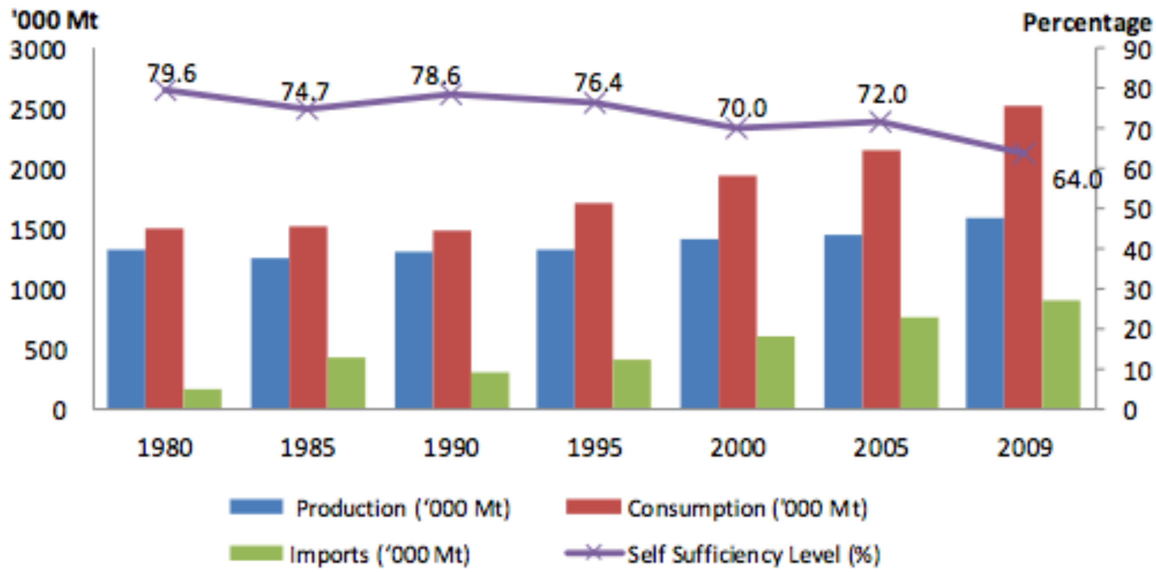

Figure 2.6 *Consumption, Paddy Production, Self-sufficiency Levels, and Rice Imports in Malaysia, 1980-2009*
Source: Vengedasalam, Deviga. "Rice research versus rice imports in Malaysia: A dynamic spatial equilibrium model." (2013).

From Figure 2.5, it can be observed that current production levels are insufficient to meet the amount of rice demanded by the public as the growth of rice consumption out paced local production. To meet this insufficiency in rice supply within the country, BERNAS was created to manage rice imports of the country (Vegedasalam, 2013). Most of the rice imported in the country comes from neighbouring countries such as Vietnam, Thailand, Pakistan, China, and India. Vietnam, Thailand, and Pakistan make up the three main exporters of rice to Malaysia, with 64%, 22%, and 13% respectively. As Malaysia is heavily reliant on rice imports, any shortages or price hikes in the global rice market would severely affect the nation. For example, the rice crisis of 2008 prompted the Malaysian government to implement policies to increase self-sufficiency levels. Under the 10th Malaysia Plan, rice self-sufficiency levels were targeted at 70%. This target was to be met with a series of subsidies and incentives for local farmers. Besides, FAPRI also estimates that in the next decade, total rice consumption is expected to outpace rice production growth.

In summary, rice is an important commodity in Malaysia as it makes up a large portion of the citizens' diet. With a yearly growth in demand stemming from a growing population, rice demand outweighs rice supply. Due to this, Malaysia is a net importer of rice. In an attempt to prevent the country from being affected by food crisis such as the 2008 rice crisis, the government has implemented policies to increase self-sufficiency to 70%.

2.5 Vector Error Correction Model

This section will be allocated for the review of the use of the Vector Error Correction model (VECM) in the climate change studies and economic analysis.

In the study of the mechanics of food prices, the VECM approach has been a widely used method for time series analysis. One pair of researchers who utilized the model were Ján Pokrivčák and Miroslava Rajčániová (2011) in the paper titled "The impact of biofuel policies on food prices in the European Union". The researches decided to go with the VECM route to study the presence of long term relationships between the ramping up of biofuel production by certain national governments and the prices of food. This study used the VECM model. Besides these two researchers, Serra, Zilberman, Gil, and Goodwin (2011) also employed the VECM method in their paper titled "Nonlinearities in the U.S corn-ethanol-oil-gasoline price system". Using 20 years of monthly series data of corn, ethanol and petroleum, the research found there existed a long-term relationship between the production of biofuel and the price of agriculture produce sold as food. Another analysis done on food prices in relation to the effects of the varying of other food prices correspondingly used the versatile VECM methodology. Titled "transmission of world food price change to markets in Sub-Saharan Africa" by Nicholas Minot (2010) , the paper employed the VECM methodology to study the consequences of the 2007-2008 food calamity which observed a stark increase in world food prices of important food commodities on local prices of the same commodity in sub-Saharan Africa. Thus, it is evident that the VECM methodology is broadly used in the study of food prices with time series data. The method provides insight into both long-run and short run effects. Besides, being able to easily employ more than one variable for analysis means that the method enables amble room for complicated models.

CHAPTER THREE

METHODOLOGY

This chapter explains the research methodology used in this study. The chapter is divided into three subsections, namely the data, area of study, and the methodology of analysis. The first subsection will define the data used in the study namely its source, time series data set as well as to provide the justification its usage. The next subsection will discuss the area of study and a thorough definition of the constraint on the total area of the study. The last subsection will discuss the model that will be utilized in this study and the reasoning behind it. The model that will be employed is either the Vector Error Correction Model (VECM) or a Vector Autoregressive model (VAR).

The main reason for the implementation of the VEC model or a VAR model is due to the characteristics of the data. This analysis will utilize multivariate time series data. When dealing with multivariate time series analysis, one of two models can be used (Hamilton, 1994). The two models are Vector Autoregressive models and the other being Vector Error Correction Models. To decide which model will be utilized, the stationarity of the data would first be required to be tested. If the unit roots test discovered that, the series is not stationary, then a Vector Error Correction Model will be needed. If no unit roots are discovered, a VAR model will be implemented.

3.1 Theoretical Framework

According to the Food and Agriculture Organization, food availability is mostly emphasised when dealing with measurements of food security. Due to this, the theoretical framework depicted in Figure 3.1 shows factors that affect food production. The dependent variable will be local rice production in Malaysia. Independent variables on the other hand will include carbon dioxide emissions, precipitation levels, amount of available irrigated paddy land, amount of rice imports to the country, and average crude oil prices

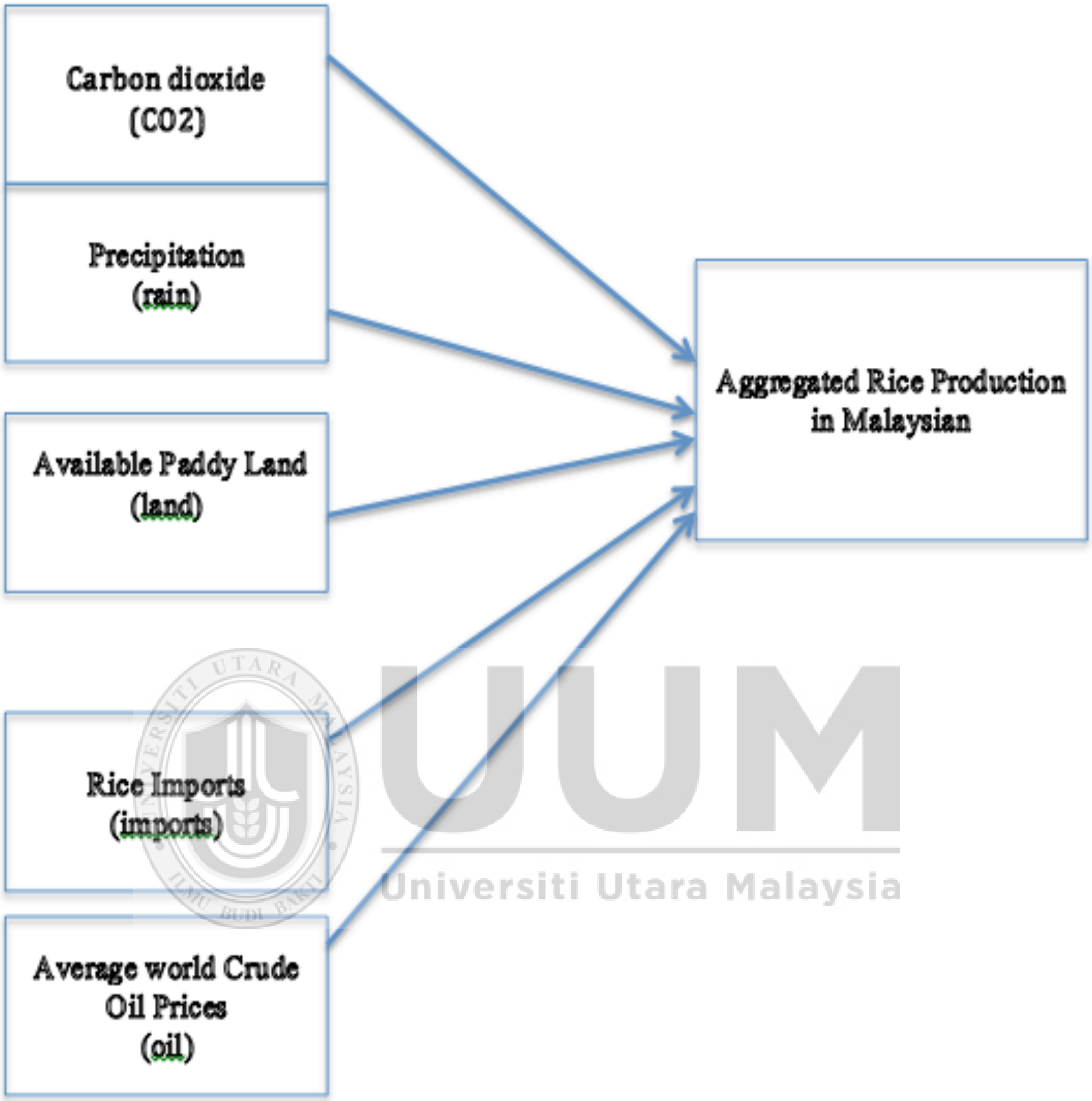

Figure 3.1

Determinants of Rice Production in Malaysia

3.1.1 Area of Study

From the literature review, it was reported that of the effects of climate change on the agriculture sector would mostly be focused on countries situated in the tropics as compared to countries situated in higher latitude or temperate countries as there are colder countries. These countries benefit from longer summers and more suitable temperatures for crop cultivation. Tropical countries on the other hand were predicted to experience temperatures that were too high for crop cultivation, resulting in a negative effect in total output. Besides, most developing countries reside in lower latitudes, which worsen the problem as these countries were less equipped to deal with food scarcity problems as compared to developed countries. As Malaysia is situated in the tropics and is still considered a developing country, the effects of climate change on crop cultivation may exist. Therefore, an analysis should be carried out in Malaysia to detect and quantify the effects of the change in temperature on crop output.

Malaysia currently has approximately 30.7 million people as of the end of 2016. Situated at a latitude of 4.2105° N, it experiences tropical weather year round. Having 16 dams in total, the Malaysian irrigation department has the capacity to deliver 460 million m^3 of water. The full conceivable capacity for irrigation is estimated to amount to a value of 413700 ha (Food and Agriculture Organization of the United Nations, 2012). The area of study will comprise of 33 million ha, including both peninsular Malaysia and the states of Sabah and Sarawak making up a total of 13 states. Out of the 33 million ha of land, 21% is allocated and used for farming and other agriculture activities.

3.1.2 Model Specification

Based on the Food and Agriculture Organization of the United Nations, food security can be broken down in to four distinct sections. These sections are utilization of food, stability of food, access to food and the availability of food. Among the four, food availability is considered most useful in measuring food security at a country level (Jones et. al 2013). One way of measuring food availability in country is through a country's total food production and is cited as the most important marker of a country's food security by the FAO.

Rice = f (CO2, rain, land, imports, oil)

$$\Delta lnrice = \beta_0 + \beta_1 \Delta lnco2_{t-1} + \beta_2 \Delta lnrain_{t-1} + \beta_3 \Delta lnland_{t-1} + \beta_4 \Delta lnimports_{t-1} + \beta_5 \Delta lnoil_{t-1} + \beta_6 ECT_{t-1} + \varepsilon_t \text{ --- } (1)$$

Where:

Rice = total local rice production (tonnes)

CO2 = concentration of carbon dioxide the atmosphere (parts per million, ppm)

Rain = precipitation (millimetres)

Land = available paddy land (% of total land)

Imports = total rice imports in Malaysia (tonnes)

Oil = average world crude oil prices (USD per barrel)

ECT= Error Correction Term

ε_t = error term

t = time period

β_0 = intercept

$\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6$ = coefficient for the explanatory variables

Due to the nature of the data multivariate and time series, one of two model can be used, that is the Vector Autoregressive model or the Vector Error Correction Term. To determine which of the two models to be used, a unit root test will be required. This is followed by the co-integration test, and lastly the Vector Auto Regression model or the Vector Error Correction model will be used. For the unit root test, the Augmented Dickey-Fuller test will be utilized. Next the Johansen co-integration test will be applied on the data to detect co-integration problems. Lastly, the appropriate vector auto-regression model will be used to determine the short-run and long-run effect of the determinants above on rice production in Malaysia. A more in depth review of methodology will be discussed in Section 3.3.

