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AN ASSESSMENT OF THE ECONOMIC IMPACT OF CLIMATE CHANGE ON THE HEALTH SECTOR IN TRINIDAD AND TOBAGO

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Notes and explanations of symbols:

The following symbols have been used in this study:

A full stop (.) is used to indicate decimals

n.a. is used to indicate that data are not available

The use of a hyphen (-) between years, for example, 2010-2019, signifies an annual average for the calendar years involved, including the beginning and ending years, unless otherwise specified.

The word “dollar” refers to United States dollars, unless otherwise specified.

The term “billion” refers to a thousand million.

The boundaries and names shown and the designations used on maps do not imply official endorsement or acceptance by the United Nations.

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Executive Summary

This research paper assesses the likely economic impact of climate change on the health sector in Trinidad and Tobago. The analysis, however, was limited to the economic impact of only a few climate-related diseases[1] for which data were available. The approach utilized in this paper makes for easy extrapolation once the data on the other climate-related illnesses become available so that a full impact assessment can be carried out. Despite this shortcoming, however, the most important outcome of this study, which will have a direct bearing on policy, is the finding that climate change has had and is expected to have, based on the Special Report Emissions Scenarios (SRES) of the Intergovernmental Panel on Climate Change (IPCC), and impact on disease incidence in Trinidad and Tobago.

In this study, incidence levels in the A2 and B2 emissions trajectories scenarios are analyzed and compared. A baseline or Business as Usual (BAU) scenario is also utilized but is simply used as a reference point to understand how vulnerability may change which is reflected in the A2 and B2 scenarios. IPCC (2000) defines the A2 storyline and scenario family as a very heterogeneous world in which the underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which result in continuously increasing global population. Economic development is primarily regionally oriented and per capita economic growth and technological changes are both more fragmented and slower than in other storylines. The B2 storyline and scenario family, however, describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability problems. It is a world with continuously increasing global population but at a rate lower than A2. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels. The baseline scenario simply uses past trends in deriving forecast changes in the variable or variables, under consideration - in our case, disease incidence.

Regression models were constructed to establish relationships, if any, between disease incidence and climate and non-climate variables before constructing the scenarios. In the model for dengue fever, the adjusted R-squared was 75% which is a reasonably good fit. The independent variables were significant at the 5% and 10% levels of significance. Population and rainfall were found to be positively related with dengue fever incidence while increased access to improved water sources and increased access to improved sanitation facilities were found to be inversely related with dengue fever incidence. All four variables satisfied a priori expectations. Using polynomial representations to analyze the temperature variable, it was found that this variable had an increasing effect on dengue fever incidence. This means that the slope of the quadratic temperature relationship is a steadily rising one. Calculating the change in the dependent variable (dengue fever incidence) given the actual temperature values, it was observed that as the temperature rose the change in dengue fever was positive; as temperature increases so too does the incidence of dengue fever. The relative humidity variable also showed a similar effect on the dependent variable but at a rate of change that is lower, thus resulting in a flatter slope.

The model for leptospirosis had an adjusted R-squared of approximately 46% which indicates that the variables in the model are moderately useful in explaining the variation in the incidence of leptospirosis. All the independent variables were significant at 5% and 10%. Consistent with the literature, and as expected, the model shows a positive relationship between rainfall (lagged one period) and leptospirosis incidence. In addition, as increases in access to improved sanitation facilities occur, the model shows that the incidence of leptospirosis decreases. As predicted, the model shows a negative relationship between forest area and leptospirosis incidence. This relationship could be explained by assuming that since forested areas serve as habitats for rodents, destruction of such habitats would mean that rodent populations may have to seek new homes, thus possibly increasing their contact with humans.

[1] The diseases analysed were, dengue, leptospirosis, food-borne illnesses and gastroenteritis.

With an adjusted R-squared of 24%, the model for food-borne illnesses shows that the effects of the relative humidity variable and the rainfall variable may not be very strong. The relative humidity variable is shown to have an increasing effect on food-borne illnesses which means that the slope of the relationship between the two variables is increasing. The outcome, however, is that of a cumulative positive relationship, with a rise in relative humidity being linked to a positive change in food-borne illnesses; as relative humidity increases so, too, do the number of cases of food-borne illnesses. This is consistent with the links identified in the literature. The point here is that high relative humidity means that the air is saturated with *moisture* which is a key factor in the growth of mould and bacteria. Somewhat surprisingly, for rainfall the result has been an overall diminishing effect. As rainfall increases, the incidence of food-borne diseases was seen to decrease.

The model for food-borne illnesses suggested that although an increase in access to water sources is linked to an increase in gastroenteritis cases, the second round effects of increases in access to improved water sources were found to be diminishing. In other words, although the number of gastroenteritis cases was rising alongside increases in access to improved water sources, it was doing so at a decreasing rate. This proves the importance of the improvements in water sources in probably counteracting the other factors responsible for gastroenteritis. In addition, the cumulative outcome of relative humidity showed that, as expected, there was a positive relationship with gastroenteritis, but only up to a certain level - the turning point in the quadratic relationship.

The scenarios were constructed using the empirical results and some interesting results were obtained. Dengue fever incidence levels are remarkably higher in the BAU scenario for the most part of 2008 to 2050. The B2 scenario is the lowest impact scenario in terms of incidence levels. Total number of new cases for the period 2008 to 2050 was 204,786 in BAU, 153,725 in A2 and 131,890 in B2.

For leptospirosis, A2 and B2 seem to be following a similar path with total number of new cases in A2 being 9,727 and 9,218 cases in B2. Although incidence levels in the BAU scenario coincided with those of A2 and B2 prior to 2020, they became somewhat lower post 2020. Total number of new cases of leptospirosis in the BAU scenario for the period under consideration amounted to 7,338. This is a surprising result which points to the need for further investigation.

A similar picture emerges for the scenarios as they relate to food-borne illnesses and to gastroenteritis. In the case of food-borne illnesses, all three scenarios seem to be following along similar paths, with the exception of the few outliers in the BAU scenario. What is interesting is that when the total number of new cases of food-borne illnesses is compared in all three scenarios, the BAU scenario recorded 27,537 new cases, the A2 recorded 28,568 new cases and the B2 recorded 28,679 new cases. Although these numbers are close enough, the fact that the BAU emerges as the preferred scenario is certainly indicative of the need for more research.

In the case of gastroenteritis, the BAU scenario again appears to be the most stable scenario and least impact scenario (978,427 new cases over the period**).**

Despite the mixed results for impact of the individual diseases on the health sector across scenarios, when the overall picture is taken, our analysis shows that the most costly impact on the health sector is expected to be in the BAU scenario. This was seen when the cost of treating the diseases in question was considered. The least cost impact was experienced in the B2 scenario. In other words, making the necessary corrections in the recalcitrant cases cited above will only compound the overall result that was expected.

The study also points to the adaptation measures which can be taken to reduce or alleviate the impact of climate change on disease incidence. While an independent benefit value to these adaptation measures has not been placed, in terms of the impact on disease incidence, it was possible to use the models to explore the impact of a 1% increase in the percentage of the population with access to improved water sources on the different diseases. In the case of dengue fever, a reduced incidence of 308 cases was projected. A similar exploration, looking at a 1% increase in the percentage of population with access to improved sanitation facilities, showed a decrease in the incidence of dengue fever by 453 cases and in the incidence of leptospirosis by 10.44 cases. In addition, increases in access to improved water sources are shown to cause a decrease in the rate at which gastroenteritis is increasing.

In order to get an idea of the scale of investment required for the improvements suggested, the study assumes a unit elastic relationship between *total expenditure* on improved water sources and sanitation facilities and the access to these improved sources and facilities. In other words, the 1% increase in access assumed earlier will require at least a 1% increase in total expenditure. It must be emphasized that the adaptation measures outlined may not represent all areas of expenditure regarding the improvement of sanitation facilities and water sources in Trinidad and Tobago. At the very least, the 1% expenditure increases indicated can be seen as a well-placed platform for additional investments to achieve the disease incidence required. Such investments can be justified on two grounds:

a) According to the empirical results, such efforts to improve sanitation and water sources are expected to have an impact on disease incidence and, so, welfare benefits of less morbidity amongst the population will be achieved; and

b) Maintaining and/or improving health status of a population is one of main factors in the achievement of sustainable development.

In this context, a range of adaptation measures were discussed in relation to water resources, sanitation and attitudes, behaviours and lifestyles as these were found in the study to be major drivers of the diseases considered in Trinidad and Tobago. While all the measures showed merit in reducing disease incidence, perhaps the most important finding is that it is the behavioural change on the part of the population that is likely to have the greatest beneficial impact.

The study, therefore, concludes that the challenges and the imperatives facing policy makers are therefore twofold. On the one hand, policy will have to make the necessary prioritization of resources which will constitute adaptation. On the other hand, public policy will need to use all facilities at its disposal to appropriately educate and motivate the population, and to develop a pattern of incentives and sanctions aimed at encouraging the population to behave in a manner which will minimize the avoidable impact of climate change.

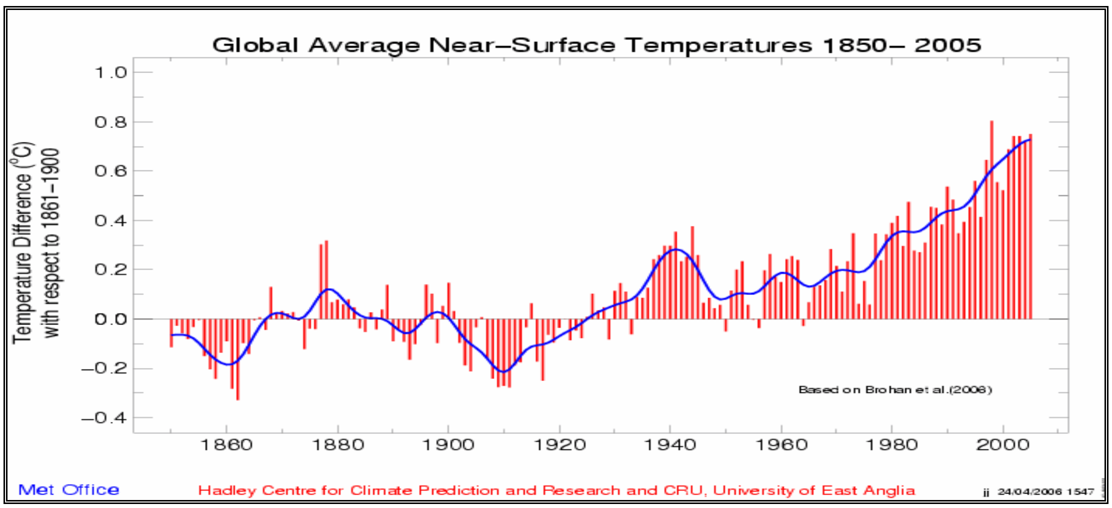
I. THE SCIENTIFIC EVIDENCE OF CLIMATE CHANGE

It is evident from observations that the climate system is warming given the increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level (IPCC 2007a).

A. AVERAGE NEAR-SURFACE TEMPERATURES

The Earth has warmed about 0.7°C since 1900 (Stern 2007). The first IPCC report (1990) on climate change made projections that global average temperature would increase between 0.15°C and 0.3°C per decade from 1990 to 2005. Observed values for this period show an increase of 0.2°C per decade (IPCC 2007a). Figure 1 shows the increasing trend in global average near- surface temperatures during the period 1850 to 2005.

Figure 1: Global average near-surface temperatures, 1985-2005



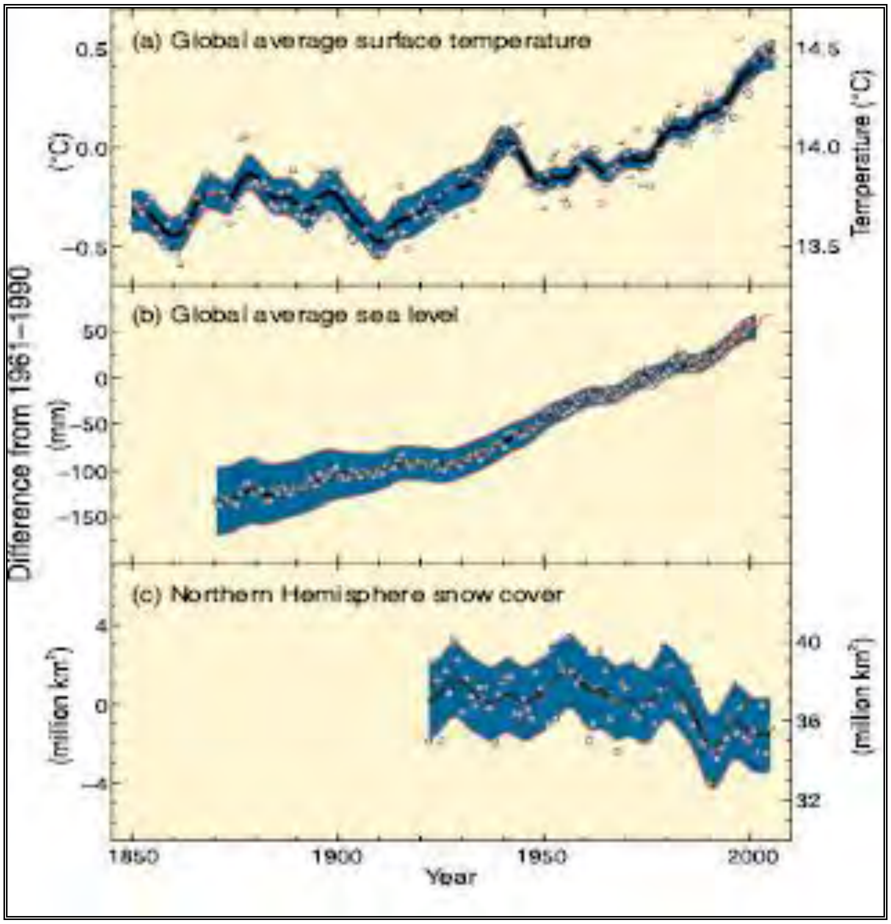
Source: Brohan et al. (2006), cited by Stern (2007).

The temperature increase is widespread over the globe and is greater at higher northern latitudes; average Arctic temperatures have increased at almost twice the global average rate in the past 100 years. Land regions have, however, warmed faster than the oceans. The warmest years in record of global surface temperatures are 1998 and 2005. Eleven of the 12 years spanning 1995 to 2006 rank among the 12 warmest years on record since 1850. (IPCC 2007a, 2007b)

B. AVERAGE SEA LEVEL RISE AND SNOW AND ICE EXTENT

Warming has resulted in an increase in global average sea level which rose at an average rate of 1.8 ± 0.5 mm per year over 1961 to 2003 and at an average rate of about 3.1 ± 0.7 mm per year from 1993-2003 (see figure 2). This suggests that the rise in global mean sea level is accompanied by substantial decadal variability. Contributing to this since 1993 have been thermal expansion of the oceans, decreases in glaciers and ice caps and loss of polar ice sheets. There have been observed declines in snow and ice cover. Arctic sea extent has shrunk by 2.7% per decade with larger decreases in summer of 7.4% per decade. Mountain glaciers and snow cover on average have also declined in both hemispheres. (IPCC 2007a, 2007b)

Figure 2: Changes in temperature, sea level and Northern Hemisphere snow cover



Source: IPCC (2007a).

C. Extreme Events

Eastern parts of North and South America, northern Europe and northern and central Asia have experienced significant increases in precipitation while there have been declines in Sahel, the Mediterranean, southern Africa and parts of southern Asia over the period 1900-2005. Substantial increases were found in heavy precipitation events within many land regions, and the incidence of diarrhoea has increased since the 1970s, more so in the tropics and subtropics. (IPCC 2007a, 2007b)

Changes have also been recorded in the frequency and intensity of extreme weather events over the last 50 years. A widespread reduction in the number of frost days in mid-latitude regions, an increase in the number of warm extremes and a reduction in the number of daily cold extremes are observed in 70% to 75% of the land regions where data are available. Since 1970, drought has become more frequent, especially in the tropics and subtropics. Observational evidence shows an increase in the intensity of tropical cyclones in the North Atlantic since about 1970. (IPCC 2007a, 2007b)

D. PROJECTIONS: GLOBAL, SMALL ISLAND DEVELOPING STATES AND TRINIDAD AND TOBAGO

1. Global

Global projections on climate change by IPCC (2007a) show that warming of about 0.2° C is expected for the next two decades. Projected global average warming is expected to be 1.1°C to 6.4°C at 2090-2099 while sea level rise is expected to be within the range 0.18m and 0.59m. Precipitation is also likely to decrease in most subtropical land regions and sea ice in both the Arctic and Antarctic is expected to decrease.

2. Small Island Developing States (SIDS)

In regions where small islands are located, data show that temperatures have been increasing by as much as 0.1°C per decade, and sea level has risen by 2 mm per year (IPCC 2001). Sea levels are likely to continue to rise in and around small islands and temperature increases are expected to continue with the increase being smaller than the global mean (IPCC 2007b).

3. Trinidad and Tobago

Below are climate change projections for Trinidad and Tobago from its Climate Change Policy Summary.

"Downscaled regional models give projections for Trinidad and Tobago for higher temperatures and lower rainfall. The mean annual temperature is projected to increase by 0.7 to 2.6°C by the 2060s, and 1.1 to 4.3 degrees by the 2090s. The range of projections by the 2090s under any scenario is around 1-2°C. The projected rate of warming is similar throughout the year. Projections of mean annual rainfall indicate decreases in rainfall for Trinidad and Tobago. Sea-level in this region is projected by climate models to rise by the following levels by the 2090s, relative to 1980-1999 sea-level: 0.13 to 0.43m under B1 scenario and 0.18 to 0.56m under A2 scenario." (The Government of Trinidad and Tobago (GOVTT 2009, 2).

II. THE IMPACTS OF CLIMATE CHANGE

Although some regions may experience beneficial effects of climate change, human-induced climate change is adding new stress to already sensitive ecological and socio economic systems and, as such, net negative impacts are therefore more likely in most parts of the world (IPCC 1995, 2001). A summary of climate change impacts is shown in table 1 as provided by Stern (2007). The impacts are mainly on food and water resources, eco-systems, coastal zones, human settlements, energy and industry and human health. Table 2 highlights possible climate impacts on different sectors at different degrees of warming. It is noted that the higher the degree of warming the greater are the impacts on human health and on human settlements.

Table 1 – Summary of climate change impacts

Climate change trends	Impacts
Melting glaciers	**Increase flood risk during the wet season and strongly reduce dry-season water supplies to one-sixth of the world's population, predominantly in the Indian sub-continent, parts of China, and the Andes in South America.**
Declining crop yields	**Especially in Africa, this is likely to leave hundreds of millions without the ability to produce or purchase sufficient food. At mid to high latitudes, crop yields may increase for moderate temperature rises (2 – 3°C), but then decline with greater amounts of warming.**
Ocean acidification	**This is a direct result of rising carbon dioxide levels and will have major effects on marine ecosystems, with possible adverse consequences on fish stocks.**
Rising sea levels	**This will result in tens to hundreds of millions more people flooded each year with a warming of 3 or 4°C. There will be serious risks and increasing pressures for coastal protection in South East Asia (Bangladesh and Vietnam), small islands in the Caribbean and the Pacific, and large coastal cities. By the middle of the century, 200 million more people may become permanently displaced due to rising sea levels, heavier floods, and more intense drought, according to one estimate.**
Heat Stress	**Climate change will increase worldwide deaths from malnutrition and heat stress. Vector-borne diseases such as malaria and dengue fever could become more widespread if effective control measures are not in place. In higher latitudes, cold-related deaths will decrease.**
Eco-systems	**These systems will be particularly vulnerable to climate change, with one study estimating that around 15 – 40% of species face extinction with 2°C of warming. Strong drying over the Amazon, as predicted by some climate models, would result in dieback of the forest with the highest biodiversity on the planet.**

Source: Stern (2007)

Table 2 - Highlights of possible climate impacts on different sectors at different degrees of warming

Temp rise (°C)	Water	Food	Health	Land	Environment	Abrupt and Large-Scale Impacts
1°C	Small glaciers in the Andes disappear completely, threatening water supplies for 50 million people	Modest increases in cereal yields in temperate regions	At least 300,000 people each year die from climate-related diseases (predominantly diarrhoea, malaria, and malnutrition) Reduction in winter mortality in higher latitudes (Northern Europe, USA)	Permafrost thawing damages buildings and roads in parts of Canada and Russia	At least 10% of land species facing extinction (according to one estimate) 80% bleaching of coral reefs, including Great Barrier Reef	Atlantic Thermohaline Circulation starts to weaken
2°C	Potentially 20 - 30% decrease in water availability in some vulnerable regions, e.g. Southern Africa and Mediterranean	Sharp declines in crop yield in tropical regions (5 - 10% in Africa)	40 – 60 million more people exposed to malaria in Africa	Up to 10 million more people affected by coastal flooding each year	15 – 40% of species facing extinction (according to one estimate) High risk of extinction of Arctic species, including polar bear and caribou	Potential for Greenland ice sheet to begin melting irreversibly, accelerating sea level rise and committing world to an eventual 7 m sea level rise Rising risk of abrupt changes to atmospheric circulations, e.g. the monsoon Rising risk of collapse of West Antarctic Ice Sheet Rising risk of collapse of Atlantic Thermohaline Circulation
3°C	In Southern Europe, serious droughts occur once every 10 years 1 - 4 billion more people suffer water shortages, while 1 – 5 billion gain water, which may increase flood risk	150 - 550 additional millions at risk of hunger (if carbon fertilisation weak) Agricultural yields in higher latitudes likely to peak	1 – 3 million more people die from malnutrition (if carbon fertilisation weak)	1 – 170 million more people affected by coastal flooding each year	20 – 50% of species facing extinction (according to one estimate), including 25 – 60% mammals, 30 – 40% birds and 15 – 70% butterflies in South Africa Collapse of Amazon rainforest (according to some models)	
4°C	Potentially 30 – 50% decrease in water availability in Southern Africa and Mediterranean	Agricultural yields decline by 15 – 35% in Africa, and entire regions out of production (e.g. parts of Australia)	Up to 80 million more people exposed to malaria in Africa	7 – 300 million more people affected by coastal flooding each year	Loss of around half Arctic tundra Around half of all the world's nature reserves cannot fulfill objectives	
5°C	Possible disappearance of large glaciers in Himalayas, affecting one-quarter of China's population and hundreds of millions in India	Continued increase in ocean acidity seriously disrupting marine ecosystems and possibly fish stocks		Sea level rise threatens small islands, low-lying coastal areas (Florida) and major world cities such as New York, London, and Tokyo		
More than 5°C	The latest science suggests that the Earth's average temperature will rise by even more than 5 or 6°C if emissions continue to grow and positive feedbacks amplify the warming effect of greenhouse gases (e.g. release of carbon dioxide from soils or methane from permafrost). This level of global temperature rise would be equivalent to the amount of warming that occurred between the last age and today – and is likely to lead to major disruption and large-scale movement of population. Such "socially contingent" effects could be catastrophic, but are currently very hard to capture with current models as temperatures would be so far outside human experience.					

Note: This table shows illustrative impacts at different degrees of warming. Some of the uncertainty is captured in the ranges shown, but there will be additional uncertainties about the exact size of impacts. Temperatures represent increases relative to pre-industrial levels. At each temperature, the impacts are expressed for a 1°C band around the central temperature, e.g. 1°C represents the range 0.5 – 1.5°C etc. Numbers of people affected at different temperatures assume population and GDP scenarios for the 2080s from the Intergovernmental Panel on Climate Change (IPCC). Figures generally assume adaptation at the level of an individual or firm, but not economy-wide adaptations due to policy intervention. Source: Extracted from Stern (2007).

Small islands contribute less than 1% to global greenhouse gas (GHG) emissions but they are faced with potentially catastrophic consequences of climate change (UNFCCC, 2005). Of greater concern is the fact that small islands have characteristics which make them vulnerable to the effects of climate change: small size, proneness to natural hazards, vulnerability to external shocks, geographic location. (IPCC, 2007c). The following are some projected climate change impacts for small islands:

- "Sea level rise is expected to exacerbate inundation, storm surge, erosion and other coastal hazards, thus threatening vital infrastructure, settlements and facilities that support the livelihood of island communities;
- There is strong evidence that under most climate scenarios, water resources in small islands are likely to be seriously compromised (very high confidence);
- On some islands, especially those at higher latitudes, warming has already led to the replacement of some local species (high confidence);
- It is very likely that subsistence and commercial agriculture on small islands will be adversely affected by climate change (high confidence);
- New studies confirm previous findings that the effects of climate change on tourism are likely to be direct and indirect and largely negative (high confidence) and
- There is a growing concern that global climate change is likely to impact human health, mostly in adverse ways (medium confidence)".

(IPCC 2007c)

Trinidad and Tobago, one of the SIDS in the Caribbean, contributes insignificantly to total global carbon emissions. However, according to the Carbon Dioxide Information Analysis Center, Trinidad and Tobago in 2007 was ranked sixth in the world and first in the region based on its per capita fossil-fuel CO_2 emissions, reflecting its vibrant economy and its small population[2]. For the period 1990 to 2006, GHG inventories conducted indicated that the energy, transportation and industrial sectors account for the majority of carbon dioxide emissions (GOVTT, 2009).