3.2 Data

Climate data such as carbon dioxide concentration in the atmosphere and precipitation will be included in the model. The series sets were chosen to provide a somewhat full coverage of all the fluctuations and variations that were predicted in the General Circulation Models. Below, the definition and elaboration on all the variables that will be incorporated in the model is provided.

3.2.1 Climate Data API

Most of the climate data focusing on Malaysia used in this study were obtained from Climate Data API from the World Bank. The Application Program Interface (API) provided by the World Bank enables developers to access, use and incorporate data sets and series into their applications and websites. The API provides real time data sets giving developers up to date data and ultimately accurate results.

3.2.2 Time Frame of Study

From climate models such as the global circulation models, data proxies such as tree rings and ice cores and regression approximations, highly accurate historical data can be obtained as far back as 300 years (that is of relevant to the study). Although having as many observations would be the ideal situation, this is not the case as other data proved to be harder to obtain. As we are focusing on defining the effects of climate change on rice production, the availability of local rice output went back as far as 1970only. For this reason alone, we will be using the API data series starting year of 1970. The data series will go until the year 2013 as that is the latest data point that is available. Thus, the study will utilize data from year 1970 to the year 2013. In total there will 43 data points for the model.

3.2.3 Precipitation

As it was discussed in Chapter 2, one more the main effects of rising concentrations of carbon dioxide in the atmosphere is increased rainfall (IPCC, 2013). This is due to warmer air being able to carry more water vapour and more water vapour in the air leads to more precipitation. Due to this projected increase in rainfall, it will be useful to analyse how different rates of rainfall affects agriculture in within the country. Comparisons of the effects of increase rain on crops can be made with increase temperature. This will allow to confirm on weather increase rainfall will be able to offset the negative affects of increase temperatures (Saseendran, 2000).

Precipitation data is taken from the year 1970 to the year 2013. By using the climate change data API from the World Bank, our request for precipitation data on Malaysia were met. The data consist of precipitation data taken from weather stations over the entire land expense of the country of Malaysia. The data is then averaged out to obtain the average volume of rainfall in a given year. As there are no know Stevenson Screens situated in granary areas, precipitation data for these areas were unavailable.

3.2.4 Carbon Dioxide emission

We will measure the deposition of carbon dioxide in to the atmosphere by Malaysia in terms of total concentration; i.e. the carbon dioxide from solid fuel consumption refers mainly to the use of coal and other fossil fuels as an energy source (Oak Ridge National Laboratory).

The data is obtained from the Carbon Dioxide Analysis Centre, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, and United States. This will eliminate a time-based factor in the variable while still working with time series data. In other words, we are able to quantify what amount of carbon dioxide that is deposited in terms of concentration. The data values are measured in tonnes.

The data points for Malaysia are acquired by the Carbon Dioxide Information Analysis Centre whereby the Centre calculates the yearly carbon dioxide emissions from anthropogenic activities through the use of fossil fuel consumption of the country in question. The fossil fuel consumption data is obtained from the United Nations Statistics Division's World Energy Data Set. What is appealing about the use of this data set is the accuracy of the series, where by the data is accurate within 10%. This is the result of consistent and periodical reiteration and evaluations carried out by the institution. The institution re-evaluates data sets later than the year 1949. Important new findings and the publication of new data sets to the public are used to recalculate the values in the data series. This variable will use the data time series of Malaysia beginning from the year 1970.

The use of carbon dioxide emission is required in the study as it is the number one green house gas affecting the worlds' climate (IPCC, 2013). From the literature review in the previous chapter, it was shown there some crops experience the fertilization effects of increased carbon dioxide (Ainsworth, 2008). As a review, a fertilization effect entails the increase of above ground crop biomass and elevated levels of total produce output. Carbon dioxide being one of the key nutrients needed for plant growth and general wellbeing, or this reason, we thus need to evaluate the influence of the effects of carbon dioxide fertilization. If an effect and relationship is found, it will be interesting to observe whether it is a positive of negative relationship and thus being able to confirm if developing countries situated in the tropics are truly in the danger zone of being negatively impacted by the change in climate in the following years.

3.2.5 World petroleum prices

This analysis will also utilize the world petroleum price data set. This will incorporate the petroleum price instance of price fluctuations. The analysis will utilize the numbered values of world crude oil price in the form of average spot data. The nominal year that will be employed is the year 2010. The use of petroleum prices is to encompass the effect of transportation and increased agriculture cost associated from increased world crude oil prices that will be channelled in to food prices indefinitely.

The effect of crude oil prices can be seen in the paper by Esmaeili and Shokoohi (2011), titled “Assessing the effects of oil prices on world food prices: Application of principal component analysis”. According to author, there existed a relationship between the current price of crude oil and subsequently the cost of consumer petroleum with the food production cost and lastly food prices for consumers. According to Esmaeili, increase crude oil prices would increase the cost of transportation for farmers and traders. To cover the cost of the increase in petroleum used for transportation, the price of crops sold is also increased to cover the cost of increase petroleum prices. Since there exist an oil and food price relationship, it will be useful for comparison purposes to assess the disparities between the effects of climate change versus oil prices, observing which of the two would be of greater impact to consumers. This analysis will employ the data set of world crude oil prices in the form of Brent crude from the year 1970 to the year 2013.

3.2.6 Area of land apportioned to paddy farming

Lastly, this analysis will also incorporate the use of the area of land allotted for paddy plantation. The usage of the data set will serve to accommodate some of the supply factors associated with the fluctuations of food prices. As we know increased agriculture land should in turn increase total output of crops produced and consequently change the market prices. Besides the change in output, the inclusion of the proportion of total agriculture land to total land mass of Malaysia will also address the problem of changing land mass due to the effects of climate change. Increasing sea levels coupled by abnormal non-seasonal floods has caused desolation of fertile croplands in numerous countries.

Based on a study conducted by Wassmann, Hien, Hoanh and Tuong (2004). titled "Sea Level Rise Affecting The Vietnamese Mekong Delta: Water Elevation in The Flood Season and The Implication on Rice Production", the notion of decaying agricultural surface area did indeed showed an important effect on food production, albeit being negative in nature. Through extensive studies and simulations using the hydraulic model, rising global sea levels caused substantial increases in the severity of flooding season around the Vietnamese Mekong delta. The total area of fertile agricultural land (in the terms of contour lines of water levels) saw a decrease of around 14cm to 35cm around the Mekong delta. This increase in water surface area of the delta severely decreased the total available land for farmers to hold their agriculture tenure (Wassmann, 2004). Besides, sea level rise has also caused salt-water intrusion, jeopardizing agriculture (Trang, 2012). The data is obtained from the Department of Statistic and depicts the area of land used for paddy farming in the country. The data is measured in the form of total paddy land to total land.

3.2.7 Total Local Paddy Output.

As it was discussed in the earlier chapters, rice is a fundamental crop in Malaysia as it is the staple food of most households. Due to its high demand, the country is currently in a trade deficit whereby imports exceeded export. In other words, local production is insufficient to meet local demand. Since the government has incorporated policies to increase self-sufficiency levels, it is important to see how climate change affects total rice output. Besides, according to the Food and Agriculture Organization, food availability is often the main determinant of food security for countries and total output of crops is a good measurement of food availability.

The data is adapted from the Department of Statistic Malaysia. Prior to the year 1991, the data were acquired through crop cutting test on wet paddy crop planted during the main season. After the year 1991, the data were obtained from the Department of Agriculture of Malaysia. Using surveys on paddy yield and paddy cultivation activities, the Department of Agriculture constructs time series data sets on paddy yield. The total paddy output in Malaysia refers to the aggregate of crop output reported during the main season and the off-season. Data is measured in metric tonnes.

3.2.8 Total rice Imports to Malaysia

Besides the locally produced rice, Malaysia imports about 40 percent of its supply of rice. This is due to local output being insufficient in meeting demand. Thus, rice imports also make up the total supply of rice to households in Malaysia. According to a thesis written by Deviga Vengedasalam (2013), a removal of all trade barriers could potentially cause local rice output to drop by 10 percent. This was due to increase in cheaper imported rice, resulting in local farmers being unable to compete. Therefore it is important that rice imports be also incorporated into the model. This will enable comparisons between the effect of trade policies and climate factors. Trade policies can be manipulated to counter the effects of climate factors.

The data was obtained from the Department of Statistic of Malaysia and is measured in metric tones. The department employed a general system of recording the total value of imports of rice in to the country. Within the system, the statistical frontier used was the national boundary of the country. All rice products being imported into the country were documented, with or without clearance. The goods recorded encompass goods that entered bonded warehouses, Free Commercial Zones, and Free Zones, Free Industrial Zones.

3.3 Analysis Method

3.3.1 Unit Root Test

The Johanses and Julieus (1990) procedure will be used to study the long run relationship between the variables. This will be the specific relationship between the variations of local rice production in Malaysia and the various climatic characteristics of the country, as well as other contributing aspects. Since we are interested in determining how our shifting climate affects the rice production in the long run. This procedure is required in the use of the co-integration testing procedure. The procedure necessitates the use of stationarity testing before further regression process to determine the order of integration. The term stationarity can be thought of in terms of variables that are found to be integrated of the same order, d, which can be written as I(d). If found to be integrated in the same order, then the set of data will need to be differenced d number of times to obtain stationarity. So in other words, an integration of I(0) will mean stationarity while I(1) will need differencing of a total one time to obtain stationarity. Another more common definition is when the probability distribution of a series is time invariant (Johansen & Juselius, 1990). For example, if the dependent variable, rice production is found to have a mean, variance, and autocorrelation that are not constant over time, the rice production may be not stationary and further steps need to be taken. It is imperative to make sure a data series is stationary except for VECM where two variables need to be non-stationary to have co-integration. Thus is our case, we will be on the lookout for the existence of stationarity problems to allow us to further continue our analysis by way of VECM. But for other models, if a data is not stationary, a spurious effect may exist and normal asymptotical analysis will not be possible. R^2's for regression models will be very high and t-statistics will also be very high but the variables being investigated may have no relationship. This is due to the possibility of individual data series to drift upwards together or drift downwards together. But as stated above for the co-integration test, data sets must not be stationary but integrated of same order. The method that will be used for this analysis will be the Augmented Dickey-Fuller Test (ADF) (1979). The purpose of the ADF is to test for the existence of unit roots, whereby if the presence of unit roots are found, a data is said to be non-stationary. This test also takes into account the right number of lags to accommodate serial correlation. The test equation for the ADF test is as follows:

$$\Delta Y_t = \beta_1 + \beta_2 t + \alpha Y_{t-1} + \delta_3 \Sigma \Delta Y_{t-1} + \varepsilon_t \quad \text{------------------------}(2)$$

The terms above are, ε_t is an error term which has a mean of zero and covariance of also zero as it is the case of all white noise terms, β_1 is the terminology for drift which can be thought of as the intercept and $\beta_2 t$ is the trend in a specific period which shows how the data trends over time or its deterministic coefficient and the delta refers to the differencing of the proceeding term. This can be interpreted as if Y_t follows the above relationship, and has a random walk, so the change in the difference of that particular term is stationary. Looking further, α and δ are the coefficients of one period lagged value Y_{t-1} and ΔY_{t-1}, respectively; where ΔY_{t-1} is the change in of the variable in the current period from the last. According to Gujerati (2009), the right amount of lag is required to be included so that equation is not serially correlated. The Schwarz Information Criterion (SIC) will be utilized to determine the require total of lags. When all this is applied, the ADF test will assess whether α is equalled to 0. Thus the null and alternate hypothesis of ADF will be as follows:

Ho: $\alpha = 0$ (Y_t is non-stationary or there is a unit root).

H_1: $\alpha < 0$ (Y_t is stationary or there is no unit root).

The null hypothesis will be rejected if the tau value is smaller than that of the critical tau obtained. Thus, the data will not have a unit root and, hence, it will be stationary in level (depending on the difference level selected). The critical values at 1%, 5%, and 10% of tau are obtained from Mackinnon. If a data is found to have a unit root at level, the process is repeated again at 1st difference. If it is found to be stationary, it is integrated at 1st order.

3.3.2 Co-integration test

To test for the presence of co-integration, a set of data will be required to possess unit roots and integrated of the same order as was covered in the preceding section above. When we have checked that all data is integrated of the same order, we can proceed with the co-integration test. The test is a procedure that finds whether two variables have similar stochastic trends, which in turn implies the variables display a long-run relationship. For this study, the Johansen and Juselius (1990) method will be used. This test utilizes the process of the maximum likelihood methods for Vector Autoregressive Model. After applying the process, the number of co-integration vectors that are present in the set of data can be found and this is dubbed the co-integrating rank, r. Furthermore, if let's say that two series are co-integrated, then it must be that causality will exist but the direction of the causality will not be able to be determined.