Trinidad and Tobago is particularly vulnerable to the adverse impacts of climate change such as those related to temperature increases, changes in precipitation and sea level rise (GOVTT 2009). Official awareness of the situation is found in the Draft National Climate Change Policy of Trinidad and Tobago which states that,

"As a small island developing state, Trinidad and Tobago is particularly vulnerable to the adverse impacts of climate change such as those related to temperature increases, changes in precipitation and sea level rise. Specific sectors that are likely to be impacted on are the agriculture sector, human health, human settlements, coastal zones, and water resources as well as cross-sectional socio-economic systems." (GOVTT, 2009, 2)

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[2] Carbon Dioxide Information Analysis Center (CDIAC), "Fossil-Fuel CO_2 Emissions: Per Capita Emissions". Available from http://cdiac.ornl.gov/trends/emis/meth_reg.html (accessed June 20, 2011).

Table 3 outlines the projected impacts for specific sectors in Trinidad and Tobago.

Table 3: Sectoral impacts of climate change

	Projected Sectoral Impacts
Agriculture	Projected increases in ambient air temperature and decreases in precipitation is likely to result in increased aridity of soils and decreased crop yields due to intolerance of crop varieties and reduced water availability for irrigation. Projected increases in sea level are likely to result in inundation and flooding of coastal areas and salinisation of productive soils leading to decreased crop yields and available areas for agricultural production.
Human Settlements	Projected increases in heavy precipitation events can result in increased incidences of flooding which can have adverse impacts on human settlements and human health, resulting in disruption of settlements, commerce, transport and towns and villages. This further adds pressure on urban and rural infrastructure and loss of property.
Coastal Zones	The impacts in the coastal zone are expected to be multisectoral given the fact that a coastal zone encompasses a broad range of users. The impacts will arise largely as a result of sea level rise and temperature increases. Impacts include: increased inundation, increased erosion and loss of coastline and coastal amenities, loss of natural resources, loss of coastal agricultural lands due to soil salinisation, loss of natural coastal defenses such as coral reefs etc.
Water Resources	Loss of available surface water due to temperature increases, reduced availability of surface water and potable water resulting from decreased rainfall and contamination of water sources are some of the projected impacts on water resources.
Human Health	Projected increases in air temperature are likely to increase vector populations thereby increasing the spread of vector-borne diseases. Projected decreases in precipitation are likely to result in reduced availability of safe water for household use and agriculture thereby contributing to a host of water-borne and food-borne illnesses. The projected increase in precipitation intensity is also expected to contribute to water-borne diseases especially in areas prone to flooding. Impacts on water resources, human settlements, coastal zones and agriculture can also indirectly impact human health. For example, loss of livelihoods along coastlines resulting from sea level rise can affect the ability of households to meet basic needs such as food and clothing exposing them to a host of health problems. Also, high intensity precipitation followed by severe flooding can affect the availability and quality of locally cultivated food thereby impacting nutritional levels.

Source: Adapted from GOVTT (2009).

A. HUMAN HEALTH IMPACTS OF CLIMATE CHANGE

1. Introduction

Since the focus of this study is on the impact of climate change on the health sector in Trinidad and Tobago, it is necessary to delve deeper into the human health impacts of this environmental change.

Following the noticeable increase in global temperatures, some health outcomes are likely to have already been affected. However, there is nothing distinctive about the actual types of health outcomes due to long-term climate change versus short-term natural variation. As such, the detection of health effects due to climate change is, at this early stage, difficult. Despite this, however, if changes in various health outcomes occur, each plausibly due to the preceding climate change, then pattern-recognition can be used, as was used for the assessment of non-human effects of recent climate change. (Walther et al., 2002, cited by McMichael, Woodruff and Hales, 2006).

Pattern-recognition requires several decades of health surveillance data to determine whether or not any observed changes in diseases might be related to changes in climate. The complexity of this causal pathway makes attribution of health effects to climate change difficult. This is so especially since there are other potential competing explanations of changes in disease patterns, such as, changes in important health determinants and changes in the way diagnoses may be recorded. (Haines et al., 2006)

McMichael, Woodruff and Hales (2006) note that although no one extreme event can be attributed solely to climate change, the probability of a particular event occurring under modified climatic conditions can be estimated. This paper uses a similar approach to analyze disease patterns under different GHG emissions scenarios.

2. Pathways by which climate change affects population health

Although there is no conclusive evidence in the literature that links observed health outcomes to climate change, what is clear, however, is that long-term changes in climatic variables will have implications for human health (figure 3 illustrates).

Figure 3 shows that climate change is influenced by both natural climate and anthropogenic forces. There are a number of environmental effects of climate change, each of which is linked to numerous health impacts. Some of the health impacts of climate change relate to extreme events, microbial proliferation, changes in vector-pathogen-host relations and infectious disease geography and seasonality, impaired crop, livestock and fisheries yields, and loss of livelihoods and displacement. Mitigation in the diagram refers to prevention to reduce GHG emissions while adaptation refers to interventions to lessen and cope with the adverse health effects of climate change.

The health effects of climate change highlighted can be classified into *direct and indirect health impacts*. Human beings are directly exposed to climate change through changing weather patterns[3] and indirectly through changes in water, air and food quality; ecosystems; agriculture; industry and settlements and the economy (IPCC 2007c). Box 1 illustrates.

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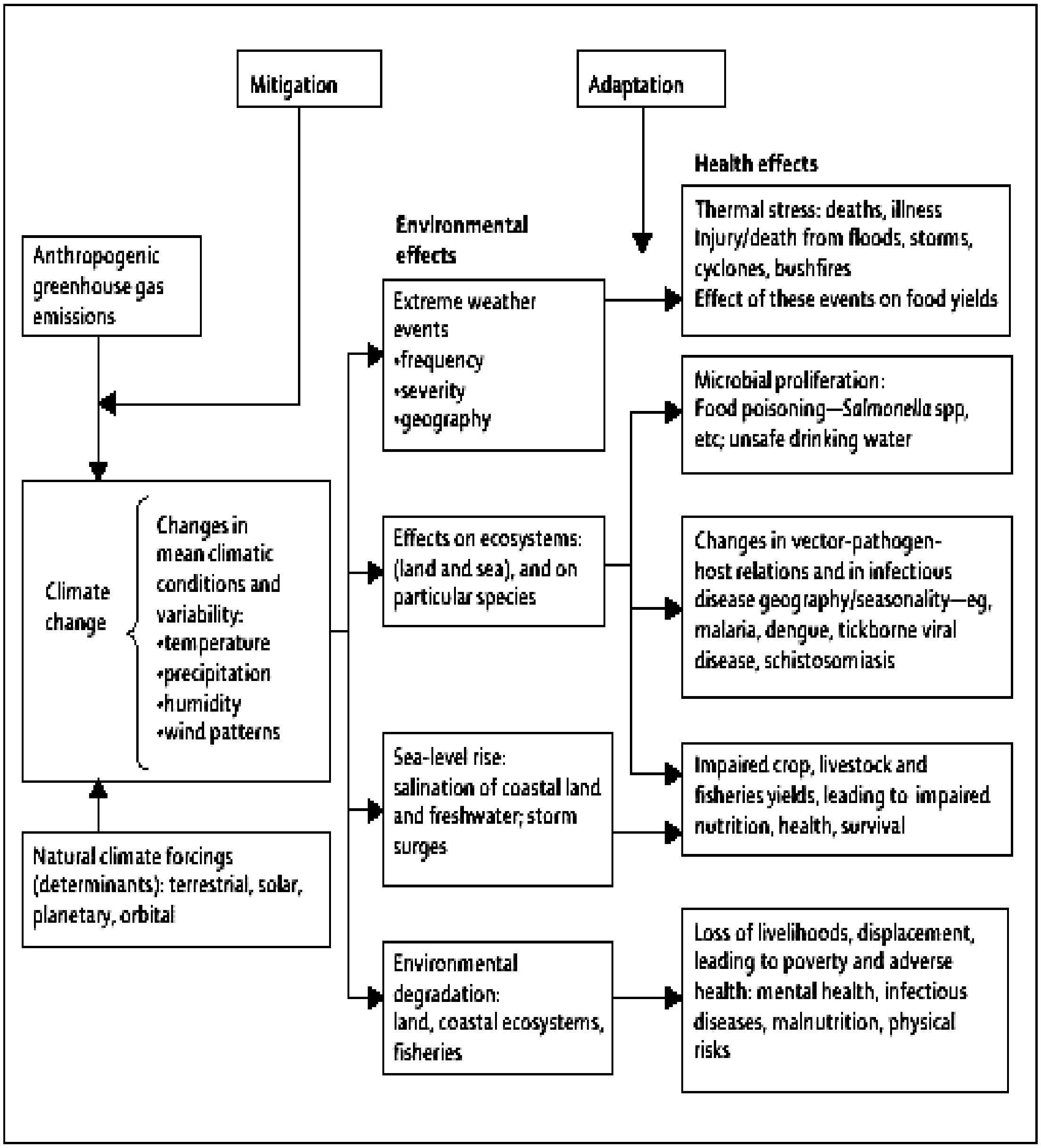
[3] Temperature, precipitation, sea-level rise and more frequent extreme events.

Figure 3: Pathways by which climate change affects human health



Source: Extracted from McMichael, Woodruff and Hales (2006).

Box 1 – Direct and indirect impacts of climate change

Direct Health Impacts

Altered rates of heat and cold-related illness and death, especially cardiovascular and respiratory diseases resulting from exposure to thermal extremes (particularly heatwaves)
Deaths, injuries, psychological disorders and damage to public health infrastructure resulting from altered frequency and or intensity of other extreme weather events such as floods and storms.

Indirect Health Impacts

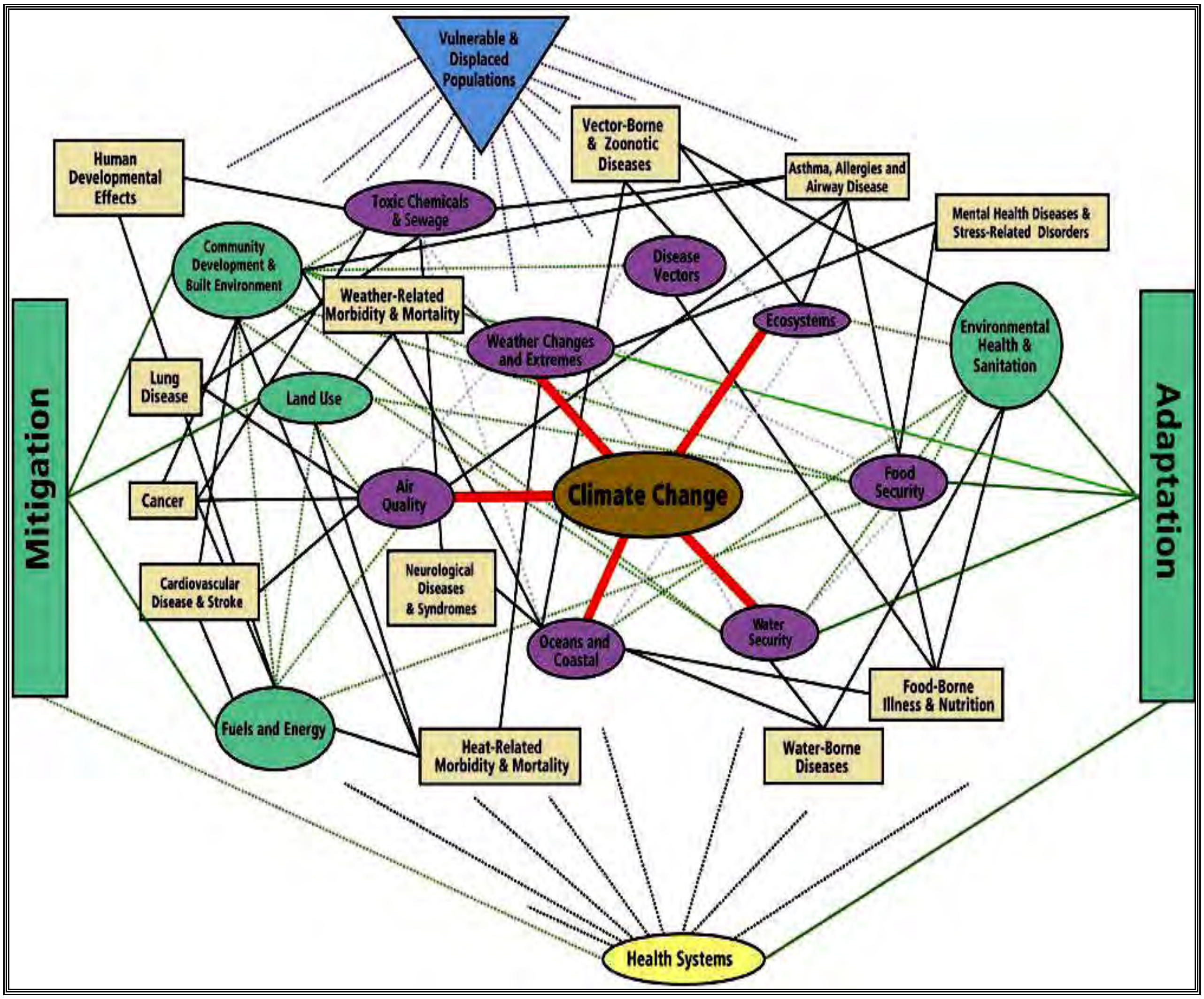
Changes in incidences of vector-borne diseases such as, (malaria, dengue fever, yellow fever and some viral encephalitis) **resulting from extensions of geographic ranges and season of vector organisms.**
Changed incidence of diarrhoeal and other infectious diseases resulting from altered local ecology of water-borne and food-borne infective agents;
Malnutrition and hunger and consequent impairment of child growth and development due to changes in the availability and quality of food;
Injuries, increased risks of infectious diseases and psychological disorders resulting from sea-level rise associated with population displacement and damage to important infrastructure for example, sanitation facilities;
Likely increase in Asthma and allergic disorders and other acute and chronic respiratory disorders and deaths due to levels and biological impacts of air pollution including pollens and spores; and
A wide range of public health consequences such as, mental health, nutritional impairment, infectious diseases and civil strife.
Source: Adapted from (IPCC 1995).