Thus, with the application of the co-integration assessment and two co-integrated variables are found, the Vector Error Correction Model must therefore be used definitively. For determining the cut-off point of determining if two sets of variables are indeed co-integrated, test statistics will be employed. The two test statistics that will be implemented in the co-integration test to enable a generalization of the series are the Trace Test Statistic and the Max Eigen Value statistic. These statistics can be used to determine the number of co-integrating vectors, r. The results can then be later used to determine if there exists a long run equilibrium of the variables. The equations used for the analysis:

$\Delta lnY_t = \alpha_0 + \Sigma\beta_i\Delta lnY_t + \Sigma\chi_j lnX_{t+}\epsilon_t$---------------------------------(3)

$\Delta lnx_t = \gamma_0 + \Sigma\sigma_i\Delta lnx_t + \Sigma\tau_j lny_{t+}\epsilon_t$----------------------------------(4)

Y_t is total local paddy output index while X_t is temperature. For the purpose of laying out the sequencing and framework of the analysis, only a single variable x is in the testing equation. However, in the actual analysis that will be carried out in this study, it will utilize several more types of variables such as carbon dioxide intensity, precipitation levels, among others, as stated in the previous section. Δ is to show the difference process, ϵ_t is to represent the white noise which has a mean=0 and cov=0, α_0 and γ_0 are the intercepts, and β_i, χ_j, σ_i, τ_j show how the lagged of the different series will affect the dependent variable. The null hypothesis to test will be:

H_0: (r = 0, which means that no co-integration exists between Y_t, and X_t).

H_1: (r ≠0, which means that co-integration exists between Y_t, and X_t).

Thus, null hypothesis is that there is no co-integration among the variables. If the Trance and Max Eigen Value surpass the critical value, null hypothesis will be rejected, and there will be co-integration. The lag chosen for the test is important. The lag is selected based on Schwarz Information Criterion profile.

Although co-integration test proves the existence of Granger-causality, it does not show the direction of causality. The direction of causality can be determined through the VECM or though the Granger-Causality test.

3.3.3 Vector Error-Correction Model (VECM)

From the Johansen co-integration test, if and when the variables are found to be co-integrated, Granger proposed that the equilibrium between the used variables could be explained by the error correction model (ECM). This is called the Vector Error Correction Model. The model is a variation of the Vector Autoregressive Model. The model was created with the intention to be used with data series that are not stationary and also found to be co-integrated. To enable the method to properly model the co-integration, the model has co-integration relations built into the specification. This built in mechanism (in the form of a new term) enables the model to adjust the long-run behaviours of the exogenous variables so that following the shifting of time based causality in the short run to the long run, they will tend to move to the steady state in co-integrating equilibrium. This new term is dubbed the error correction term. The term is able to adjust the deviance resulting from the long-run relationship by progressively employing multiply fractional short-run adjustments. For this study, the ability of the VECM model in explaining the long-run as well as the short-run relationship will prove useful in our analysis. For an amount of variables tested to be co-integrated and the deviations in other independent variables, shifts in the dependent variable can be shown by an error corresponding illustration which is a function of the amount of volatility in the long-run equilibrium.

$\Delta Y_t = \alpha_0 + \Sigma\beta_i \Delta X_{t-1} + \Sigma\chi_j \Delta Y_{t-1} + \gamma_i ECT_t + \mathcal{E}_t$---------------------------(5)

$\Delta X_t = \alpha_0 + \Sigma\beta_i \Delta Y_{t-1} + \Sigma\chi_j \Delta X_{t-1} + \gamma_i ECT_t + \mathcal{E}_t$---------------------------(6)

$ECT = Y_t - \delta X_t$--(7)

Y_t=dependent variable

X_{t-1}=independent variable

Δ =difference determiner

$\varepsilon_{t=}$white noise term

α_0, β_i and χ_j show how each variable will affect total local paddy output

δ= co-integrating dynamic

γ_i= coefficient estimates for error correction term

that is (X_t ,Y_t) are carbon dioxide (and other climate based and also non-climate based variables) and total local paddy output index, Δ is a difference determiner where by it shows the change of the variable from one period to the next, ε_t is a white noise term, α_0, β_i and χ_j show how each variable will effect total local paddy output. These three terms will require a pre-vector autoregressive regression to be determined. δ is the co-integrating dynamic, which again will require a pre-ordinary least square regression in a first stage and γ_i is the coefficient estimates for error correction term (ECT_{t-1}). The ECT represents the error correction term, which shows how fast at which the model is corrected. By including this term into the model, we can then determine the studied variables and their causality.

In this study, the previous equations will be used to test the causation from carbon dioxide intensity (X_t) to total local paddy output (Y_t) and the reverse. The causality is determined using the Wald test and calculating the F-statistics of the dynamic terms based on the null hypothesis where by the coefficient of the lagged variable is equalled to zero.

H_0: Coefficient of β_i and χ_j is equal to 0.

H_1: At least one of the coefficients of $\beta_i$and χ_j is not equal to 0.

VECM for total local paddy output, Carbon dioxide concentration, precipitation, and agriculture land, total rice imports, and average oil prices

Total local paddy output

$$\Delta lnrice_t = \beta_0 + \Delta\beta_1 lnco2_{t-1} + \Delta\beta_2 lnrain_{t-1} + \Delta\beta_3 lnland_{t-1} + \Delta\beta_4 lnimports_{t-1} + \Delta\beta_5 lnoil_{t-1} + \Delta ECT_{t-1} \text{----------------------------------} (8)$$

where

$$ECT_{t-1} = \beta_0 - \Delta\beta_1 lnco2_{t-1} - \Delta\beta_2 lnrain_{t-1} - \Delta\beta_3 lnland_{t-1} - \Delta\beta_4 lnimports_{t-1} - \Delta\beta_5 lnoil_{t-1} \text{--} (9)$$

From the equation, carbon dioxide, precipitation, total agricultural land, imports of rice, crude oil prices are the independent variables are the factors of the study. The equation depicts how the change in the variables variables will affect the change in total local rice production. This is due to the delta symbol present before each variable. Besides, these variables are also in the form of lagged variables, meaning the equation shows how these variables in the previous year affects rice production in the following year. Lastly, the equation also contains a variable dubbed the Error Correction term (ECT). This term shows how fast the system will shift back to its equilibrium if any shocks within the system to happen.

CHAPTER FOUR
RESEARCH RESULTS

In the previous chapter, the theoretical framework for the study was discussed together with a thorough description of the various steps and processes required to carry out the needed regression. Results obtained from the regression will be described and analysed in this chapter, stating the values and relationships found after running the regression.

4.1 Lag Length Criterion Testing

The Lag Length Criterion test was performed on the set of time series data used in the study to select the most appropriate lag to add when carrying out the various test and regressions. The results from the test can be observed from Table 4.1 below which shows the various Akaike Information Criterion values at different lag length.

Table 4.1: Lag Order Selection Criterion with respect to the Akaike Information Criterion.

Lag	LogL	LR Test Stat	Final Prediction Error	Akaike Info Criterion	Schwarz Criterios	Hannan-Quinn
0	53.69273	NA	4.16e-09	-2.271083	-2.022844	-2.180093
1	278.1891	374.1606	5.36e-13	-11.24710	-9.509431*	-10.61018
2	329.3100	70.59548*	2.90e-13*	-11.96714*	-8.740041	-10.78428*

Note: * denote statistically significant test values with respect to the Akaike Information Criterion.

From the table, it can be established that with a lag order of 2, the Akaike Information Criterion value has the smallest denomination. From this, it can be interpreted that a lag length of 2 should be selected when carrying out the rest of the regression process.

4.2 Unit Root Test

Dealing with time series data on the whole, the regression necessitates the testing of stationarity of all data sets via a unit root test before progressing to the actual regression. Therefore, this section analyses the results observed from the unit test carried out on the data.

Applying the Augmented Dicky Fuller Test on both levels and first difference on all the variables, the following results were obtained:

Table 4.2: Augmented Dickey Fuller test for stationarity

Variables	ADF			
	Level		1st Difference	
	t-statistic	p-values	t-statistic	p-value
lnrice	-0.095048	0.9432	-7.622675	0.0000*
lnco2	1.570737	0.9992	-6.904429	0.0000*
lnrain	-2.919105	0.0536	-4.951447	0.0002*
lnland	-1.815021	0.3684	-2.704178	0.0818**
lnimports	-0.585457	0.8628	-8.239492	0.0000*

lnoil	-2.596788	0.1014	-6.089977	0.0000*

***, **, * denote 1%, 5% and 10% significant respectively.
The Optimal Lag Length for the test determined by Schwarz Information Criterion.

From the Augmented Dickey Fuller test results in Table 4.2, it can be shown that all variables used in the regression contain a unit root problem at level as all p-values were seen to be insignificant. Based on these values, the null hypothesis that the data contains a unit root cannot be rejected. In other words, the variables used consisted of non-stationary data on level. If these non-stationary data sets are analysed without any modifications, spurious regressions may occur. Spurious regressions happen when or more sets of data trend in the same direction, provided the illusion that they have a relationship. Spurious regression will provide the analysis with incorrect conclusions.

Repeating the test on first difference on the other hand, I (1) yielded results that showed the p-values for all the variables were significant and that null hypothesis for the test could be rejected. This entails that the all variables currently do not possess any unit root problem at first difference and are now stationary. Since all variables are I (1), the possibility of co-integration in the model arises. This validates the selecting of the vector error correction model over the Vector Auto Regression Model.

4.3 Co-Integration Test

Discovering the existence of unit roots in the series of data at level, the data was then tested for the existence of co-integration relationships. Included in the co-integration test were the variables lnrice, lnco2, lnrain, lnland, lnimports, lnoil. The resulting model is displayed below:

lnrice= lnco2 + lnrain + lnland + lnimports + lnoil

By following the Johansen and Juselius procedure, the results are presented in Table 4.3 below.

Table 4.3: Johansen's Test for Multivariate Co-Integration Vectors.

Model: LRICE, LCO2, LRAIN, LAGRILAND, LIMPORTS, LOIL					
No. of CE(s)	Trace Trace Statistic	Critical Values 0.05	Max Eigenvalue	Critical Values 0.05	Results
None *(r-0)	165.0787 *	95.75366	68.62177*	40.07757	Both maximum Eigen Values and Trace Test point towards all the variables possessing co-integration relationships at
At most 1* (r≤1)	96.45693 *	69.81889	35.92069*	33.87687	
At most 2* (r≤ 2)	60.53624 *	47.85613	32.85228*	27.58434	
At most	27.68397	29.79707	15.34495	21.13162	

3 (r≤ 3)					significant value of 5%.

Note: * denote test statistics over the critical value.

By previously performing the lag length criterion test using the Akaike Information Criterion, an appropriate lag length was used for the test. Table 4.3 indicates that the trace statistic value and the critical value at 5% significance are 165.0787 and 95.75366 respectively for testing the null hypothesis. The null hypothesis of r=0 implies that if this hypothesis is accepted, the group of data contains no co-integrating relationships. From these values, it can be seen that the trace statistic value of 165.0787 is comparably larger than the critical value at 5% of 95.75366. This implies that the null hypothesis is rejected and that there indeed exist a co-integration relationship between the set of data used. Meanwhile, the same can be interpreted for the maximum Eigen Values. The maximum Eigen Values for the first null hypothesis is significantly larger than the corresponding critical value at 5% significance.

Looking further, the null hypothesis for (r≤1), whereby there is at least one or less co-integrating relationship between the variables, there is more evidence of co-integration. This is because the null hypothesis is rejected at a significance of 5%. The test generates a Trace Statistic value of 96.45693. Comparing the figure with the 5% significance critical value of 69.81889, the null hypothesis is thus rejected. This implies that all of our data sets may contain at least one co-integrating relationship which would lead to spurious relationships. Similarly, the same can be noticed for the maximum Eigen Value.

The Maximum Eigen value for the null hypothesis of r≤1 is larger than the 5% significance critical value counterpart. This further strengthens that there is indeed co-integration relationship present between the variables.

Further down on table 4.4, the results for the null hypothesis test that r≤2 are also presented. Comparing the trace statistic and the critical value at 5% significance, the trace statistic is once again bigger at 60.53624, compared the smaller value of the critical value at 47.85613. A bigger trace statistic value infers that there may indeed be the presence of two or less co-integrating relationships within the model. Equally, the maximum Eigen values yield matching results that show similar conclusions.

Thus, from each null hypothesis tested, it can be concluded that there are indeed the existence of co-integrating correlations between the time series variables utilized in the model. This is in line with the previous findings from the unit root test. It was surmised from the previous section that all variables were non-stationary at level. Co-integration can only exist in the presence of similar levels of non-stationarity throughout the variables. With the presence of co-integration relationships, the implementation of the Vector Error Correction model is further justified as the model can only be applied with the presence of long-run co-integration processes. This is due to the presence of spurious relationships. If a regular Vector Autoregressive mode is applied, the models' output will see spurious relationships. These relationships will cause analysis conclusions to be not be accurate and skewed. Spurious relationships happen when two data sets which trend in the same direction are regressed, providing a causal relationship which may not be actually true. Thus to prevent this problem from happening, a Vector Error Correction Model is needed.

4.4 Long-run Co-integration Equation

Besides testing the presence of co-integrating relationship between time series variables, the Johansen and Juselius test outputs the resulting long-run relatoship equation. Below depicts the resulting long-run relationship:

$$lnrice = -1.111474\ lnco2 + 5.570506\ lnrain + 4.706470\ lnland$$

(-3.97902) (6.87470) (5.76935)

$$-1.314691\ lnimports + 0.367464\ lnoil \text{ ----------------------(10)}$$

(-5.14972) (6.16628)

From Equation 10, variables for carbon dioxide, rain, irrigated paddy land, rice imports and average oil price are all significant determinants of paddy output in Malaysia following the interpretation from the variables corresponding t-statistics. In other words, these variables are determinants of the paddy production function. The results infer that carbon dioxide in the atmosphere have a negative relationship production in the country. An increase in carbon dioxide output in the atmosphere in the long run will cause a decrease in the total yield of paddy grown locally in the country. This negative relationship was also realized in other studies, namely in a study carried out by Saseendran et al. (2002). Increase temperature from elevated carbon dioxide present in the atmosphere similarly caused reduction in rice production in India. Another studied carried out by Lobell and Field (2007) found similar reductions in crop outputs in relation to increase temperature resulting from carbon dioxide build up. Thus, Malaysia's effort to increase rice output may see set backs in the long-run from increased carbon dioxide in the atmosphere.

Rain on the other hand has an opposite relationship as that of carbon dioxide. The long-run equation showed that there is a strong positive relationship between changes in rain and changes in paddy crop yield. As rain increases, the amount of paddy crop yield is also expected to increase together. With increase in yearly precipitation, reservoir levels are less likely to deplete and thus providing more water supply for irrigation. This result was also similarly found in Saseendran et al.'s research. In the study, it was found that increase rainfall above normal values yielded increase in rice output in India. These increases were usually in the factor of exponential values. Comparing this with carbon dioxide, rain is found to be more significant than carbon dioxide deposition. Due to this, it can be said that projected increased rain from increased temperatures may be able to alleviate the affects of increase green house gas deposition in the atmosphere.

Besides the influence of rain, the area of available land for paddy cultivation has also been found to be significant in determining paddy output in Malaysia with a t-value of 5.76935. The co-integration tests results indicate that in the long-run, paddy yield will increase alongside the increase in area of available irrigated land for paddy farming. This finding is in line with other studies whereby an increase in the land assigned for paddy farming will in turn enable a larger capacity for agriculture output. Research carried out by Yan et al. (2009) discovered that increasing new land opened for agriculture caused increased in agriculture output in China and thus allowing it to dampen the effects of agriculture land transformation and urbanization. From the long run equation above, it has been discovered that in the long-run, Malaysia's rice output will be able to benefit from the opening of new irrigated land for paddy farming to counter the adverse effects of increased carbon dioxide in the atmosphere found in the previous section. A coefficient of 4.706470 implies a 4.70% increase for every 1% increase in land allocated for agriculture. This also shows that land allocation has a bigger effect on rice output than increased carbon dioxide deposition in the atmosphere. This means that the percentage of agricultural land can be readily manipulated to counted the effects of climate change.

The test results also indicate the existence of a long-run negative relationship between rice imports and paddy output in the country with a t-value of -5.14972. With every 1% increase in rice imported, rice production would be expected to drop by 1.31% percent. This is consistent with other prior studies on the subject. A study carried out by researcher Deviga (2013) found that opening the rice market in Malaysia to full trade liberalization would result in an influx of rice import into the country and a reduction in local rice production.

Lastly, the Johansen and Juselius co-integration test also demonstrated the presence of a long-run relationship amongst the variables: rice productions and average oil prices. With a t-value of 6.16628, the influence of the world oil price average is significant and will determine the country's long-run paddy production. Earlier studies point to similar conclusions. For instance, Anjanovic (2011) determined that although increases in average world crude oil prices did escalate biofuel demand, competition between biofuel crop production and other food crops did not cause a reduction in food output. This was due to advancement and the opening of new agriculture land keeping pace with growing biofuel demand. From the results in Equation 10, it can be expected that a 1% rise in world average oil prices could coincide with a 0.37% increase in rice production which is a very insignificant effect as the coefficient is very small. This is mainly due to the Malaysian agricultural sector being heavily subsidies and incentivised. Petroleum price shocks have small effects on local farmers as the government has policies and programs to help these farmers (Arshad, F. M., & Shamsudin, M. N. 2006). Local petroleum prices are also heavily subsidies. Due to this subsidies, any immediate price shocks to the world crude oil prices do no directly affect farmers.

In summary, from the Johansen and Juselius Co-integration test output, it can be determined that there are five variables present determining the long-run equilibrium of the system. These variables are carbon dioxide concentration within the atmosphere, amount of rain received, irrigated paddy land, imported rice percentage and world average oil prices. Carbon dioxide concentration and imports of rice were found to negatively affect the long-run equilibrium while rain, agriculture land and world oil prices were found to positively affect rice output. Finding the existence of co-integrating relationship allowed the application of the Vector Error Correction Model which will be discussed and analysed in the following sub-section.

4.5 Vector Error Correction Model (VECM)

Locating the existence of co-integrating relations resulted in the need for the application of the Vector Error Correction Model. This ensures that spurious regression problems are eliminated and meaningful results obtained. By utilizing the Akaike Information Criterion, an adequate amount of lag was applied to the model. The amount of lag settled on was a lag of two periods as shown from the results in equation 10. Below displays the resulted Vector Error Correction Model:

$$\Delta lnrice = -0.024 + \underset{(0.398)}{0.045\,\Delta lnco2_{t-1}} - \underset{(0.421)}{0.035\,\Delta lnco2_{t-2}} + \underset{(0.002)^{***}}{0.545\,\Delta lnrain_{t-1}}$$

$$+\underset{(0.000)^{***}}{0.548\,\Delta lnrain_{t-2}} - \underset{(0.296)}{0.645\,\Delta lnland_{t-1}} + \underset{(0.015)^{***}}{3.00\,\Delta lnland_{t-2}} - \underset{(0.014)^{***}}{0.137\,\Delta lnimports_{t-1}}$$

$$+\underset{(0.410)}{0.01\,\Delta lnimports_{t-2}} - \underset{(0.162)}{0.050\,\Delta lnoil_{t-1}} - \underset{(0.299)}{0.02\,\Delta lnoil_{t-2}} - \underset{(0.004)^{***}}{0.106\,ECT_{t-1}} + \varepsilon_t$$

---(11)

Note: *** denotes variables that are statistically significant at 1%

From Equation 11, it can be observed that only rain, irrigated paddy land, imports, and the error correction term are deemed significant at a 5% level of significance. The null hypothesis that the coefficients are valued at one is thus rejected. These coefficients are also found to be significant at 1% level. The other variables on the other hand were found to be insignificant and did not influence the production of paddy in the country over a short-run period as the respective p-values for testing their null hypothesis were lager than the minimum 10% level.

From the regression results, every 1% increase in the change of rain downfall in country during the previous year will result in a 0.55% increase in paddy output within the country. This is considered to be an inelastic effect as the lagged one rain variable's coefficient is below unit. An increase and well distributed rain-fall throughout the year is expected to increase paddy output as farmers are not required to fully rely on the countries' irrigation system (Saseendran et al., 2000). Being less reliant on irrigation results in less strain on the whole system. Thus, allowing the aforementioned system to water a larger area. Saseendran's results similarly found positive long-term effects of rain on paddy production in the order of below unity.

From equation 11, besides the effect or rain, the p-value for the area of irrigated paddy land is proven to be significant at 5% level with a p-value of 0.014. Furthermore, analysing the coefficient, available irrigate paddy land can be observed to have an elasticity value of 3.00, making it above unity. In other words, whenever a 1% increase in area of available irrigate paddy land occurs, a 3% increase in total paddy output can be expected from the short-run. This can be interpreted as the demand for food increase, stress on the country's food producing sector will prompt the opening of agricultural land (Lambin & Mayfroidt, 2011). This may lead to more deforestation and open burning which may worse greenhouse effects.

Lastly, the utilization of the vector error correction model necessitates the analysing of the error correction term. This term allows the model's system to correct any disequilibrium that may potentially occur in the system and adds adjustments to bring the model back to equilibrium. In the model above, the estimated coefficient for the error correction term is significant at 5% level and thus points to the validity of the existence of a long-run relationship between the tested variables, i.e., the relationship that was discussed preceding section. With a coefficient of 0.106, the speed of adjustment during events of shock can be said to be slow. In other words, the system has a speed of adjustment of about 10.6% during shocks. The model is also expected to be stable as any corrections made to reach the long-run equilibrium during short-run disequilibrium will not cause the model to explode and increase exponentially as the coefficient possesses a value smaller than one ($a<1$). Besides that, the value for the coefficient of the error term is also negative, falling into the expected range of values that the error term should be, to keep the model stable. What this entails is that whenever the model encounters shocks, after a period of time, the model will shift back to equilibrium and not grow exponentially and break down. For example, crude oil spikes, draughts, and floods are a few commonly encountered shocks.

Comparing the effects of increase carbon dioxide with the other variables, it can be observed that the other variables are more significant. Rain has a bigger effect on rice output within the country than increasing carbon dioxide. Due to this, it can be inferred that increased precipitation from climate change may be able to alleviate the effect of green house gasses. Besides that, land allocation for farming has also been found to be more significant than increase carbon dioxide. Thus it can be said that increase in agriculture intensification may be able to counteract the effects of increased green house gasses in the atmosphere.

For the sake of comparison, the model with paddy import as the dependent variable was also examined to determine factors that affect the country's food import. Below displays the paddy import short-run model:

$$\Delta lnimports = 0.92 - \underset{(0.425)}{0.106\, \Delta lnrice_{t-1}} - \underset{(0.289)}{0.295\, \Delta lnrice_{t-2}} - \underset{(0.346)}{0.190\, \Delta lnco2_{t-1}}$$

$$+\underset{(0.104)}{0.658\, \Delta lnco2_{t-2}} - \underset{(0.286)}{0.299\, \Delta lnrain_{t-1}} - \underset{(0.029)^{**}}{0.845\, \Delta lnrain_{t-2}} - \underset{(0.091)^{*}}{4.767\, \Delta lnland_{t-1}}$$

$$+\underset{(0.472)}{0.273\, \Delta lnland_{t-2}} - \underset{(0.174)}{0.138\, \Delta lnoil_{t-1}} + \underset{(0.162)}{0.135\, \Delta lnoil_{t-2}} + \underset{(0.102)}{0.144\, ECT_{t-1}} + \varepsilon_t \text{ --------------------------------(12)}$$

Note: ***, **, *, denote variables that are 1%, 5%, and 10% statistically significant respectively.

From Equation 12, it can be gathered that there is only one variable significant at 5% and two variables significant at 10% level. Using a 5% level criterion, only rain at lag order two is significant, while at 10% level, both rain at lag order two and area of irrigated paddy land at lag order one is significant. The error correction term on the other hand is found to be insignificant. This invalidates the existence of long-run relationships on the model as over a long period of time, the model is unable to adjust itself to the model's long-run equilibrium. What this entails is that whenever a shock to the system happens, such as crude oil spikes and droughts, the model will not be able to shift back to its equilibrium state and instead increase exponentially.

Analysing the variables of this model, rain of lag order two is realized to have an inverse relationship with the country's total import. The coefficient of 0.845 denotes a 0.85% decrease in rice imports from neighbouring countries where there is 1% increase in total rain fall in the country. These are similar result obtained by Awange et al. (2007). Increase droughts in the country will result in low yielding crop seasons. Lower yields will then prompt the need to increase food import to meet increasing demand. Conversely, increased precipitation will see more productive planting seasons and thus reducing the dependency of food import to meet the county's demand. Examining the variable, irrigated land on the other hand, it can be observed that the variable equally exhibits inverse relationships with total paddy imported. With every 1% increase in change in irrigate paddy land, there will be a subsequent 4.7% decrease in change of total rice imports by the country. In other words, by the opening up of new agricultural land, the amount of imported rice will decrease. This will lead to import substitution and reduce dependence on food imports (Pancheco, 2006).

4.6 Conclusion

Results from the Johansen and Juselius Co-integration Test have shown the existence of long-run co-integrating relationships, prompting the application of the Vector Error Correction Model over the Vector Auto Regression model. There exist a long-run negative relationship between the variables; carbon dioxide in the atmosphere and total paddy imported with total paddy output. This implies that effects from rising temperatures from carbon dioxide outweigh the effects of carbon fertilization on the crops and that increasing food imports would deter local farmers from ramping up operations. Besides that, precipitation and area of available irrigated paddy land were also found to affect paddy output within the country, albeit in a positive way. Increases in rainfall resulting from increased atmospheric temperature would in turn increase crop-planting productivity. The opening of new agricultural land on the other hand, would also be able to increase paddy output within the country by means of enlarging the agricultural capacity of the country.

Furthermore, comparing the negative effects of carbon dioxide and temperature with the other determinants of paddy output, it can be inferred that these other determinants will be able to alleviate the detrimental effects of global warming.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

This chapter will discuss the key findings of the study conducted and the discussion will be tied in to the answers for the each of the research questions. . Conclusions which were derived from these discussions will be presented. This will be followed by the implications of the study, limitations of the study and suggestions for future studies.