Having discussed the pathways by which climate change can affect human health, figure 4 provides a network that helps to crystallize the relationships identified between climate change and health. Figure 4 is a global view of the complex ecological networks that can be disrupted by climate change and the human health implications of such disruptions.

Climate change, at the centre of the network, has direct impacts on five aspects of the human environment (red lines, purple circles): weather changes and extremes, eco-systems, water security, oceans and coastal and air quality. These in turn impact additional environmental factors and results in environmental changes that impact 12 separate aspects of human health (tan boxes).

The network identifies the issue of vulnerability and shows that susceptible populations exist for all climate-targeted health points. Finally, the network clearly highlights the mitigation and adaptation components which alter the human environment in order to address climate change and, in this way, alter human health. Interestingly, the network is positioned in such a way as it shows the importance of the health system in addressing the health concerns driven by climate change.

Figure 4 - Complex network of the human health impacts of climate change



Source: Extracted from Portier et al. (2010).

Climate change was found to be (with very high confidence) contributing to the global burden of disease and premature deaths (IPCC, 2007c). Given the already high baseline prevalence rates of malnutrition, diarrhoeal diseases and malaria, these are expected to contribute the greatest burdens of mortality and morbidity attributable to climate change, based on current estimates from epidemiological modelling (Hall 2009). In addition, emerging evidence of the effects of climate change on human health shows that it has altered the distribution of some infectious diseases and some allergenic pollen species (IPCC, 2007c). In Europe, there is now evidence of vector species responding to recent climate change (Purse et al., 2005, cited by Haines et al., 2006).

a) Water, Vector and food-borne illnesses

Weather can significantly affect the availability and quality of water sources available to a country's population. In Trinidad and Tobago, the primary supply of water is surface water (60%), followed by wells (30%) and desalination (10%). Surface water refers to precipitation (rainwater) that is stored in streams, lakes, rivers and ponds. Given the heavy dependence on rainwater in Trinidad and Tobago, changes in rainfall can significantly impinge on the availability of safe drinking water and water for household use, thereby contributing to water-borne diseases. For instance, reduced rainfall can result in the use of unsafe water for household use which may contain bacteria and pathogens that can lead to a host of infectious diseases. Also, high intensity rainfall linked to severe flooding may contaminate fresh water sources with pollutants such as sewerage again, impacting disease incidence. A study done in 1999 (cited by Water Resource Agency, 2001) revealed that more pollutants were present in the Caroni River (a major water source) during the rainy season when flooding is more likely.

For vector-borne diseases, temperature and rainfall have been identified in the literature as influencing factors (IPCC, 1995; McMichael et al., 2003). Some vectors favour warmer temperatures and, so, a small increase in temperature can significantly increase vector populations thereby increasing the risk of infection. Heavy precipitation events that result in flooding can also contribute to vector-borne diseases. In fact, the emergence and manifestation of the mosquito-borne dengue fever and the rat-borne leptospirosis has been linked to an increase in flooding in Jamaica and other countries (Hotez, 2008). Although dengue fever is transmitted via a vector, the vector's association with water storage is a factor contributing to its endemic aspect in Trinidad and Tobago (PAHO Country Health Profile: Trinidad and Tobago). This is because there is poor coverage in terms of potable water supply and efficient wastewater treatment, especially in rural areas.

Environmental factors such as temperature, independent of other factors such as population behaviour, impact the abundance of pathogens, their survival and/or their virulence in food[4] (Fisman, 2007, cited by the Food and Agriculture Organization of the United Nations 2008). In fact, the three most common microbiological organisms causing food-borne illness are bacteria, mould and yeast which are found everywhere that temperature, moisture, and substrate favour life and growth (Malhotra, 1997). Given the role of moisture in the growth of bacteria and mould in food, relative humidity[5] becomes important in the analysis. The higher the relative humidity, the more saturated the air with moisture which facilities the growth of bacteria and mould. Notwithstanding the impact of climate variables on the spread of food-borne illnesses in Trinidad and Tobago, the role of human behaviour in this context should not be underscored, especially as it relates to food safety practices.

A study done by Surujlal and Badrie (2004) on household consumer food safety in Trinidad and Tobago revealed that most respondents washed their hands with soap and water before preparation of meals (88.1%), after using the toilet facilities (92.9%) and after handling raw foods or contaminated objects (84.5%). Also, 61.9% of the consumers responded positively when asked whether or not they looked at food labels and expiry dates before purchase of foods, while 33.3% indicated 'sometimes'. Some (16.7%) consumers did not separate cooked or ready-to-eat foods from raw foods. Some consumers (45.2 %) unwittingly committed a critical violation of thawing frozen foods at room temperature 30°C (86 °F) , while 33.3% 'sometimes' did. Only 20.2 % allowed the foods to be thawed in a refrigerator, or under

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[4] The relative ability of a microorganism to cause disease. http://dictionary.reference.com/browse/virulence (accessed March 15, 2011).

[5] Relative humidity refers to the amount of moisture in the air compared to the total amount of moisture in the air could hold at that temperature (United States 2007).

running water. The results from this study therefore support the claim made above that human behaviour plays a major part in the spread of food-borne illnesses.

b) Food security

Given the link between nutritious food and health, food security in terms of the quality of food may be viewed as a pillar of the health of the population as well as a function of health outcomes. Changes in climate may affect agricultural output thereby decreasing the quantity and quality of food (nutritional characteristics) available for a given population. Heat stress may affect the growth of root crops and vegetables, insufficient rainfall can lead to water shortages and drought and heavy precipitation can cause destruction to crops and livestock. The availability of fish stock and variety of fish species may be affected by changes in water temperatures.

In Trinidad and Tobago, high intensity rainfall that has been associated with catastrophic flooding has significantly affected domestic cultivation of food over the last few decades. In fact, with excessive rainfall regularly destroying crops and livestock, the Government of Trinidad and Tobago has had to intervene to protect the agricultural sector especially in recent times, the experience of food production has not been a successful one[6]. One form of intervention has been in the area compensation to farmers for losses resulting from the destruction of crops and livestock by floods. For example, following major flooding in May 2010, the Government of Trinidad and Tobago allocated TT$ 13 million for flood relief to farmers[7].

Already, estimates show that for the period 2005 to 2007, 11% of the population was undernourished (FAO, 2010). Any further strain on the quantity and quality of food available in Trinidad and Tobago resulting from climate change, can have significant health consequences.

c) Social and economic systems

Climate change impacts could increase the vulnerability of already poor households and individuals which will have implications for health status determinants, including lifestyle, nutritional intake, and use of, and access to health care. The expected increase in the frequency of extreme events associated with climate change can result in damage to key infrastructure disrupting social and economic activities thereby impacting livelihoods. The island of Trinidad has had a history of catastrophic flooding which has consistently caused significant damage to infrastructure (homes, roads and schools), crops and livestock. Any increase in the occurrence or intensity of such flooding can have further unpleasant outcomes.

In addition, the projected increase in climate-related diseases in some regions will significantly impact morbidity and mortality levels in these regions which have a host of consequences at both the household and national levels. For example, both morbidity and mortality could compromise household income, impacting the ability of the household to meet basic expenditure demands.

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[6] In 2009, the agriculture sector contributed less than 1% to Gross Domestic Product (GDP) at constant prices and experienced real GDP growth in the sector was -31% (Review of the Economy 2010).

[7] Government of the Republic of Trinidad and Tobago, "Twenty farmers receive over $313,000 in flood relief", 5 July, 2010. Available from http://69.94.137.26/editorialcontrol/ed-guidelines/footnotes/footnotes_chap_04.htm#J (accessed June 20, 2011).

In addition, impacts on coastal areas from sea level rise can have severe consequences for human settlement, livelihoods and infrastructure along coastlines. Although there are no substantial sea level data for Trinidad and Tobago, a recent event along the southern coastline of Trinidad (Icacos) has attracted some attention[8]. Houses and important infrastructure (recreation facilities and telephone lines) were damaged. Some infrastructure even disappeared, causing significant disruption of social and economic activities in the area.

d) Projections of the major impacts on human health based on IPCC's Special Emissions Scenarios

Projections to mid-to late twenty-first century were made by IPCC (2007a) of the major impacts on human health along with their likelihood using IPCC SRES. The projected health impacts relate both to mortality and morbidity. These impacts are presented in table 4.

Table 4: Possible human health impacts of climate change due to changes in extreme weather and climate events

Phenomenon and direction of trend	Likelihood of future trends based on projections for 21st century using SRES scenarios	Examples of major projected impacts by sector
		Human health
Over most land areas, warmer and fewer cold days and nights, warmer and more frequent hot days and nights	Virtually certain[a]	Reduced human mortality from decreased cold exposure
Warm spells/heat waves. Frequency increases over most land areas	Very likely	Increased risk of heat-related mortality, especially for the elderly, chronically sick, very young and socially isolated
Heavy precipitation events. Frequency increases over most areas	Very likely	Increased risk of deaths, injuries and infectious, respiratory and skin diseases
Area affected by diarrhoea increases	Likely	Increased risk of food and water shortage; increased risk of malnutrition; increased risk of water- and food- borne diseases
Intense tropical cyclone activity increases	Likely	Increased risk of deaths, injuries, water- and food- borne diseases; post-traumatic stress disorders
Increased incidence of extreme high sea level (excludes tsunamis)[b]	Likely[c]	Increased risk of deaths and injuries by drowning in floods; migration-related health effects

Notes: a) Warming of the most extreme days and nights each year.
b) Extreme high sea level depends on average sea level and on regional weather systems. It is defined as the highest 1% of hourly values of observed sea level at a station for a given reference period.
c) In all scenarios, the projected global average sea level at 2100 is higher than in the reference period. The effect of changes in regional weather systems on sea level extremes has not been assessed.
Source: IPCC (2007a).

[8] The Santa Aguila Foundation, "Sea claims lands, houses in Icacos, Trinidad and Tobago", 19 July, 2010. Available from http://coastalcare.org/2010/07/sea-claims-lands-houses-in-icacos-trinidad-and-tobago/ (accessed June 20, 2011).

III. THE HEALTH SITUATION IN TRINIDAD AND TOBAGO

The epidemiological profile of Trinidad and Tobago is not different from that of the countries of the developed world, with chronic diseases like heart disease, cancer, diabetes and hypertension being very high on the mortality list. Data for the period 1990 to 2003 from PAHO (2008) show that mortality rates were the highest for diseases of the circulatory system followed by malignant neoplasms, external causes, communicable diseases, and AIDS. Although ranked fourth in the region, the mortality rate per 1,000 population for communicable diseases (such as diarrhoeal disease, dengue fever, leptospirosis and malaria) assumed an increasingly important role in the burden of mortality over the period 1990-2003 (see table 5). The increase in the mortality rate for communicable diseases may be linked to a number of factors, one of which may be climate change. Climate change, via changes in weather patterns, can impact the spread of some communicable diseases through changes in water, air and food quality and vector populations.

Table 5: Mortality rates (per 1,000 population) for Trinidad and Tobago, 1990-2003

Period	General	Maternal*	Commu-nicable Diseases	TB	AIDS	Malaria	Circulatory system diseases	Malignant neoplastic diseases	External causes
1990 -1994	6.96	61.36	0.28	0.02	0.14	0.00	2.67	0.87	0.53
1995 -1999	7.52	51.94	0.46	0.03	0.32	0.00	2.89	0.97	0.49
2000 -2003	7.73	37.75	0.53	0.02	0.39	0.00	2.83	0.99	0.60

Source: PAHO (2008).

Table 6 gives a snapshot of some of the indicators outlined by the World Health Organization (WHO) on Trinidad and Tobago's Health Profile[9]. Life expectancy at birth is below the regional average for both sexes. Both the adult mortality rate and the "under 5" mortality rate are higher than the regional average. It is worth noting that the percentage of population living in urban areas is significantly lower than that for other countries in the subregion. Using estimates in table 6, it was found that more than 85% of the population live in rural areas and, thus, may be more exposed to the risk of contracting diseases such as dengue fever, malaria and leptospirosis and gastroenteritis.