5.1 Recapitulation of the Study Findings

The central objective of this study is to test the existence of the influence of alleviated carbon dioxide level on crop output in the short-run and as well as in the long-run. Besides climatic influences on crop output in Malaysia, non-climate variables that similarly affect Malaysia's capacity to produce food were also included. This was done to enable comparisons between the effects of global warming and other more conventional determinants of food production. The four main questions of the study that were listed in Chapter 1 are: (1) Do changes in carbon dioxide concentrations in the atmosphere affect rice production of Malaysia in the short-run?; (2) Do changes in carbon dioxide concentrations in the atmosphere affect rice production of Malaysia in the long-run?; (3) How do the two different by-products of increased carbon dioxide (i.e. rising temperatures and increased rainfall) affect the country's rice production?; (4) How do these climate factors compare to other more conventional determinants of rice production such as import policies, area of available irrigated paddy land, and average crude oil prices.

5.2 Discussions

The subsequent sections discuss the results obtained from the regressions. The discussion will be divided into subsections with accordance with the four main questions listed above.

5.2.1 Research Question 1: Do changes in carbon dioxide concentrations in the atmosphere affect rice production in the short-run?

To answer this question, historical climate data and other non-climate data associated with rice production in Malaysia were obtained to carry out an analysis. The inclusion of carbon dioxide data allowed insight into its effects on rice production based on resulting changes in temperature and the fertilization effect in the short-run. Carrying out the regression, the results from the Vector Error Correction Model did not indicate the existence of a short-run effect on rice production. In other words, rising temperature and the fertilization effect of intensified carbon dioxide concentration in the atmosphere do not have significant effects on agriculture plants in Malaysia. This may be due to the rise in temperature being in the form of small increments as small increments in temperature rise prevents crops from entering a state of shock. Put differently, there exist threshold temperatures where plants are unaffected. Environments with temperatures below this threshold may not necessarily affect crops negatively. Temperatures above this threshold on the other hand may cause declines in crop output (Masud, M. M., Rahman, M. S., Al-Amin, A. Q., Kari, F., & Leal Filho, W. 2014).

Besides affecting plants negatively through temperature rise, elevated carbon dioxide levels also affects crops positively through carbon fertilization. Based on the results obtained from the regression, this conflicting affect does not seem to be present. The insignificance of carbon fertilization, initially predicted by some to alleviate the effects of global warming, can be attributed to the actual low concentration of carbon dioxide available to the crops due to the pollutant diffusing into the air and not being available to the crops in a non-diffused state. This is was similarly discussed by Ainsworth (2008), whereby by using newer open air techniques to test fertilization factors on plants as compared to older more traditional closed chambered test, actual carbon fertilization factors were far smaller than initially thought. Thus in the short-run, paddy crops are not expected to benefit from any rise in carbon dioxide concentration in relation to carbon fertilization.

One important by-product of increased temperature on the ecosystem is the increased levels of rainfall. Being in the tropics and susceptible to the monsoon, Malaysia is expected to have more precipitation during these seasons, as well as throughout the year (Xie, et al. 2010). From the results, it can be observed that in the short-run, paddy crops are expected to benefit from an increased in rain fall. With increased rainfall, less strain will likely be put on the irrigation system, making sure all paddy crops will receive adequate amount of water. With less drought instances, farmers will be expected to have fewer occurrences of crops perishing. For example, droughts that occurred in the state of Perlis during the year 2016 prevented farmers from planting paddy (New Straight Times, September 4th, 2016). The drought caused water levels in the Timah Tasoh Dam to drop to critically low levels. This resulted in water levels that were sufficient for domestic use only and now water was able to be channelled for irrigation. Thus, projected rain-fall increase from climate change will be able increase crop output in a given planting season.

Thus, within a short-run period, it can be implied that paddy crops in Malaysia are not set to be affected by increased levels of carbon dioxide in the atmosphere. With Malaysia being a developing country, and carbon dioxide levels set to increase exponentially over the next few decades from new industries and population rise, the negative impact of carbon dioxide on Malaysian food security in the short-run may be off less importance, compared to other determinants. Moreover, Malaysian farmers are also to benefit from increased precipitation in the short run.

5.2.2 Research Question 2: Do changes in carbon dioxide concentrations in the atmosphere affect rice production in Malaysia in the long-run?

With Malaysia continuing its' rapid development path, in terms of industry and coupled with increasing population, carbon dioxide levels are slated to increase exponentially in the country (Safaai, N. S. M., Noor, Z. Z., Hashim, H., Ujang, Z., & Talib, J. 2011). Thus it is similarly necessary to investigate its effect over the coming decades through the long-run effects of carbon dioxide. Applying the Vector Error Correction Model provided both short-run effect and long-run effects of the determinants used. From the model, it was shown that carbon dioxide would have a significant, negative effect on crop output. Being negative in nature, it can be inferred that the adverse effects of temperature rise will be more prevalent than the beneficial effects of carbon fertilization. This may be attributed to temperature exceeding the temperature threshold needed for plants to develop properly. Comparatively, this is different from what was discovered in the short-run aspect of the model. In the long run, temperature rise are poised to be more abrupt and less incremental, with the resulting temperature totalling to a larger value. With an unsuitable environment, crops will not be able to mature properly. Thus, if left without remedial actions being taken, carbon dioxide emissions may be damaging to the country's food security.

5.2.3 Research question 3: How do the two different by-products of increased carbon dioxide (i.e. rising temperatures and increased rainfall) affect the country's rice production?

As was previously mentioned, rice cultivation requires large volumes of water for optimal production. In the past, drought had severe effects on rice output such as in 2016 (New Straight Times, September 4th, 2016). This negative effect is exacerbated by the existence of smaller irrigation systems which in turn meant smaller rice production capacities. To alleviate this problem, policies were implemented to invest more capital towards improving the nation's irrigation. With escalating temperatures resulting from increased carbon dioxide levels, precipitation is also expected to rise concurrently and consequently reducing the strain on the irrigation system in the future. From the results of the regression, it was discovered that increased rainfall had significant positive effects on crop production, both in the long run and the short-run. With fewer instances of drought, water in the reservoir will less likely be depleted in times of need. As water in the reservoirs around the country divide water allocation to both domestic use and agricultural use, having more rainfall in the future would enable adequate water supply on both ends. This will be favourable development in the future for farmers as domestic water supply usually has precedence over agricultural needs. Thus, increased rainfall in the area from increased temperatures will benefit farmers both in the short-run and the long-run as there will be adequate water for crop development and less instances of drought.

5.2.4 Research question 4: How do these climate factors compare to other more conventional determinants of rice production such as import policies, area of available irrigated paddy land, and average crude oil prices.

Besides climatic factors such as temperature, precipitation, and carbon dioxide levels; other more conventional determinants of total crop output exist. It is important to include these variables in the study for a number of reasons. Firstly, it will be valuable to show the existence of climate factors in the midst of other more orthodox determinants such as area of available irrigated paddy land, total imports and crude oil prices. This will demonstrate the importance of climatic factors in dictating resource allocation during policy making. Secondly, non-climatic factors are more easily manipulated in the short-run. For example, manipulating carbon dioxide levels in the atmosphere is a long process, stretched over decades. Reduction of carbon dioxide concentration levels cannot be realistically achieved in the span of a year. Whereas total imports during the following year can easily be managed through trade policies. Thus, it is important to learn the effects of other determinants as compared to climate factors, to enable better policy making in curbing the effect of global warming. Lastly, comparing the two types of variables will also give insights into which category of variable affect food security worse.

From the short-run portion of the results, it can be deduced that rainfall levels, rice imports, and irrigated paddy land are significant in determining future rice output. Increased irrigated paddy land is expected to intensify crop output by means of increasing the agriculture sector. More land would allow more crops to be planted and thus increasing the resulting yield. A larger agriculture sector would also mean the need for more farmers. Rice imports on the other, increased imports in the previous year may deter local farmers from producing more rice and may find it more worthwhile to substitute a planting season for other more profitable ventures. Besides that, increased rice imports in a preceding year may reduce the amount of government revenue available for agriculture incentives for local farmers. As Malaysia imports more food than it produces, the government spends a large sum of revenue on food yearly to meet the demand of the country. Importing more food in a given year would reduce the government's ability to provide adequate subsidies and incentives to local farmers. This may cause crop output decrease as many farmers depend on government subsidies and incentives. Lastly, rain has also been shown to increase agriculture yield in the short-run. This can be attributed to increased water supply in reservoirs, resulting in less strained on the irrigation system. Since domestic use is prioritized, having adequate supply of water will ensure farmers receive enough water to supply their crops.

Comparatively, it can be observed that in the short-run, both climate factors, as well as non-climate factors are important in determining crop output in the country. Subsequently comparing the coefficients of the variables, area of available paddy land shows the highest value compared to the other two significant variables. This can be interpreted as land having the most direct effect in manipulating crop output. In terms of policymaking, manipulation of this variable will be an invaluable tool in addressing food security in the short run. Changes in rainfall and rice imports on the other hand demonstrate values below unity and correspondingly have a smaller effect on crop output in the short run. Although not as influential, water supply and food trade should not be ignored as they can be supplemented with land policies, allowing for a more effective and holistic approach in tacking food supply problems in the country.

Inspecting the output of long-run effects on rice output, it can be determined that all variables, climate and not-climate factors, are significant. Carbon dioxide, precipitation levels, available agricultural land, and rice imports are seen to significantly affect rice output in the country as corresponding coefficients are above unity. As carbon dioxide emissions are allowed to be increasingly deposited into the atmosphere, the accumulation over a long period of time would substantially negatively affect rice production. The exponential increase in temperature will also promote more rainfall, resulting in a considerably positive effect on rice production. Comparing these two contributing factors, precipitation alone is able to overcome the negative effect of carbon dioxide pollution. Thus it can be inferred that Malaysia may not be as adversely affected by carbon dioxide pollution as previously predicted. Aggregating the coefficients of the other determinants show a value significantly larger than the coefficient of carbon dioxide. This would imply that in the future, the government will be able to undertake a diverse range in policies to ease the negative effects of increased carbon pollution in the atmosphere.

5.3 Recommendations

Various researchers have cautioned the existence of global warming from recent increases of greenhouse gases in the atmosphere (Garcia, & Randel, 2008; Keeling, & Whorf, 2005 ; Searchinger, Heimlich, Houghton, Dong, Elobeid, Fabiosa, ... & Yu, 2009; Van Groenigen, Osenberg, & Hungate, 2011). The rising temperature has been found to have detrimental negative effects on plants and various food crops around the world. Left on its own, the problem has been projected to snowball with effects on the world's food system, further limiting the fight against food poverty in certain parts of the world. It has been forecasted that various countries in the tropics will be hit first by the rising temperatures. With Malaysia situated in this defined area, Malaysia is expected to experience food production reductions in the near future. Thus it will be important for steps to be taken immediately to ease the negative effects of global warming. Thus, this portion of the chapter will be allocated to discussions on recommendations and suggested policies to curb future effect of excessive carbon dioxide levels in the atmosphere. From the results and findings the regression analyses, several policies and actions can be put forward.

5.3.1 Irrigation policies

From the results of the analysis, it was observed that increased rain-fall from high global temperature caused local rice production to increase. With more precipitation, the government should allocate a portion of its budget on irrigation policies and projects. More efficient dams and reservoirs should be added. The number of pumps and tube wells will ensure that all sectors receive adequate supply of water, such as the domestic and agricultural sector. As with the recent drought that occurred in 2016, farmers in the state of Perlis were unable to plant their paddy crop as water was instead diverted for domestic use (New Straight Times, September 4th, 2016). With more precipitation projected to arrive, better irrigation and water management will allow all sectors to obtain sufficient water.

Besides that, floods prevent should also be considered as increased precipitation may destroy farms due to flooding. Programmes such as the Irrigated Flood and Rainfall Management (IFFRM) should be continued and further enhance to prevent floods in the future. Programs such as these will be able to forecast and predict floods before they happen, allow ample time for preventive measures. Besides that, projects such as the Sungai Muda Flood Mitigation project was also implement to prevent flooding. Among the methods employed to tackle the problems were; river mouth improvement, widening and deepening rivers, new barrages, and riverbank erosion control.

5.3.2 Reducing Carbon emissions

Although it has been shown that the effects of carbon dioxide are not as profound as compared to other factors, it is still important that efforts are taken in manage the country's carbon emissions. This is because without any intervention, carbon dioxide deposition may reach levels that would cause severe temperature rise over the coming decades. These temperatures may cause unsuitable environments for crop cultivation. Besides that, policies to reduce carbon emission would greatly benefit the environment as Malaysia is the fourth largest contributor of greenhouse gases within ASEAN. Thus it is the responsibility of every country in the world to band together to stop the worrying trend.

Among policies that can be applied are carbon taxes, increased budget on biofuel development, improved mass public transport, better urbanization management, and reduce deforestation. One significant step taken by the Malaysian government in this endeavour was the ratifying of the Paris climate change agreement. With this, the government has pledge to reduce carbon emissions through various policies. Thus it can be seen that the government is ready to allocate its budget to undertake greener projects.

5.3.3 Research and Development

During policy-making, it should be recognized that altering the natural environment such as surrounding temperatures and precipitation, are difficult undertakings in a short period of time. With that in mind, policy makers should take into consideration other variables that can be more easily manipulated to increase crop output and increase self-sufficiency. One method would be through to channel funding into research and development efforts. A study conducted by Vengedasalam (2013) suggested that increased funding on agricultural technology would facilitate the governments efforts in increasing self-sufficiency in rice. Better varieties of paddy can be developed, with higher tolerance on extreme temperature. Varieties with higher yield could also decrease the opening of new agricultural land and also increase output in a given growing season. For example, funding should be allocated to conduct similar research such as those carried out in the International Institute of Rice Research. Besides rice varieties, more efficient cultivation techniques could also be developed.