[9] World Health Organization, "Trinidad and Tobago: health profile", 4 April 2011. Available from http://www.who.int/gho/countries/tto.pdf (accessed June 20, 2011).

Table 6: Selected health indicators 2008

Selected Indicators		Country	Regional Average	Global Average
Life expectancy at birth (years)	Male	66	73	66
	Female	73	79	70
	Both Sexes	70	76	68
Adult mortality rate (per 1000 adults 15-59 years)	Both Sexes	163	126	180
Under 5 mortality (per 1000 live births) Both sexes		35	18	65
Population living in urban areas (%)		13	80	50

Source: WHO: Trinidad and Tobago Health Profile.

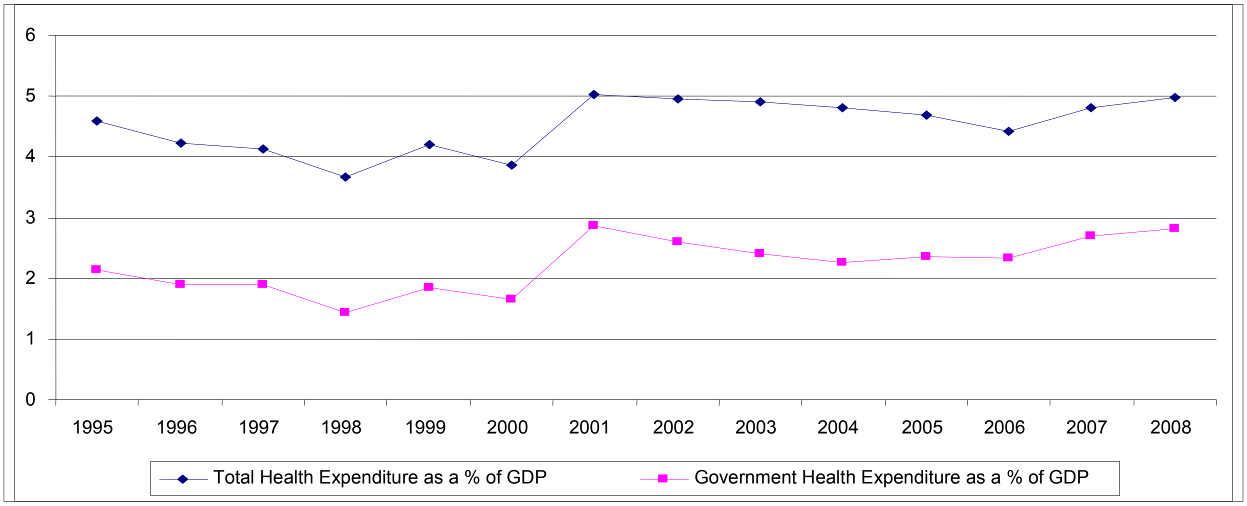
A. THE POTENTIAL FOR HEALTH IMPACTS IN TRINIDAD AND TOBAGO

Given the potential health effects of climate change, the resilience of the health system will be severely tested in the next 30 years. Observing past data, as mentioned earlier, the health system itself is characterized by an epidemiological profile similar to other middle-and high-income countries with non-communicable diseases such as heart disease, strokes, cancers and diabetes accounting for over 60% of total deaths (Baal, 2010). Moreover, although the health reforms instituted in 1994 sought to decentralize the system with the aim of putting more emphasis on primary care and health promotion, it is not clear that the past decade and a half has brought about any major changes.

Analysis reveals, with the population growing slowly (less than 1% per year) but with the demographic structure changing in the direction of an ageing population, the demand for health services in the country may be growing by just about 1% per year, a reflection mainly of the growth in employment in the health sector. On the other hand, there has been an interesting picture in respect of the capacity of the health system.

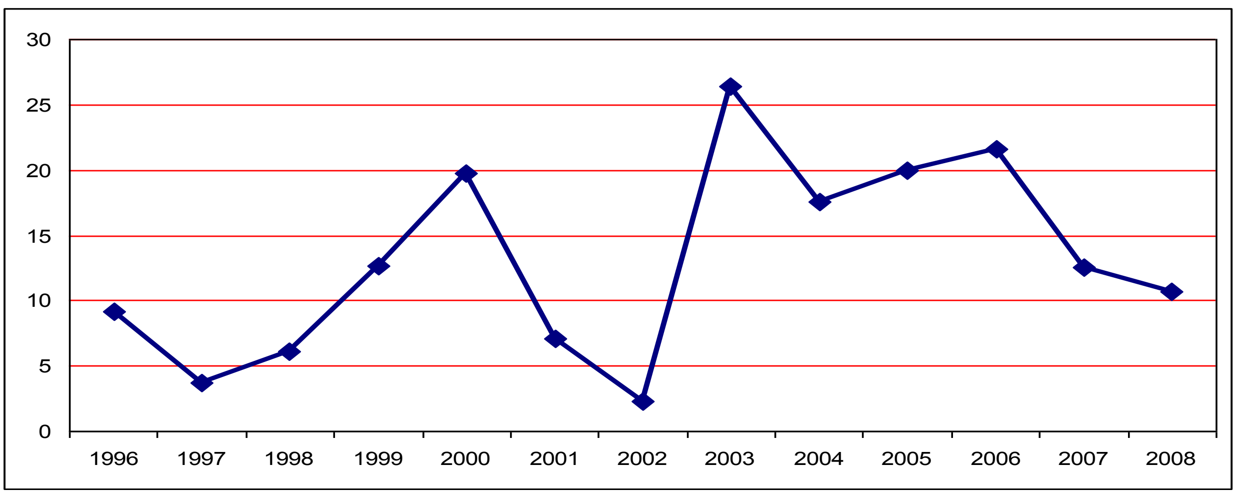
As figure 5 shows, total health spending as a share of GDP fell steadily between 2001 and 2006, from around 5% to about 4.4% but then rebounded in 2007 to 4.8%. However, given the rate at which GDP was increasing over the period 1995-2008 (see figures 6 and 7) these changes in expenditure shares tell only a part of the story. What is noticeable, for example, is that, measured in Purchasing Power Parity (PPP), in real terms per capita health spending increased from US$63 in 1995 to close to US$206 in 2008, an annual increase of about 16.7% (see figure 8).

Figure 5: Health expenditures as a percent of GDP 1995 to 2008



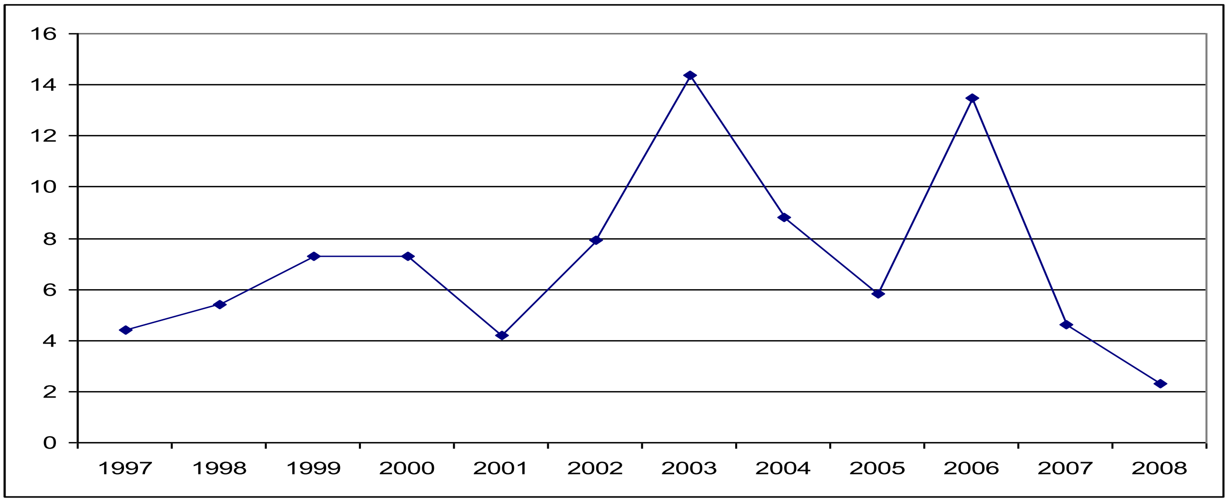
Source: World Health Organization: Trinidad and Tobago - National Expenditure on Health.

Figure 6: Growth (%) in nominal GDP, 1996 to 2008



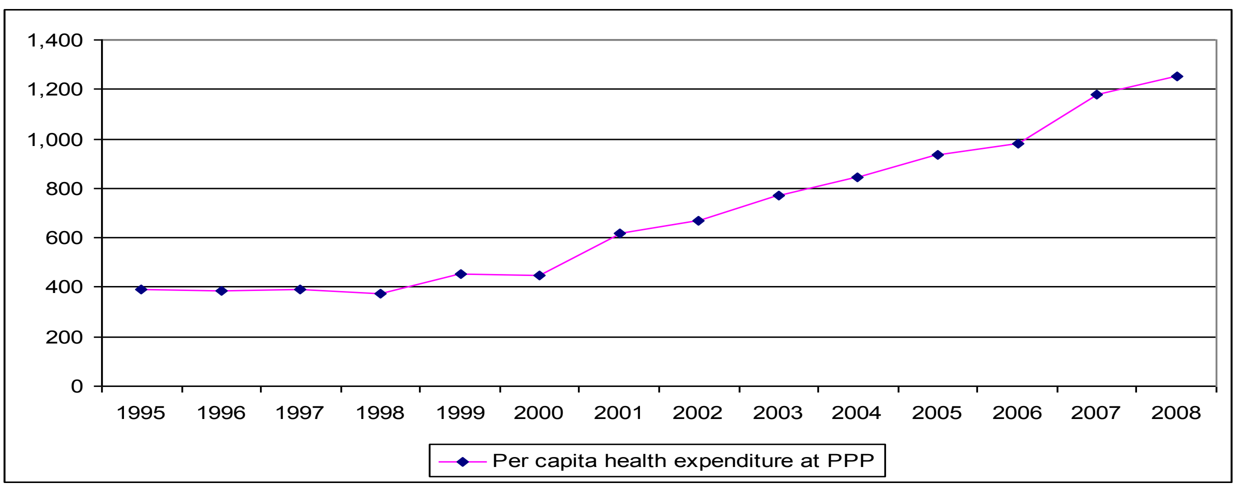
Source: World Health Organization: Trinidad and Tobago - National Expenditure on Health.

Figure 7: Real GDP growth (%) 1997 to 2008



Source: Trinidad and Tobago Economic Review, 2001, 2004, 2006, 2009.

Figure 8: Per capita expenditure on health at PPP 1995 to 2008



Source: World Health Organization: Trinidad and Tobago - National Expenditure on Health.

This capacity expansion is consistent with what is shown in table 7. Here it is noted that there have been significant increases in key inputs over the period 1996 to 2005. These input increases have been used to estimate the capacity expansion assumed in this study. Over the period 1996 to 2005 the capacity of the health system (as measured by the increase in staff) increased by approximately 96%. During this time, the demand for health services would have increased by approximately 9% (assuming an estimated 1% increase per year). This paints a very good picture in that the increase in capacity is estimated to have outstripped the increase in the demand for health services. The fact that the capacity of the system is estimated to have increased more than 10 times the demand over the same period is most likely due to the catching up that was made possible by the phenomenal increase in the country's real income (more than 100%) over the period 1995 to 2005. In other words, the attempt was made to bring the Trinidad and Tobago health system closer to being able to meet the population demand for health services. From a resilience perspective, this is a positive action.

Although such expansions in capacity have been noted and welcomed, the fact that Trinidad and Tobago still falls well below the regional average for physicians, nurses and midwives per 10,000 population should be highlighted. The number of physicians, nurses and midwives per 10,000 population in Trinidad and Tobago is 8 and 29, respectively; both estimates are below the regional averages of 19 and 49, respectively, for the Americas (WHO, 2009a).

It should also be borne in mind that the past does not always emulate the future and the expansion in the health system's capacity that has been observed was obviously linked to a corresponding phenomenal increase in national income over the same period. Since this study seeks to address the potential outcomes in health as they pertain to climate change, the emphasis will be on the uncertainty which characterizes all climate change discussions. In this context, different scenarios will need to be considered.

Table 7: Health system input changes 1996 to 2005

STAFF	1996	2005	% change
Physicians	957	1504	+ 57.2
Dentists	142	295	+107.7
Optometrists	45	80	+77.8
Veterinarians	77	166	+115.6
Pharmacists	514	517	+0.6
Nurses &Midwives	1569	2313	+47.4
Nursing Assistants	1428	1461	+2.3
Nursing Aides	154	710	+361.0
Average			+96.2

Source: Ministry of Health, Annual Reports.

IV. A LOOK AT CLIMATE-SENSITIVE DISEASES AND CLIMATE-RELATED ILLNESSES IN TRINIDAD AND TOBAGO

Although a full economic impact assessment of climate change on the health sector was intended, the analysis was limited to the economic impact of only a few climate-related diseases[10] for which data were available for Trinidad and Tobago[11]. In addition, in the case of those diseases for which surveillance data were available, the absence of long time series data sets limits the scope of the analysis. Background information on these diseases as well as data sets will be presented in this section. Information on the diseases selected was obtained from a range of sources while surveillance data on diseases were sourced from the Caribbean Epidemiology Centre and the National Surveillance Unit of the Ministry of Health, Trinidad and Tobago.

A. MALARIA[12]

Malaria is the world's most important and well-known vector-borne disease and is caused by Plasmodium parasites. The parasite is transmitted through the bite of an infected *Anopheles* mosquito, called a "malaria vector". The *Anopheles* mosquito usually bites between dusk and dawn. The intensity of transmission depends on factors related to the parasite, the vector, the human host, and the environment.

The *Anopheles* mosquito breeds in shallow collections of freshwater such as puddles. Transmission is more intense in areas where the mosquito is relatively long-lived which facilitates the complete development of the parasite inside the mosquito and where the mosquito prefers to bite humans rather than other animals. Climatic conditions play an important role in the degree of transmission since conditions, such as rainfall, temperature and humidity may affect the abundance and survival of mosquitoes. For example, in desert and highland fringe areas, rainfall and temperature are important variables for the transmission of the disease.

Theoretically, high temperatures should increase the likelihood of malaria transmission given that they reduce the extrinsic incubation period. Transmission may also increase during high temperatures as activities such as biting and egg laying are also accelerated. It should be pointed out that biting and egg laying are high risk activities for mosquitoes and so these two activities may affect the vector's survival rate.

While very high temperatures and low humidity may prove fatal to mosquitoes, mounting concern is that at low temperatures, a small increase in temperature (temporary or permanent) can greatly increase the risk of transmission of malaria as mosquito-enhanced conditions are created. In addition, in regions where these conditions (high temperature and low humidity) are normal, the vectors have adapted themselves. For example, in periods of diarrhoea and severe heat, blood feeding may continue, not disturbing malaria transmission, but the ovaries do not begin to develop eggs until the rains return (this is common in parts of Sudan).

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[10] The diseases analysed were, malaria, dengue, leptospirosis, food-borne illnesses and gastroenteritis.

[11] These were the only climate-related diseases for which surveillance data for a reasonable time series (>15 years) were available. It should be noted however, in the context of this study, longer time series would have proved more useful in developing the analysis.

[12] Background information and key facts for this disease were sourced from the Hales, Edwards and Kovats (2003), Reiter (2001) and the World Health Organization, " Media centre: Malaria". Available from http://www.who.int/mediacentre/factsheets/fs094/en/index.html (accessed June 23, 2011).

Malaria transmission is usually seasonal, peaking during and just after the rainy season. Rainfall can create ground pools and other breeding sites whilst heavy rainfall can have a "flushing effect", cleansing such sites of mosquitoes. During episodes of diarrhoea, standing water may be eliminated but flowing water may be allowed to stagnate which may cause malaria to decline. Drought may, however, encourage the storage of water in artificial containers which serve as breeding sites.

The level of human immunity is also another important factor affecting the intensity of transmission. Malaria outbreaks can occur when conditions such as climate favour transmission in areas where people have little or no immunity to the disease, or when people with low immunity move into areas with intense malaria transmission. Other important factors influencing malaria incidence are public health infrastructure (lack of resources to adequately address the situation), insecticide and drug resistance, human population growth, land-use change, forest clearance (new habitats such as sunlit pools may be created), agriculture (creation of irrigation dams, abandoned fish farming projects, cattle hoofprints are all possible habitats), urbanization (extensive water storage and inadequate water disposal may create new breeding sites) and war, civil strife and natural disaster (mass movement of people can promote malaria transmission).

Malaria is the world's main vector-borne disease and caused approximately one million deaths in 2008, mostly among African children; over 247 million fell ill from the disease that same year. Malaria accounts for 20% of all childhood deaths. The disease can decrease GDP by as much as 1.3% in countries with high disease rates and, over time, can lead to huge gaps in GDP between countries with and without malaria. In countries with high rates of transmission, the disease accounts for up to 40% of public health expenditure, clearly a significant portion. In 2008, malaria was present in 108 countries and territories, although most of the cases and deaths occur in sub-Saharan Africa. It is estimated that, half of the world's population is at risk from the disease.

Symptoms appear after seven or more days after the bite of an infective mosquito and include fever, headache, chills, vomiting. Symptoms may be mild and similar to the common flu, making it difficult to recognize as malaria. *Plasmodium falciparum* malaria, if not treated within 24 hours, can progress to severe illnesses often leading to death.

The picture is somewhat different in Trinidad and Tobago. The twin-island state has obtained malaria-free Status since 1965 although data for the period 1980 to 2005 show that imported cases have been reported (see table 8). Trinidad and Tobago accounted for 20% of the 894 reported cases of imported malaria in the Caribbean over the period 1980 to 2005. Trinidad and Tobago has recorded three outbreaks involving imported index cases and later local transmission (indigenous spreads). These occurred in 1991, 1994/1995 and 2000. Over the period 2001 to 2005, there have been 13 indigenous malaria cases in Trinidad and Tobago. (CAREC, 2008)

Since most of the reported cases of malaria in Trinidad and Tobago are imported, it is difficult to analyze the impact of climate change on malaria transmission. What is worth highlighting, though, is that with an abundance of *Anopheles* mosquitoes, any increase in imported malaria cases can significantly increase the risk of the indigenous spread of malaria. This would, of course, have implications for the health system.

Over the period, the number of imported malaria cases fluctuated largely with the highest number of imported cases occurring in 1994 and 1995 (table 8). Though a bit dated, data in table 9 give an idea of the imported malaria cases in Trinidad and Tobago by continent of origin. The data show that for the period 1968 to 1997, Africa was the most common continent of origin for imported cases of malaria in Trinidad and Tobago. It is worth noting, however, that for the last cluster of years (1993 to 1997), most of the imported malaria cases were from South America. The most common malaria parasite during this period was *Plasmodium falciparum.*

Table 8: Malaria cases (imported) and rates per 100,000 population 1980 to 2005

Years	Number of Cases	Rate per 100,000 population
1980	0	0
1981	3	0.27
1982	4	0.36
1983	2	0.18
1984	4	0.34
1985	17	1.45
1986	18	1.51
1987	5	0.42
1988	6	0.5
1989	9	0.74
1990	4	0.33
1991	3	0.24
1992	0	0
1993	0	0
1994	20	1.59
1995	20	1.58
1996	11	0.86
1997	6	0.47
1998	0	0
1999	6	0.47
2000	5	0.39
2001	7	0.54
2002	6	0.46
2003	4	0.30
2004	11	0.84
2005	1	0.08

Source: CAREC (2008), Author's calculations.

Table 9 – Imported malaria cases by continent 1968 to 1997

Years	Africa	Asia	South America
1968-1972	**10**	**1**	**0**
1973-1977	**5**	**3**	**2**
1978-1982	**11**	**8**	**1**
1983-1987	**26**	**14**	**9**
1988-1992	**17**	**9**	**8**
1993-1997	**11**	**4**	**25**
Total	**80**	**39**	**45**

Source: Chadee and Kitron (1999).

B. Dengue Fever[13]

Dengue fever is transmitted through the bite of a female *Aedes aegypti* mosquito[14] infected with any one of four dengue fever viruses which breeds mainly in man-made containers that contain water (plant pots, water barrels, old tyres). It occurs mainly in tropical and sub-tropical regions. Dengue fever is a severe flu-like illness that affects all ages but seldom causes death. Symptoms of dengue fever include mild to high fever with severe headache, pain behind the eyes, muscle and joint pain and rash. Dengue haemorrhagic fever (fever, abdominal pain, vomiting, bleeding, enlargement of the liver and in severe cases circulatory failure) is a potentially fatal complication of dengue fever which requires hospitalization. Although there is no specific treatment for dengue fever or vaccine to prevent dengue fever, with early clinical diagnosis and careful clinical management the survival rate of patients diagnosed with the disease can increase.

Approximately 2.5 billion people (two fifths of the world's population) are at risk from dengue fever and the disease is now endemic in more than 100 countries (Africa, the Americas, the Eastern Mediterranean, South-east Asia and the Western Pacific). The disease has spread to new areas and more importantly, explosive outbreaks are occurring.

Rainfall has been found to influence the transmission of the disease since pools of rain water are often collected in discarded coconut shells, automobile tyres and other non-biodegradable containers that serve as breeding habitats for the vector. In the absence of rainfall and in dry periods, water stored in open containers also provides a breeding ground for the *Aedes aegypti* mosquito. In fact, transmission is usually high in areas where household water storage is common and where solid waste disposal services are inadequate. Very heavy rainfall, however, can wash away larvae reducing the risk of dengue fever transmission.

At higher temperatures, the incubation period of the parasite in the vector is shorter leading to a possible increase in the transmission rate. Also as temperature increases, the amount of feeding by

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[13] Background information and key facts for this disease were sourced from
Hales, Edwards and Kovats (2003); and
World Health Organization, " Media centre: Dengue and dengue haemorrhagic fever". Available from http://www.who.int/mediacentre/factsheets/fs117/en/index.html (accessed June 23, 2011).

[14] Dengue can also be transmitted by the *Aedes albopictus* mosquito which can tolerate colder temperatures.

vectors also increases which influences the rate of transmission of dengue fever to new hosts. High temperatures may also speed up the larval stage resulting in smaller vectors that require more frequent blood meals. Drought can reduce larval habitats but increase water storage which itself enhances vector habitat conditions.

Results of an analysis of disease data for Barbados and Saint Lucia revealed that dengue fever exhibited seasonal patterns and correlations of disease data with climate data indicated significant (moderate r and low p values) associations of dengue fever with temperature and rainfall (Amarakoon, Stennett and Chen 2004). Table 10 below shows that the probability of a dengue fever outbreak is greater at high temperatures and light or medium rainfall.

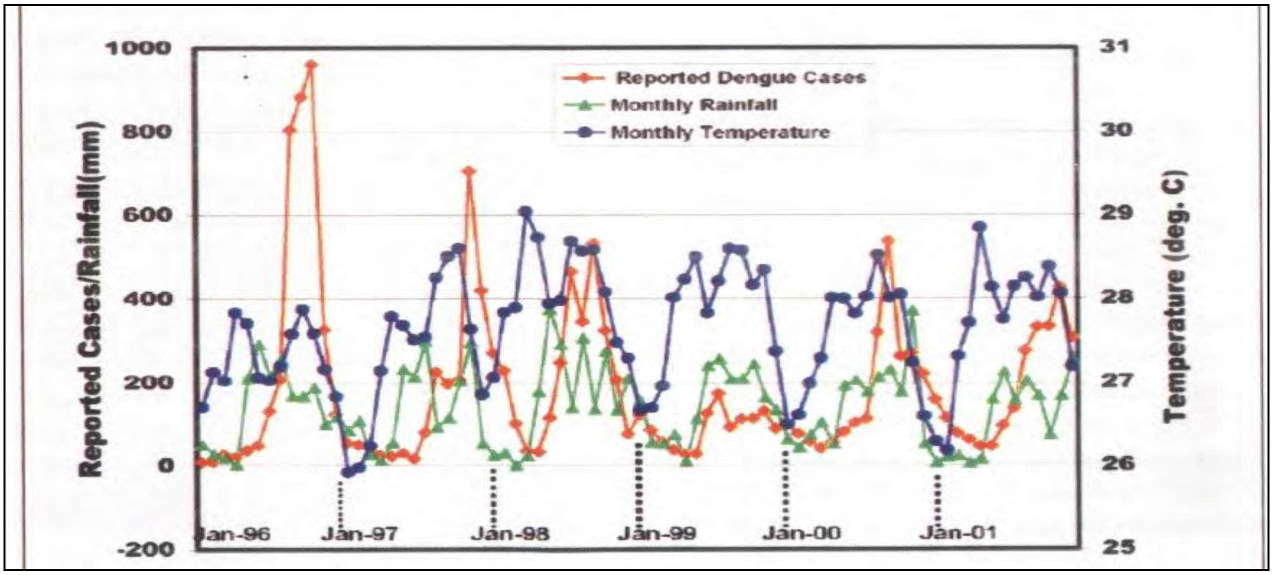
Table 10: Probability of dengue fever outbreak

TEMPERATURE	RAINFALL		
	Heavy	Medium	Light
High	Medium probability	Higher probability	Higher probability
Low	Lower probability	Medium probability	Medium probability

Source: Chen (n.d).