5.3.4 Trade barriers

The results point to a negative relationship between imports and rice production, whereby rice yields will see decreases as the country imports more. If all trade barriers were removed, rice prices in the country would drop but at the cost of increased rice imports to the country (Vengedasalam (2013). Local rice production was also predicted to fall as a result. This fall in local rice production would be counter-productive to the government's efforts to achieve self-sufficiency in rice production. Therefore, trade barriers should continuously be implemented, similar to what is already done with BERNAS.

Although BERNAS was created to protect local farmers and to ensure the country's sufficient stockpile of rice, it is also the sole imported of rice. Being the sole importer, BERNAS has monopolistic powers in the dealings of import and export. Granted BERNAS provides important protection for local farmers, the trade barriers do bring about adverse consequences to consumers in the form of higher rice prices. Therefore, bodies like BERNAS should be closely monitored to ensure that the welfares of both farmers and consumers are taken care off.

5.3.5 Incentives and Subsidies

Petroleum is an important input in rice production for its use as fuel in agricultural machinery during land preparation, planting, harvesting, and transportation. With fluctuating prices in crude oil, farmers should be protected from the high cost of fuel. Better petrol subsidy schemes can be implemented to ensure farmers continue producing rice and not refocus on other ventures such as land conversion and urbanization. For example, the Malaysian government has allocated RM 1.3 bil in incentives and subsidies to spur growth in the sector. Among some of the current fertilizer subsidies provided by the Malaysian Government are subsidies for 240kg/hectare for mixed fertilizer and 80kg/hectare for organic ferlizer (Vengedasalam, 2013). The government also provided yield incentives for farmers by allocated RM 650 for each tonne of yield increase compared to the previous. Incentives and subsidies of these sort should be continued as it helps the agricultural sector a lot.

5.3.6 Land management

The opening of new agricultural land remains an important way of increasing Malaysia's output capacity. Although it is a quick way to achieve the target of self-sufficiency, the cutting down of forest may exacerbate the effects of global warming with the release of more carbon dioxide the loss of carbon sinks. Hence, even with the country's strong aspirations to develop quickly in industry and agriculture, the forest should be simultaneous protected. Instead of the opening of new agriculture land, a bigger budget should be allocated to agriculture research and development, allowing of a greater yield in a smaller hectare of land. Policies that centre on land use efficiency should be implemented, such as urban agriculture.

With the protection of the county's forest, Malaysia's pledge in the Paris Climate Change agreement to reduce carbon emissions can be more easily accomplished. This will ensure that in the future, the spiraling increase in carbon dioxide can be dampened, reducing its effect on rice production.

5.4 Research Limitations

Within this research, there exist limitations that need to be described and discussed. In this study, the main limitations arose from data availability.

1. Only 43 data points for each variable were available, limiting the accuracy of the short-run analysis and the long-run projections. The severity of increased surrounding temperature on food production may not be fully understood.
2. Precipitation data were also obtained from circulation models provided a degree of inaccuracy. Rainfalls may not be as high or low as predicted, making estimations of increased yield inaccurate.
3. Rice was considered a homogenous good, grouping all rice varieties into one.

5.5 Further Research Suggestions

Future research to focus on developing new ways to overcome the limitations of this study, as previously discussed. Due to the lack of data, simulations could be implemented, enabling estimations of missing data. Besides that, research into different food crops should also be carried out. This will provide information to determine whether the results of this study encompass the whole agriculture sector. A more diverse range of variable could also be incorporated, such as solar radiation, coastal decay, and rising sea levels. This will enable a more holistic look into climate effects on food security as climate change affects the environment in a broad way. Simulations could also be implemented to determine how climate changes will affect the market price of different crops. This could be important for the population and the government to ensure food security through all levels of income.

5.6 Conclusions

This study set out to answer four objectives drafted in Chapter One, namely (1) Do changes in carbon dioxide concentrations in the atmosphere affect rice production in the short-run?; (2) Do changes in carbon dioxide concentrations in the atmosphere affect rice production in the long-run?; (3) How do the two different by-products of increased carbon dioxide (i.e. rising temperatures and increased rainfall) affect the country's rice production?; (4) How do these climate factors compare to other more conventional determinants of rice production such as import policies, area of available irrigated paddy land, and average crude oil prices.

In summary, results showed that increased carbon dioxides emissions were found to affect rice cultivation in Malaysia. Carbon dioxide increase saw a drop in total local rice output, both in the short-run and in the long-run. This could be attributed to increase temperatures having a greater effect than the fertilization effect of carbon dioxide. Precipitation on the other hand showed a positive effect on rice cultivation, with increased rice output from the projected increased rainfall in the future. The total effect of rain was also shown to be more significant than carbon dioxide effects on rice output. Land changes were also shown to affect rice output, with increased land used for paddy farming causing and increase in output. This was important, as recent agriculture land transformation to housing and urbanization could reduce self-sufficiency levels in ensuring food security. Imports were shown to negatively affect local farming of rice, with increased imports of rice from neighbouring countries causing a reduction in local rice output.

Thus, it was observed that climate change could affect rice production. This effect may negative affect the governments efforts in increasing the country's self-sufficiency in rice production, leading to a greater dependency in imports. Due to this, any future global rice crisis may affect the country's ability to meet its demand. With a potential reduction in supply, demand may outweigh supply, causing prices to rise, affect lower-income households. As climate change was seen to affect one type of crop, other types of crops maybe similarly affected. This in turn may affect the country's food output on the whole and resulting in lower self-sufficiency when it comes to various types of food. Due to the effects of climate determinants on food production, the government should take this in to consideration when drafting policies in the future. This will allow the government to achieve its self-sufficiency levels for rice supply at 70%. With less dependency on neighbouring countries for the country's supply in food, Malaysia's food security can be ensured.

REFERENCES

Ainsworth, E. A. (2008), Rice production in a changing climate: a meta‐analysis of responses to elevated carbon dioxide and elevated ozone concentration, Global Change Biology 14 (7), 1642-1650.

Ainsworth, E. A., Davey, P. A., Bernacchi, C. J., Dermody, O. C., Heaton, E. A., Moore, D. J., ... & Curtis, P. S. (2002). A meta‐analysis of elevated [CO2] effects on soybean (glycine max) physiology, growth and yield. Global Change Biology, 8(8), 695-709.

Ajanovic, Amela. (2011). Biofuels versus Food Production: Does Biofuels Production Increase Food Prices? *Energy* 36.4: 2070-076. Web.

Akbari, H., Matthews, H. D., & Seto, D. (2012). The long-term effect of increasing the albedo of urban areas. Environmental Research Letters, 7(2), 024004.

Arandez-Tanchuling, H. (2011). Two years after the 2008 rice crisis. *Kasarinlan: Philippine Journal of Third World Studies*, *26*(1-2), 295-311.

Arrhenius, S. (1896). XXXI. On the influence of carbonic acid in the air upon the temperature of the ground. The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science, 41(251), 237-276.

Arshad, F. M., & Shamsudin, M. N. (2006). „Implications of Oil Price Increase on the Malaysian Food System‟. *Pacific Food System Outlook*, *7*, 17-19.

Asseng, S., Jamieson, P. D., Kimball, B., Pinter, P., Sayre, K., Bowden, J. W., & Howden, S. M. (2004). Simulated wheat growth affected by rising temperature, increased water deficit and elevated atmospheric CO 2. *Field Crops Research*, *85*(2), 85-102.

Awange, J. L., Aluoch, J., Ogallo, L. A., Omulo, M., & Omondi, P. (2007). Frequency and severity of drought in the Lake Victoria region (Kenya) and its effects on food security. *Climate Research*, *33*(2), 135-142.

Baharuddin, M. K. (2007, June). Climate Change–Its effects on the agricultural sector in Malaysia. In *National seminar on socio-economic impacts of extreme weather and climate change* (pp. 21-22).

Barnes, C. A. (2010). United States Land Cover Land Use Change, Albedo and Radiative Forcing: Past and Potential Climate Implications. (Doctoral Dissertation). South Dakota State University. Retrieved from http://openprairie.sdstate.edu/etd/1081

Blanc, E. (2011). The impact of climate change on crop production in Sub-Saharan Africa . (Doctoral Dissertation). University of Otago. Retrieved from http://hdl.handle.net/10523/1724

Brown, M. E., Antle, J. M., Backlund, P., Carr, E. R., Easterling, W. E., Walsh, M. K., & Tebaldi, C. (2015). Climate change, global food security, and the US food system. Washington, DC: United States Department of Agriculture. http://www. usda. gov/oce/climate_change/FoodSecurity. htm, accessed October, 15, 2015.

CCSP, 2007: *Effects of Climate Change on Energy Production and Use in the United States*. A Report by the U.S. Climate Change Science Program and the subcommittee on Global Change Research. [Thomas J. Wilbanks, Vatsal Bhatt, Daniel E. Bilello, Stanley R. Bull, James Ekmann, William C. Horak, Y. Joe Huang, Mark D. Levine, Michael J. Sale, David K. Schmalzer, and Michael J. Scott (eds.)]. Department of Energy, Office of Biological & Environmental Research, Wash- ington, DC., USA, 160 pp.

Chase, Thomas N. (Thomas Newell), 1. (2007). The role of historical land-cover changes as a mechanism for global and regional climate change. (Thesis). Colorado State University. Retrieved from http://hdl.handle.net/10217/60539

Chen, S. T., Kuo, H. I., & Chen, C. C. (2010). Modeling the relationship between the oil price and global food prices. Applied Energy, 87(8), 2517-2525.

Cho, Kyung Bok. (2006). How will the High Gas Prices Affect the North Carolina Food Supply. The University of North Carolina at Chapel Hill, ProQuest, UMI Dissertations Publishing.

CIA (Central Intelligence Agency). 2009. The World Factbook: Malaysia.

Climate Research Unit of the University of East Anglia, Climate Research Unit Temperature Database, CRUTEM4

Coakley, J. A. "Reflectance and albedo, surface." *Encyclopedia of the Atmosphere* (2003): 1914-1923.

Collins, Keith. (2008). The Role of Biofuels and Other Factors in Increasing Farm and Food Prices: A Review of Recent Development with a Focus on Feed Grain Markets and Market Prospects

Cook, J., Oreskes, N., Doran, P. T., Anderegg, W. R., Verheggen, B., Maibach, E. W., ... & Nuccitelli, D. (2016). Consensus on consensus: a synthesis of consensus estimates on human-caused global warming. *Environmental Research Letters*, *11*(4), 048002.

Darwin, R., Tsigas, M. E., Lewandrowski, J., & Raneses, A. (1995). World agriculture and climate change: Economic adaptations (No. 33933). United States Department of Agriculture, Economic Research Service.

Davies, S. (2016). Adaptable livelihoods: Coping with food insecurity in the Malian Sahel. Springer.

Dian Rahmita Sari, , (2013) The Role of MADA to Improve Paddy Sub-Sector in Kedah Darul Aman. Masters thesis, Universiti Utara Malaysia.

Dick, N. A. (2014). Analysis of biofuel potential in Nigeria. (Doctoral Dissertation). University of Newcastle upon Tyne. Retrieved from http://hdl.handle.net/10443/2679

Dogruer, T. (2016). The demand and welfare analysis of Vegetable oils, biofuel, Sugar cane, and ethanol in Europe, Brazil and the US (Doctoral dissertation, Texas Tech University).

Dorosh, Paul A.; Rashid, Shahidur. 2012. Bangladesh rice trade and price stabilization: Implications of the 2007/08 experience for public stocks. IFPRI Discussion Paper 1209. Washington, D.C.: International Food Policy Research Institute (IFPRI). http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/127130

Dr. Pieter Tans, NOAA/ESRL (www.esrl.noaa.gov/gmd/ccgg/trends/)

Esmaeili, A., & Shokoohi, Z. (2011). Assessing the effect of oil price on world food prices: Application of principal component analysis. Energy Policy, 39(2), 1022-1025.

Ewing, M., & Msangi, S. (2009). Biofuels production in developing countries: assessing tradeoffs in welfare and food security. *Environmental Science & Policy*, *12*(4), 520-528.

FAO. 1999. Irrigation in Asia in figures. FAO Water Report No. 18. Rome.

FAO. 2009. Back to office report Project: GCP/RAS/241/JPN. Thierry Facon, 3/11/2009.

Fischer, G., Shah, M., & van Velthuizen, H. (2002). Climate Change and Agricultural Vulnerability, A Special Report Prepared as a Contribution to the World Summit on Sustainable Development. International Institute for Applied Systems Analysis, Laxenburg, Austria.

Foley, J. A., Ramankutty, N., Brauman, K. A., Cassidy, E. S., Gerber, J. S., Johnston, M., ... & Balzer, C. (2011). Solutions for a cultivated planet. Nature, 478(7369), 337-342.

Frierson, D. (2013). Global Climate change from Anthropogenic Activities. University of Washington. Retrieved from Lecture Noted Online Website: http://www.atmos.washington.edu/~dargan/111/111_03.pdf

Garcia, R. R., & Randel, W. J. (2008). Acceleration of the Brewer–Dobson circulation due to increases in greenhouse gases. Journal of the Atmospheric Sciences, 65(8), 2731-2739.