A retrospective study was undertaken by Amarakoon et al. (2007) as part of a larger regional project that looked at the nature and extent of the association between climate and the incidence of dengue fever in the Caribbean. Citing this study, Taylor, Chen and Bailey (2009) pointed out that the outbreaks of dengue fever in the Caribbean have a well-defined seasonality occurring in the latter half of the year. This seasonality was clear in the patterns of the disease for the countries studied, for example, in Trinidad and Tobago, during the period 1996 to 2001 a pattern emerged of warming, then rainfall, followed by the dengue fever outbreak (see figure 9). It is important to note however that the association of dengue fever outbreaks with temperature is much stronger than with rainfall and although moisture availability was observed to be necessary for the onset of the epidemic, the amount of moisture did not appear to be of importance.

Figure 9: Time series of monthly reported dengue fever cases, rainfall and temperature in Trinidad and Tobago 1996 to 2001



Source: Amarakoon et al. (2007), cited by Taylor, Chen and Bailey (2009).

Surveillance data for dengue fever in Trinidad and Tobago show that over the period 1981 to 2007, the number of new dengue fever cases in Trinidad and Tobago increased in general, with 15 cases being reported in 1981 and 916 in 2007 (see table 11). Large fluctuations around these values were recorded throughout the period with 6,246 cases being reported in 2002 (highest) and 5 reported in 1985 (lowest). Over 31,000 cases of dengue fever have been reported for the period of analysis.

Analysis of the rates per 100,000 population over the period shows a falling underlying trend. Although there was an outbreak in 2002, this did not affect the overall incidence of dengue fever which continued to decrease. Dengue fever cases and rates for the period 1981 to 2007 are shown in table 11.

Table 11: Dengue fever[15] cases and rates per 100,000 population 1981 to 2007

Years	Number of Cases	Rate per 100,000 population
1981	15	1.36
1982	16	1.43
1983	117	10.25
1984	31	2.67
1985	5	0.42
1986	145	12.20
1987	106	8.85
1988	31	2.57
1989	11	0.91
1990	526	43.16
1991	31	2.53
1992	642	51.90
1993	3050	244.62
1994	504	40.12
1995	282	22.30
1996	3588	282.07
1997	2081	162.76
1998	2984	232.31
1999	1199	92.95
2000	2238	172.80
2001	2417	185.92
2002	6246	478.76
2003	2464	188.22
2004	546	41.56
2005	411	31.18
2006	446	33.71
2007	916	68.96

Source: CAREC (2008), National Surveillance Unit, Author's calculations.

[15] Data refers to Dengue Fever and Dengue haemorrhagic fever.

C. RODENT- BORNE DISEASES[16]

Rodents can spread diseases as infected hosts or as hosts for arthropod vectors such as ticks. Rodent-borne diseases that are associated with flooding include leptospirosis, tularaemia and viral haemorrhagic diseases. Diseases that are associated with rodents and ticks include Plaque, Lyme disease, Tick Borne Encephalitis and Hantavirus Pulmonary Syndrome and Leptospirosis[17].

Leptospirosis is an infectious disease caused by infection with bacteria of the genus Leptospira which is a type of bacteria called spirochete. Leptospira exist in two groups, the pathogenic parasitic type and the free-living saprophytes. Both groups require the same basics to survive (water, oxygen, stable pH and temperature). Pathogenic leptospires reproduce best at body temperature, but can survive at varying temperatures. Their levels of activity and ability to reproduce drop when cooled below 10°C. In addition, Leptospires must remain immersed in water to survive. Given their inability to survive out of water, they are unable to create infection risks from dry surfaces. Temperature and water are therefore critical factors for their survival and reproduction.

Leptospirosis is transmitted by animals such as rats, skunks, opossums, raccoons, foxes and other vermin. Rodents are the most common type of reservoirs for the disease. Sites that host rats include urban ponds, slow-moving rivers and canals and lakes near farm buildings. Humans become infected when they are exposed to the bacteria that have been shed by an infected animal; 90% of the time it is the animal's urine. The bacteria have to physically enter the bloodstream before it can cause an infection. Common routes of entry are through injuries where skin is broken, mucous membranes lining the airway, mouth, lungs and female sexual organs. As such, contact with infected soil or water, ingestion of contaminated food or water and breathing in or swallowing bacteria are risks. The disease can sometimes spread via sexual intercourse.

Symptoms occur in two phases. The first phase of symptoms resemble flu-like symptoms such as muscle aches, eye pain with bright lights, headache, chills, fever, watering and redness of the eyes and symptoms will seem to be improving after a few days. The second phase would begin after a few days of feeling well where the initial flu-like symptoms recur with fever, aching with stiffness of the neck and in some cases, right upper abdominal pain may occur. Meningitis could occur in patients who develop severe inflammation of the nerves to the eyes, brain, and spinal column. Leptospirosis is also associated with Weil's syndrome where patients develop liver and kidney problems. Diagnosis of leptospirosis usually requires a range of clinical tests involving blood, spinal fluid or urine. Leptospirosis occurs worldwide but is most common in sub-tropical and tropical regions.

Above average precipitation which results in flooding can displace rodent populations forcing them to seek shelter and food in higher ground, thereby increasing possible human contact with rodents. Flooding can also increase the risk of food and water contamination with rodent urine and/or faeces increasing the risk of transmission. Increases in temperatures may also enhance reproduction of the bacteria.

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[16] Background information and key facts for this disease were sourced from
Hales, Edwards and Kovats (2003);
World Health Organization, "Health Topics: Leptospirosis". Available from http://www.who.int/topics/leptospirosis/en/ (accessed, June 24th, 2011);
MedicineNet Incorporation, "Leptospirosis". Available from http://www.medicinenet.com/leptospirosis/article.htm (accessed June 20, 2011); and
The Leptospirosis Information Centre. Available from http://www.leptospirosis.org/topic.php?t=10 (accessed June 20th, 2011).

[17] This study will focus on leptospirosis since it is the most common rodent-borne disease in Trinidad and Tobago.

In Trinidad and Tobago, the number of new leptospirosis cases has increased significantly over the period 1981 to 2007; more than 2,500 cases were reported during this period (see table 12). Over 100 cases were reported each year from 1997 to 2006. Leptospirosis incidence per 100,000 population in 2007 was three times that in 1981. Relatively high incidence rates were recorded over the period 1997 to 2006.

Table 12: Leptospirosis cases and rate per 100,000 population 1981 to 2007

Years	Cases	Rate per 100, 000 population
1981	21	1.91
1982	31	2.77
1983	27	2.37
1984	47	4.05
1985	31	2.64
1986	24	2.02
1987	39	3.26
1988	76	6.31
1989	107	8.83
1990	49	4.02
1991	45	3.67
1992	101	8.15
1993	117	9.38
1994	98	7.80
1995	81	6.41
1996	95	7.47
1997	193	15.09
1998	191	14.87
1999	171	13.26
2000	153	11.81
2001	181	13.92
2002	142	10.88
2003	136	10.39
2004	125	9.53
2005	135	10.24
2006	123	9.30
2007	89	6.70

Source: CAREC (2008), National Surveillance Unit, Author's calculations.

D. FOOD-BORNE AND WATER-BORNE ILLNESSES[18]

The prevalence of food- and water-borne diseases can be related to climate change.

According to the WHO,

> "Climate change will affect, in profoundly adverse ways, some of the most fundamental determinants of health: food, air and water." (WHO 2008, 1)

Food-borne and water-borne illnesses are infectious diseases that enter the body when a person eats food or drinks water that contains harmful bacteria. Cholera, Salmonella, Shigella and *Escherichia coli* are four examples of bacterial forms that are the most common threats for food-borne and water-borne illnesses.

Symptoms of food-borne illnesses are similar to intestinal flu (abdominal cramps, nausea, vomiting, diarrhoea, fever, dehydration) and may last a few hours or even several days and can range from mild to serious. Diagnosis can be done by a doctor from considering foods eaten or through laboratory tests. In most cases, food-borne illnesses are mild and so can be treated by increasing fluid intake either orally or intravenously. In more severe cases, hospitalization may be needed to receive supportive nutritional and medical therapy. Food-borne illnesses can be prevented through proper cooking or processing of food which kills harmful bacteria. Food should also be kept in temperature in cool or cold places to prevent bacteria growth. Food safety practices such as using clean utensils can also prevent food-borne illnesses.

Box 2 provides a brief description of each of these bacteria.

In the context of food-borne illnesses, warmer climate and inappropriate food behaviour were identified by IPCC (2001) as contributory factors. A study on food-borne illnesses in the United Kingdom by Bentham and Langford (1995) was highlighted by IPCC (2001) in which a strong relationship was observed between incidence and temperature in the month preceding the illness.

The most well-known cause of food-borne illnesses is harmful bacteria[19]. Brown and Henkel (2007) noted that bacteria can cause food to spoil and can cause food poisoning when it is eaten. Food, acid, temperature, time, oxygen and moisture were identified by the authors as being „ideal' conditions for bacteria to multiply and cause illness. With regards to temperature, 41^{o}F to 140 ^{o}F was considered to be ideal for the growth of most forms of bacteria. In addition, high levels of relative humidity may be linked to food-borne illnesses as high relative humidity means that the air is saturated with *moisture*; a key factor in the growth of mould and bacteria (Dincer 1997).

In the context of water-borne diseases, climate change can have major impacts on water resources and sanitation when water supplies are compromised (IPCC 2001). IPCC also notes that reduced water availability may necessitate the use of poorer quality water sources such as rivers and ponds, which could contribute to an increase in the incidence of water-borne diseases.

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[18] Background information and key facts for this disease were sourced from
World Health Organization, "Media centre: Food safety and food-borne illnesses", Available from, http://www.who.int/mediacentre/factsheets/fs237/en/ (accessed, June 24th, 2011); and
National Digestive Diseases Information Clearinghouse, "Bacteria and Foodborne Ilnesses". Available from http://digestive.niddk.nih.gov/ddiseases/pubs/bacteria/index.htm#3 (accessed June 20, 2011).
[19] ditto"

Although the number of new cases of food-borne illnesses[20] has remained relatively high throughout the period, with over 1,000 cases being recorded from 1990 to 2005, the incidence per 100,000 population has been decreasing (see table 13). In a newspaper article, then Minister of Health, Mr. John Rahael, in 2004 indicated that a survey by British tour operators linked most of the food-borne diseases outbreaks in the Caribbean to poor food safety practices (Chan, 2004).

Box 2 – Description of select bacteria

"Salmonella *is a genus of bacteria that are a major cause of food-borne illness throughout the world. The bacteria are generally transmitted to humans through consumption of contaminated food of animal origin, mainly meat, poultry, eggs and milk.*

Shigella *is a genus of bacteria that are a major cause of diarrhoea and dysentery – diarrhoea with blood and mucus in the stools – throughout the world. The bacteria are transmitted by ingestion of contaminated food or water, or through person-to-person contact. In the body, they can invade and destroy the cells lining the large intestine, causing mucosal ulceration and bloody diarrhoea.*

Escherichia coli *is transmitted to humans primarily through consumption of contaminated foods, such as raw or undercooked ground meat products and raw milk.*

Cholera *is an acute intestinal infection caused by ingestion of food or water contaminated with the bacterium Vibrio cholerae*."

Source: WHO, Health Topics.

A closer look at some of the most common types of food-borne and water-borne diseases reveals that for Trinidad and Tobago the number of new Shigellosis and Salmonellosis cases has generally shown decreasing trends since 1985 but spiked in 2003 and continued to increase in 2004 and 2005 (figure 10). Cholera has not occurred in the past 13 years. (CAREC, 2008)

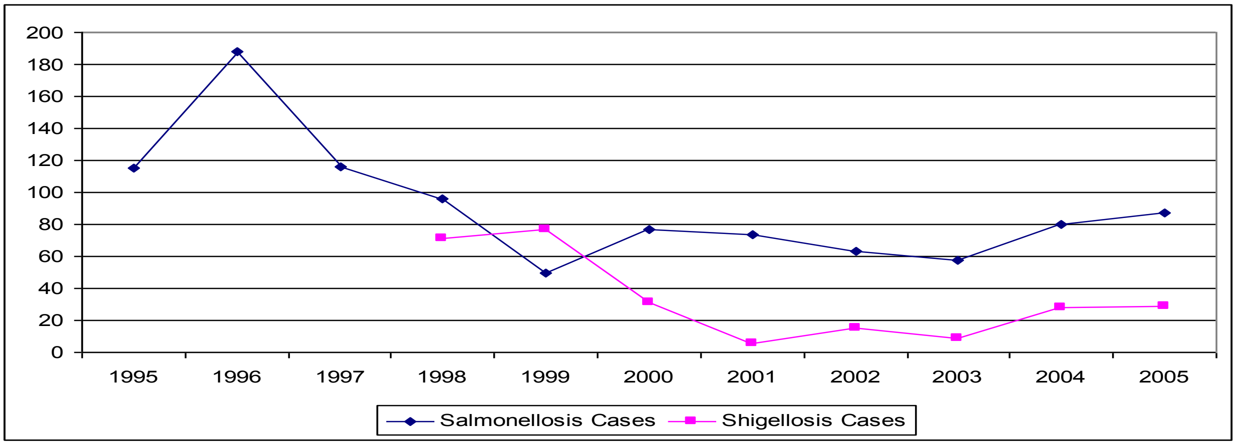
[20] This category called „food-borne illnesses' includes cases that relate to diseases such as Shigellosis, Diarrhoeal disease that may also be water-borne.