Giddens, A. (2009). The politics of climate change. *Cambridge, UK.*

Glauber, Joseph. (2008). USDA Chief Economist, in testimony before the Joint Economic committee of Congress on May 1, 2008.

Gleick, P. H. (1996). Basic water requirements for human activities: Meeting basic needs. Water international, 21(2), 83-92.

Godfray, H. C. J., Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F., John Vandermeerf, ... & Toulmin, C. (2010). Food security: the challenge of feeding 9 billion people. Science, 327(5967), 812-818.

Goldsberry, Kenneth L., 1. (2007). The effects of carbon dioxide on carnation growth. (Thesis). Colorado State University. Retrieved from http://hdl.handle.net/10217/68207

Gujarati D. N, Gujarati. (2004). Basics Econometrics Fourth Edition

Gujarati, D. N. (2009). Basic econometrics. Tata McGraw-Hill Education.

Hamilton, James Douglas. *Time series analysis*. Vol. 2. Princeton: Princeton university press, 1994.

Hanapi bin Mohamad Noor. 2011. Review of the National Water Resources study (2000-2050): Finding, outputs and recommendations. Presentation made at the Asia Pacific Regional Water Conference & Exhibition 2011, Kuala Lumpur, Malaysia, 15-17 March 2011.

Hirsch, A. I., Little, W. S., Houghton, R. A., Scott, N. A., & White, J. D. (2004). The net carbon flux due to deforestation and forest re-growth in the Brazilian Amazon: analysis using a process-based model. Global Change Biology, 10(5), 908-924.

https://www.worldwildlife.org/threats/deforestation

Ishida, A., Law, S. H., & Aita, Y. (2003). Changes in food consumption expenditure in Malaysia. *Agribusiness*, *19*(1), 61-76.

Johansen, S., and K. Juselius (1990) "Maximum Likelihood Estimation and Inference on Cointegration with Applications to the Demand for Money, Oxford Bulletin of Economics & Statistics 52, 169-210.

Johnson, J. M. F., Franzluebbers, A. J., Weyers, S. L., & Reicosky, D. C. (2007). Agricultural opportunities to mitigate greenhouse gas emissions. *Environmental pollution*, *150*(1), 107-124.

Jones, A. D., Ngure, N. M., Pelto, G., & Young, S. L. (2013). American Society for Nutrition Advanced Nutr, 4, 481-505. http://dx.doi.org/10.3945/an.113.004119

Kang, J. (2010). Analysis of Temperature and Carbon Dioxide Based on Ice Core Data. (Thesis). Uppsala University. Retrieved from http://urn.kb.se/resolve?urn=urn:nbn:se:uu:diva-126771

Kimball, B. A. (1983). Carbon dioxide and agricultural yield: an assemblage and analysis of 430 prior observations. Agronomy journal, 75(5), 779-788.

Lambin, E. F., & Meyfroidt, P. (2011). Global land use change, economic globalization, and the looming land scarcity. *Proceedings of the National Academy of Sciences*, *108*(9), 3465-3472.

Landes, David S. (1969). *The Unbound Prometheus: Technological Change and Industrial Development in Western Europe from 1750 to the Present*. Cambridge, New York: Press Syndicate of the University of Cambridge. ISBN 0-521-09418-6.

Le Huu, Ti and Facon, T. 2001. Malaysia´s Water Vision: The Way Forward. Page 25-41 From Vision to Action. A synthesis of experiences in southeast Asia. The FAO-ESCAP Pilot Project on National Water Visions.

Lee Poh Onn. 2003. The Water Issue Between Singapore and Malaysia: No Solution in Sight?. Institute of Southeast Asian Studies (ISEAS).

Leiserowitz, A. (2006). Climate change risk perception and policy preferences: The role of affect, imagery, and values. Climatic change, 77(1), 45-72.

Leiserowitz, Anthony Allen. (2003). Global warming in the American mind: the roles of affect, imagery, and worldviews in risk perception, policy preferences and behavior. Diss. University of Oregon.

Lipsky, John, First Deputy Managing Director, IMF, Commodity Prices and Global Inflation. (2008). Remarks At the Council on Foreign Relations, New York City.

Lobell, D. B., & Field, C. B. (2007). Global scale climate–crop yield relationships and the impacts of recent warming. *Environmental research letters*, *2*(1), 014002.

Loehle, C. (2007). A 2000-year global temperature reconstruction based on non-treering proxies. Energy & Environment, 18(7), 1049-1058.

Loehle, C. and J.H. McCulloch. 2008. Correction to: A 2000-year global temperature reconstruction based on non-tree ring proxies. Energy and Environment, **19**, 93-100.

Lu, J., Vecchi, G. A., & Reichler, T. (2007). Expansion of the Hadley cell under global warming. Geophysical Research Letters, 34(6).

MacKinnon, J. G. (1991). "Critical values for Co-integration tests," In *Long-run Economic Relationships: Readings inCo-integration* (Eds). R. F. Engle and C. W. J. Granger, Oxford University Press, UK, pp: 267–276.

Mason-D'Croz, D. (2016, October 24). Stress Testing the Global Food System [Web log post]. Retrieved from http://www.ifpri.org/blog/stress-testing-global-food-system

Masud, M. M., Rahman, M. S., Al-Amin, A. Q., Kari, F., & Leal Filho, W. (2014). Impact of climate change: an empirical investigation of Malaysian rice production. *Mitigation and adaptation strategies for global change*, *19*(4), 431-444.

Matthews, H. D., Weaver, A. J., Eby, M., & Meissner, K. J. (2003). Radiative forcing of climate by historical land cover change. Geophysical Research Letters, 30(2).

Matthews, H. D., Weaver, A. J., Meissner, K. J., Gillett, N. P., & Eby, M. (2004). Natural and anthropogenic climate change: incorporating historical land cover change, vegetation dynamics and the global carbon cycle. *Climate Dynamics*, *22*(5), 461-479.

McAleer, M. (2013). Modeling the Effects of Oil Prices on Global Fertilizer Prices and Volatility. (Thesis). University of Canterbury. Retrieved from http://hdl.handle.net/10092/11247

McLeod, A. R., & Long, S. P. (1999). Free-air carbon dioxide enrichment (FACE) in global change research: a review. Advances in ecological research, 28, 1-56.

Meadows, D., Randers, J., & Meadows, D. (2004). *Limits to growth: The 30-year update*. Chelsea Green Publishing.

Mihran, R. (2011). Rural Community Vulnerability to Food Security Impacts of Climate Change in Afghanistan: Evidence from Balkh, Herat, and Nangarhar Provinces. (Thesis). University of Waterloo. Retrieved from http://hdl.handle.net/10012/5965

Minot, N. (2010). Transmission of world food price changes to markets in Sub-Saharan Africa. Washington: International Food Policy Research Institute.

Mitchell, Donald. (2008). A note on rising food prices. *World Bank Policy Research Working Paper Series, Vol*

MoA (Ministry of Agriculture and Agro-based Industry]). 2009. Official web site.

Morison, J. I. L., and D. W. Lawlor. (1999). Interactions between increasing CO2 concentration and temperature on plant growth. *Plant, Cell & Environment*22.6 659-682.

Mytty, T. (2013). Does Carbon Dioxide Predict Temperature?. (Thesis). University of Helsinki. Retrieved from http://hdl.handle.net/10138/39922

Naylor, Rosamond L., et al. "Assessing risks of climate variability and climate change for Indonesian rice agriculture." *Proceedings of the National Academy of Sciences* 104.19 (2007): 7752-7757.

Nelson, Gerald C., et al. *Climate change: Impact on agriculture and costs of adaptation*. Vol. 21. Intl Food Policy Res Inst, 2009.

Netherlands Environmental Assessment Agency. (2017). CO2 time series 1990-2015 per region/country. Retrieved 2017-03-07.

Nkongolo, N. V. (2010). Quantification of greenhouse gas fluxes from soil in agricultural fields. (Thesis). Nelson Mandela Metropolitan University. Retrieved from http://hdl.handle.net/10948/1474

NOAA National Centers for Environmental Information, State of the Climate: Global Climate Report for Annual 2016, published online January 2017, retrieved on April 27, 2017 from https://www.ncdc.noaa.gov/sotc/global/20161

Oak Ridge National Laboratory, Tennessee, United States, Carbon Dioxide Analysis Centre, Environmental Sciences Division. (2015). Carbon Dioxide Intensity Data

Othman, M., Ash'aari, Z. H., Muharam, F. M., Sulaiman, W. N. A., Hamisan, H., Mohamad, N. D., & Othman, N. H. (2016, June). Assessment of drought impacts on vegetation health: a case study in Kedah. In *IOP Conference Series: Earth and Environmental Science* (Vol. 37, No. 1, p. 012072). IOP Publishing.

Pacheco, P. (2006). Agricultural expansion and deforestation in lowland Bolivia: the import substitution versus the structural adjustment model. *Land Use Policy*, *23*(3), 205-225.

Parkin, T. B., & Berry, E. C. (1999). Microbial nitrogen transformations in earthworm burrows. Soil Biology and Biochemistry, 31(13), 1765-1771.

Parkin, T. B., Doran, J. W., & Franco-Vizcaino, E. (1996). Field and laboratory tests of soil respiration. *Methods for assessing soil quality/editors, John W. Doran and Alice J. Jones; editorial committee, Richard P. Dick...[et al.]; editor-in-chief SSSA, Jerry M. Bigham; managing editor, David M. Kral; associate editor, Marian K. Viney*.

Parry, M. L., Rosenzweig, C., Iglesias, A., Livermore, M., & Fischer, G. (2004). Effects of climate change on global food production under SRES emissions and socio-economic scenarios. *Global Environmental Change*, *14*(1), 53-67.

Petit, J. R., Jouzel, J., Raynaud, D., Barkov, N. I., Barnola, J. M., Basile, I., ... & Delmotte, M. (1999). Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica. Nature, 399(6735), 429-436.

Pokrivčák, J., & Rajčániová, M. (2011). The impact of biofuel policies on food prices in the European Union. Ekonomický časopis, (05), 459-471.

Quiggin, John. (2010). Drought, climate change and food prices in Australia. *Melbourne: Australian Conservation Foundation*.

Rajagopal, D., Sexton, S., Hochman, G., & Zilberman, D. (2009). Recent developments in renewable technologies: R&D investment in advanced biofuels. Annu. Rev. Resour. Econ., 1(1), 621-644.

Ribeiro Kahn, S., Kobayashi, S., Beuthe, M., Gasca, J., Greene, D., Lee, D. S., ... & Wit, R. (2007). Transport and its infrastructure. *Climate Change (2007) Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, OR Davidson, PR Bosch, R. Dave, LA Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA*.

Roberts, M. J., & Schlenker, W. (2009). World supply and demand of food commodity calories. American Journal of Agricultural Economics, 91(5), 1235-1242.

Rosegrant, M. W., Zhu, T., Msangi, S., & Sulser, T. (2008). Global scenarios for biofuels: impacts and implications. Applied Economic Perspectives and Policy, 30(3), 495-505.

Rosenzweig, Cynthia, and Martin L. Parry. (1994). Potential impact of climate change on world food supply. *Nature* 367.6459 : 133-138.

Rustad, L. E. J. L., Campbell, J., Marion, G., Norby, R., Mitchell, M., Hartley, A., ... & Gurevitch, J. (2001). A meta-analysis of the response of soil respiration, net nitrogen mineralization, and aboveground plant growth to experimental ecosystem warming. Oecologia, 126(4), 543-562.

Safaai, N. S. M., Noor, Z. Z., Hashim, H., Ujang, Z., & Talib, J. (2011). Projection of CO2 emissions in Malaysia. *Environmental Progress & Sustainable Energy*, *30*(4), 658-665.

Saseendran, S. A., Singh, K. K., Rathore, L. S., Singh, S. V., & Sinha, S. K. (2000). Effects of climate change on rice production in the tropical humid climate of Kerala, India. *Climatic Change*, *44*(4), 495-514.

Schlenker, W., & Roberts, M. J. (2009). Nonlinear temperature effects indicate severe damages to US crop yields under climate change. *Proceedings of the National Academy of sciences*, *106*(37), 15594-15598.

Schmidt, G.A., R. Ruedy, J.E. Hansen, I. Aleinov, N. Bell, M. Bauer, S. Bauer, B. Cairns, V. Canuto, Y. Cheng, A. Del Genio, G. Faluvegi, A.D. Friend, T.M. Hall, Y. Hu, M. Kelley, N.Y. Kiang, D. Koch, A.A. Lacis, J. Lerner, K.K. Lo, R.L. Miller, L. Nazarenko, V. Oinas, J.P. Perlwitz, Ju. Perlwitz, D. Rind, A. Romanou, G.L. Russell, Mki. Sato, D.T. Shindell, P.H. Stone, S. Sun, N. Tausnev, D. Thresher, and M.-S. Yao, 2006: Present day atmospheric simulations using GISS ModelE: Comparison to in-situ, satellite and reanalysis data. J. Climate, 19, 153-192, doi:10.1175/JCLI3612.1.

Sedorovich, D. (2008). GREENHOUSE GAS EMISSIONS FROM AGROECOSYSTEMS: SIMULATING MANAGEMENT EFFECTS ON DAIRY FARM EMISSIONS. (Doctoral Dissertation). Penn State University. Retrieved from https://etda.libraries.psu.edu/catalog/8196

Serra, T., Zilberman, D., Gil, J. M., & Goodwin, B. K. (2011). Nonlinearities in the US corn‐ethanol‐oil‐gasoline price system. *Agricultural Economics*, *42*(1), 35-45.

Serra, Teresa. (2011). Volatility spillovers between food and energy markets: a semiparametric approach. *Energy Economics* 33.6 : 1155-1164.

Sionit, N., Mortensen, D. A., Strain, B. R., & Hellmers, H. (1981). Growth response of wheat to CO2 enrichment and different levels of mineral nutrition. *Agronomy Journal*, *73*(6), 1023-1027.

Solomon, S. (Ed.). (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.

Statistics Department of Malaysia. (2016). Local Paddy Production [CSV file]. Retrieved from:https://www.dosm.gov.my/v1/index.php?r=column/ctimeseries&menu_id=NHJlaGc2Rlg4ZXlGTjh1SU1kaWY5UT09

Statistics Department of Malaysia. (2016). Total Paddy Available Paddy land. [CSV file]. Retrieved from:https://www.dosm.gov.my/v1/index.php?r=column/ctimeseries&menu_id=NHJlaGc2Rlg4ZXlGTjh1SU1kaWY5UT09

Tilman, D., Balzer, C., Hill, J., & Befort, B. L. (2011). Global food demand and the sustainable intensification of agriculture. Proceedings of the National Academy of Sciences, 108(50), 20260-20264.

Trang, L. T. H. (2012). *Impacts of climate change and adaptation strategy selection under constrained conditions in Ben Tre province* (Master's thesis, Universitetet i Tromsø).

Trostle, Ronald. (2008). Global agricultural supply and demand: factors contributing to the recent increase in food commodity prices. Washington, DC, USA: US Department of Agriculture, Economic Research Service.

Tscharntke, T., Clough, Y., Wanger, T. C., Jackson, L., Motzke, I., Perfecto, I., Vandermeer, J. & Whitbread, A. (2012). Global food security, biodiversity conservation and the future of agricultural intensification. Biological conservation, 151(1), 53-59.

Turker Dogruer, "The demand and welfare analysis of vegetable oils, biofuel, sugar cane, and ethanol in Europe, Brazil and the U.S." (Masters Thesis), Texas Tech University, 2016

U.S Geological Survey Centre of Earth Resources Observation and Science (Gtop030). (2015). Global 30 Acr-second Elevation.

United Nations Statistics Division's World Energy Data Set. (2015). Global Average Crude Oil Price.

van der Mensbrugghe, Dominique (2006), "Linkage Technical Reference Document," The World Bank, Washington, DC.

Van Groenigen, K. J., Osenberg, C. W., & Hungate, B. A. (2011). Increased soil emissions of potent greenhouse gases under increased atmospheric CO2. Nature, 475(7355), 214-216.

Vengedasalam, D. (2013). Rice research versus rice imports in Malaysia: A dynamic spatial equalibrium model. (Doctoral Dissertation). University of Sidney.

Vitousek, P. M. (1997). Human Domination of Earth's Ecosystems. *Science* 277.5325 : 494-99. Web.

Von Braun, J. (2007). The world food situtation: new driving forces and required actions. Intl Food Policy Res Inst.

Wassmann, R., Hien, N. X., Hoanh, C. T., & Tuong, T. P. (2004). Sea level rise affecting the Vietnamese Mekong Delta: water elevation in the flood season and implications for rice production. Climatic Change, 66(1), 89-107.

Whitehead, D., Hogan, K. P., Rogers, G. N. D., Byers, J. N., Hunt, J. E., McSeveny, T. M., ... & Bourke, M. P. (1995). Performance of large open-top chambers for long-term field investigations of tree response to elevated carbon dioxide concentration. Journal of Biogeography, 307-313.

Wolken, A. R. (2009). Agricultural greenhouse gas emissions : costs associated with farm level mitigation. (Masters Thesis). Massey University. Retrieved from http://hdl.handle.net/10179/1359

Wong, S. C. (1979). Elevated atmospheric partial pressure of CO2 and plant growth. *Oecologia* 44.1 : 68-74.

World Bank Climate Data API. (2014). Carbon dioxide Emissions in Malaysia [API file]. Retrieved from http://climatedataapi.worldbank.org/climateweb/rest/v1/country/cru/tas/year/MYS

World Meteorological Organization. (2016). WMO Statement on the state of the Global Climate in 2016.

Xie, S. P., Deser, C., Vecchi, G. A., Ma, J., Teng, H., & Wittenberg, A. T. (2010). Global warming pattern formation: Sea surface temperature and rainfall. *Journal of Climate*, *23*(4), 966-986.

Yan, H., Liu, J., Huang, H. Q., Tao, B., & Cao, M. (2009). Assessing the consequence of land use change on agricultural productivity in China. *Global and planetary change*, *67*(1), 13-19.

Yang, X. (2012). Assessing climate impacts on crop yields using regional climate models. (Thesis). University of California – Merced. Retrieved from http://www.escholarship.org/uc/item/1tk745hr

Zhou, H. (2009). Population growth and industrialization. *Economic Inquiry*, *47*(2), 249-265.

Zilberman, D., G. Hochman, D. Rajagopal, S. Sexton, and G. Timilsina. "The Impact of Biofuels on Commodity Food Prices: Assessment of Findings." *American Journal of Agricultural Economics* 95.2 (2013): 275-81. Web.s

Zilberman, D., Hochman, G., Rajagopal, D., Sexton, S., & Timilsina, G. (2012). The impact of biofuels on commodity food prices: Assessment of findings. American Journal of Agricultural Economics, aas037.

"The United Nations Framework Convention on Climate Change". 21 March 1994. Climate change means a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.

APPENDIX

Table A.1: Lag Order Selection Criteria

VAR Lag Order Selection Criteria
Endogenous variables: LRICE LCO2 LRAIN LAGRILAND LIMPORTS LOILAVG
Exogenous variables: C
Date: 05/10/17 Time: 21:52
Sample: 1970 2016
Included observations: 42

Lag	LogL	LR	FPE	AIC	SC	HQ
0	53.69273	NA	4.16e-09	-2.271083	-2.022844	-2.180093
1	278.1891	374.1606	5.36e-13	-11.24710	-9.509431*	-10.61018
2	329.3100	70.59548*	2.90e-13*	-11.96714*	-8.740041	-10.78428*

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Table A.2: Johansen Co-integration test

Sample (adjusted): 1973 2013
Included observations: 41 after adjustments
Trend assumption: Linear deterministic trend
Series: LRICE LCO2 LRAIN LAGRILAND LIMPORTS LOILAVG
Lags interval (in first differences): 1 to 2

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.812448	165.0787	95.75366	0.0000
At most 1 *	0.583602	96.45693	69.81889	0.0001
At most 2 *	0.551244	60.53624	47.85613	0.0021
At most 3	0.311838	27.68397	29.79707	0.0860
At most 4	0.257517	12.36102	15.49471	0.1404
At most 5	0.003726	0.153060	3.841466	0.6956

Trace test indicates 3 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**

None *	0.812448	68.62177	40.07757	0.0000
At most 1 *	0.583602	35.92069	33.87687	0.0281
At most 2 *	0.551244	32.85228	27.58434	0.0096
At most 3	0.311838	15.32295	21.13162	0.2669
At most 4	0.257517	12.20796	14.26460	0.1031
At most 5	0.003726	0.153060	3.841466	0.6956

Max-eigenvalue test indicates 3 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Table A.3: Vector Error Correction Model Output
Estimation Proc:
===============================
EC(C,1) 1 2 LRICE LCO2 LRAIN LAGRILAND LIMPORTS LOILAVG

VAR Model:
===============================
D(LRICE) = A(1,1)*(B(1,1)*LRICE(-1) + B(1,2)*LCO2(-1) + B(1,3)*LRAIN(-1) + B(1,4)*LAGRILAND(-1) + B(1,5)*LIMPORTS(-1) + B(1,6)*LOILAVG(-1) + B(1,7)) + C(1,1)*D(LRICE(-1)) + C(1,2)*D(LRICE(-2)) + C(1,3)*D(LCO2(-1)) + C(1,4)*D(LCO2(-2)) + C(1,5)*D(LRAIN(-1)) + C(1,6)*D(LRAIN(-2)) + C(1,7)*D(LAGRILAND(-1)) + C(1,8)*D(LAGRILAND(-2)) + C(1,9)*D(LIMPORTS(-1)) + C(1,10)*D(LIMPORTS(-2)) + C(1,11)*D(LOILAVG(-1)) + C(1,12)*D(LOILAVG(-2)) + C(1,13)

Error Correction:	D(LRICE)	D(LCO2)	D(LRAIN)	D(LAGRILAND)	D(LIMPORTS)
CointEq1	-0.105599	0.055759	-0.155721	0.001713	0.144424
	(0.03822)	(0.04305)	(0.04372)	(0.00665)	(0.11231)
	[-2.76282]	[1.29521]	[-3.56150]	[0.25761]	[1.28597]
D(LRICE(-1))	-0.508713	-0.110874	0.055533	0.022328	-0.106229
	(0.19202)	(0.21628)	(0.21966)	(0.03341)	(0.56421)
	[-2.64932]	[-0.51265]	[0.25282]	[0.66835]	[-0.18828]
D(LRICE(-2))	-0.317084	-0.256466	-0.304378	-0.009894	-0.295044
	(0.17841)	(0.20095)	(0.20409)	(0.03104)	(0.52423)
	[-1.77727]	[-1.27626]	[-1.49136]	[-0.31873]	[-0.56281]
D(LCO2(-1))	0.044594	-0.198587	0.069700	-0.061541	-0.189533
	(0.16195)	(0.18241)	(0.18526)	(0.02818)	(0.47586)
	[0.27536]	[-1.08869]	[0.37623]	[-2.18410]	[-0.39830]
D(LCO2(-2))	-0.035050	0.023791	-0.108959	0.014494	0.657892
	(0.17464)	(0.19670)	(0.19978)	(0.03038)	(0.51314)
	[-0.20070]	[0.12095]	[-0.54541]	[0.47702]	[1.28209]
D(LRAIN(-1))	0.545400	-0.058003	0.112037	0.000196	-0.299075
	(0.17796)	(0.20044)	(0.20357)	(0.03096)	(0.52290)
	[3.06481]	[-0.28938]	[0.55035]	[0.00632]	[-0.57196]
D(LRAIN(-2))	0.548090	0.159527	0.100847	0.007300	-0.845418
	(0.14737)	(0.16599)	(0.16859)	(0.02564)	(0.43303)
	[3.71906]	[0.96105]	[0.59819]	[0.28471]	[-1.95232]

D(LAGRILAND(-1))	-0.645479	-1.167825	-0.469826	0.631082	-4.767322
	(1.19349)	(1.34428)	(1.36531)	(0.20765)	(3.50690)
	[-0.54083]	[-0.86873]	[-0.34412]	[3.03915]	[-1.35941]
D(LAGRILAND(-2))	3.004961	0.719280	2.839825	0.053784	0.272815
	(1.33637)	(1.50521)	(1.52875)	(0.23251)	(3.92672)
	[2.24860]	[0.47786]	[1.85761]	[0.23132]	[0.06948]
D(LIMPORTS(-1))	-0.136589	-0.042075	-0.235352	-1.83E-05	0.124297
	(0.05973)	(0.06728)	(0.06833)	(0.01039)	(0.17551)
	[-2.28669]	[-0.62539]	[-3.44431]	[-0.00176]	[0.70819]
D(LIMPORTS(-2))	0.011033	0.057871	-0.096528	-0.009099	-0.525489
	(0.04777)	(0.05380)	(0.05464)	(0.00831)	(0.14036)
	[0.23097]	[1.07561]	[-1.76648]	[-1.09485]	[-3.74392]
D(LOILAVG(-1))	-0.049704	-0.037377	0.016136	-0.002904	-0.138114
	(0.04967)	(0.05594)	(0.05682)	(0.00864)	(0.14594)
	[-1.00078]	[-0.66816]	[0.28401]	[-0.33611]	[-0.94641]
D(LOILAVG(-2))	-0.024072	0.009497	-0.071239	0.000833	0.134614
	(0.04579)	(0.05158)	(0.05238)	(0.00797)	(0.13455)
	[-0.52568]	[0.18413]	[-1.35992]	[0.10459]	[1.00045]
C	-0.010579	0.086976	-0.009742	0.007964	0.091669
	(0.03347)	(0.03770)	(0.03828)	(0.00582)	(0.09834)
	[-0.31609]	[2.30736]	[-0.25447]	[1.36769]	[0.93219]

Table A.4: Residual Correlation Matrix

	LRICE	LCO2	LRAIN	LAGRILAND	LIMPORTS	LOILAVG
LRICE	1.000000	0.300962	-0.466243	-0.007066	-0.394314	0.354236
LCO2	0.300962	1.000000	0.186438	-0.135177	0.083116	0.432481
LRAIN	-0.466243	0.186438	1.000000	-0.015061	0.267401	-0.374696
LAGRILAND	-0.007066	-0.135177	-0.015061	1.000000	-0.528235	-0.400549
LIMPORTS	-0.394314	0.083116	0.267401	-0.528235	1.000000	0.205853
LOILAVG	0.354236	0.432481	-0.374696	-0.400549	0.205853	1.000000