Table 13: Food-borne illnesses and rate per 100,000 population 1981 to 2005

Year	Cases	Rate per 100, 000 population
1981	102	9.27
1982	408	36.40
1983	333	29.17
1984	561	48.35
1985	656	55.78
1986	623	52.42
1987	865	72.23
1988	642	53.3
1989	673	55.56
1990	1308	107.32
1991	840	68.43
1992	855	69.12
1993	860	68.98
1994	490	39.01
1995	623	49.26
1996	664	52.20
1997	529	41.37
1998	563	43.83
1999	533	41.37
2000	782	43.83
2001	636	41.32
2002	480	60.38
2003	401	48.92
2004	772	36.79
2005	1030	30.63

Source: CAREC (2008).

Figure 10: Cases of Salmonellosis and Shigellosis



Source: CAREC (2008).

E. GASTROENTERITIS[21]

Gastroenteritis is an inflammation of the gastrointestinal tract and is sometimes referred to as stomach flu, although not being related to influenza. It is caused by viral, bacterial or parasitic infections and the common routes of infection include food, contaminated water and contact with an infected person, unwashed hands or dirty utensils. The main symptom is diarrhoea but other symptoms include abdominal pain, nausea, vomiting and fever. In severe cases of gastroenteritis, dehydration may occur and so hospitalization may be required, otherwise the body is able to fight off the disease on its own, with the help of fluids and electrolytes.

Higher temperatures associated with climate change will increase the risk of food spoilage and gastroenteritis (Stanley, 2009). Like food-borne illnesses, gastroenteritis can be bacterial. As such, factors that are considered necessary for bacteria to multiply and cause illnesses such as acid, temperature, time, oxygen and moisture (Brown and Henkel 2007) are important when considering gastroenteritis incidence. High levels of relative humidity (more moisture in the atmosphere) may very well foster the growth of bacteria in food thereby contributing to gastroenteritis incidence.

In addition, an increase in the intensity and occurrence of extreme events associated with climate change (for example flooding) may cause key water sources to become contaminated which can lead to a host of infectious diseases. Diarrhoea conditions may lead to use of stagnant water for household use, which also increases the risk of water-borne diseases. In conditions of drought or severe flooding, unsafe food safety practices such as, the use of dirty utensils and unwashed hands can, in fact, contribute to the spread of gastroenteritis.

Table 14 shows gastroenteritis incidence in Trinidad and Tobago. The number of new gastroenteritis cases and gastroenteritis cases per 100,000 population both showed an increasing linear trend over the period.

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[21] Background information and key facts for this disease were sourced from
Stanley (2010); and
Cleveland Clinic, "Diseases and Conditions: Gastroenteritis". Available from
http://my.clevelandclinic.org/disorders/Gastroenteritis/hic_Gastroenteritis.aspx (accessed June 20, 2011).

Table 14: Gastroenteritis and rate per 100,000 population 1981 to 2005

Year	Cases	Rate per 100, 000 population
1989	17033	1406
1990	15632	1283
1991	16883	1375
1992	21858	1767
1993	18222	1461
1994	15355	1222
1995	15684	1240
1996	16187	1273
1997	16026	1253
1998	14101	1098
1999	19796	1534
2000	17365	1341
2001	22694	1746
2002	16897	1295
2003	18597	1421
2004	22231	1692
2005	20770	1576

Source: National Surveillance Unit.

F. El Niño and Disease Incidence

In considering the potential health impact of climate change, it is worth highlighting the role of El Niño in the spread of infectious diseases such as those previously outlined. Arnold (2005) describes El Niño as the most powerful weather phenomenon on the earth which alters the climate across more than half the planet. El Niño is an abnormal warming of surface ocean waters and changes in weather patterns which occur about every three to seven years.

Hales, Edwards and Kovats (2003) pointed out that although the effect of climate change on El Niño is uncertain, climate change is likely to lead to greater extremes of drying and heavy rainfall and increased risk of drought and floods that occur with El Niño in many regions. The impact of long-term climate change may interact with the impact of increased climate variability and weather extremes affecting the incidence, seasonality and range of infectious diseases (Epstein, 2002). In other words, as more permanent changes[22] in the climate are recorded (climate change), infectious diseases may become

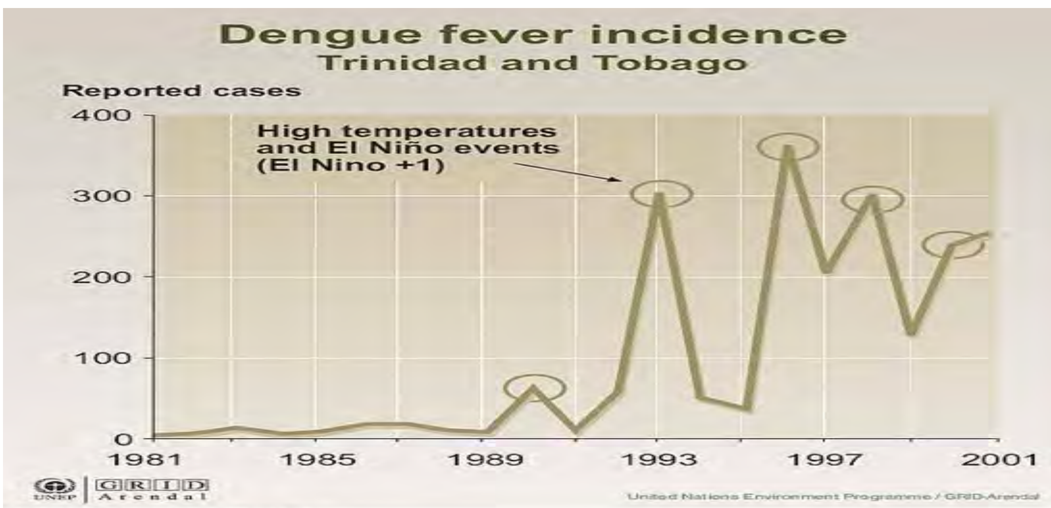
[22] Decades or longer.

even more prevalent as the conditions necessary for their emergence and survival are created and/or enhanced[23].

The associated health impact of the El Niño has attracted much interest on its influence on weather patterns and climate variability around the world (Hales, Edwards and Kovats, 2003). The interaction between El Niño effects (short-term climate extremes), such as floods and drought[24] may result in disease outbreaks. For example, in the Caribbean, seven of the eight dengue fever peaks over the period 1980 and 2001 occurred during ENSO[25] phases while in Trinidad and Tobago six of eight dengue fever peaks occurred during such phases (Taylor, Chen, Bailey 2009).

This relationship between dengue fever peaks and El Niño events arises possibly because the latter part of the El Niño year is warmer and the early part of the El Niño+1[26] year is wetter and warmer, conditions that favour mosquito breeding habitats. This relationship is seen in figure 11, which shows the increase in dengue fever cases as temperature rises to be in correlation with El Niño in Trinidad and Tobago during 1981 to 2001. Four of the five El Niño+1 years from 1990 to 2000 had some of the highest estimates of dengue fever incidence in Trinidad and Tobago (see table 15).

Figure 11: Dengue fever incidence in Trinidad and Tobago 1981 to 2001[27]



Source: Amarakoon et al. 2003

[23] It should be noted however that there are factors other than climate influencing the spread of these infectious diseases such as travel, public health infrastructure, insecticide and drug resistance, human population, immunity, land use change (Hales, Edwards and Kovats 2003).
[24] A diarrhoea is a period of abnormally dry weather which persists long enough to produce a series hydrologic imbalance (National Oceanic and Atmospheric Administration 2002).
[25] El Niño Southern Oscillation.
[26] Year following El Niño year.
[27] GRID-Arendal, "Dengue fever incidence; Trinidad and Tobago". Available from http://maps.grida.no/go/graphic/dengue_fever_incidence_trinidad_and_tobago (accessed June 20, 2011).

Table 15: El Nino and dengue fever incidence

El Niño+1 Year	Number of new dengue fever cases	Rank according to the number of new dengue fever cases over the 26 year period 1981 to 2007
1990	526	>10th
1993	3050	3rd
1996	3588	2nd
1998	2984	4th
2000	2238	6th

Source: CAREC (2008), Author's calculations.

V. THE CLIMATE IN TRINIDAD AND TOBAGO

IPCC defines climate as

"…the average weather or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time, ranging from months to thousands or millions of years". (IPCC Glossary)

Trinidad and Tobago, a twin-island State, experiences two distinct seasonal climate types: (a) tropical maritime; and (b) modified moist equatorial (Trinidad and Tobago Meteorological Service). The first type is characterized by warm days and cool nights with contributions of rainfall arising out of convective showers owing to daytime heating. It occurs mostly during the dry season (January to June). The latter type usually occurs during the wet season (July to December). Hot humid days and nights, low wind speeds and significant rainfall characterize this latter type. The climate in the southern Caribbean is influenced strongly by the El Niño/La Niña-Southern Oscillation; El Niño episodes bring warmer and drier than average conditions between June and August, while La Niña episodes bring colder and wetter conditions at this time (GOVTT 2009).

Since 1940, Trinidad and Tobago's mean rainfall has followed a decreasing linear trend, but this has not been statistically significant (see figure 12). On the other hand, mean annual temperature (Mean of Maxima) in Trinidad and Tobago has increased by 1.1°C since 1946, an average rate of 0.18°C per decade (see figure 13). The annual mean relative humidity measured at 8 a.m. and 2 p.m. during 1980 to 2005 showed a decreasing linear trend (see figures 14 and 15). Low relative humidity signifies that the air is dry and has the capacity to hold more moisture at the prevailing temperature.

According to the United Nations Development Programme Climate Change Profile for Trinidad and Tobago, the mean annual temperature is projected to increase by 0.7°C to 2.6 °C by the 2060s and 1.1°C to 4.3°C by the 2090s. There is a projected increase in the frequency of days and nights that are considered „hot'[28] in current climate. Projections are that annually hot days will occur on 33%-66% of days by the 2060s and 41%-94% of days by the 2090s. The frequency of hot nights is projected to increase more rapidly than hot days (when compared to night annual climate of 1970-1999). „Hot' nights

28 „Hot' day or „hot' night is defined by the temperature exceeded on 10% of days or nights in current climate of that region and season.

are expected to occur on 33-83% of nights by 2060s and 41-99% by 2090s. The frequency of what is considered „cold' nights[29] in current climate is also expected to decrease. Annual rainfall is also expected to decrease in Trinidad and Tobago. Annual projections vary between -61% and +23% by 2090s. In heavy events[30], the proportion of rainfall is expected to decrease in most of the models.

Given its geographic location and the pattern of wind activity in the Atlantic Ocean, Trinidad and Tobago usually escapes the passage of tropical cyclones when compared to the other islands in the more northerly locations in the Caribbean subregion. Tobago, however, has not always been as fortunate as its sister-isle in escaping the devastation of storms and hurricanes. For example, in 2004 Hurricane Ivan (category 5) caused significant damage to Tobago, while Trinidad was spared. While history has shown that the western and eastern parts of the Caribbean are more likely to be affected by tropical cyclone activity when compared to more southerly locations, recent occurrences suggest that the countries in the southernmost parts are not totally unaffected by tropical storms. For example, Grenada was battered by Hurricane Ivan in 2004 and Hurricane Emily in 2005.

As it relates to earthquakes, Trinidad and Tobago has not to date been severely affected even though it is located in a highly seismic area i.e. near the strike-slip boundary of the Caribbean and South American plates (Silverton n.d.). In 2006, a 6.1 magnitude earthquake struck Trinidad and Venezuela. Seismic experts sounded a warning of the possibility of the occurrence of a devastating earthquake in Trinidad at any time (Boodram, 2010). Acting director of the Seismic Research Unit at the University of the West Indies stated that,

> *"Statistically, a large earthquake is due near Trinidad. It can be devastating because we are not prepared."* (Boodram, 2010).

Flooding, a natural hazard mainly affecting Trinidad has been of major concern to the population and those in authority, given its frequency of occurrence and the associated damaged to vegetation, livestock, houses and other infrastructure and livelihoods.

The problem of flooding has become widespread in that areas previously unaffected by flooding are now being impacted (Environmental Management Authority, 2000). The worsening flooding situation in Trinidad and Tobago has been linked to urban development, inappropriate disposal of garbage, unplanned housing developments, slash and burn agriculture and quarrying activities[31]. Inadequate drainage and poor watershed management programmes may also be contributory factors. Additionally, given its location, and in spite of an observed decline in mean rainfall, Trinidad and Tobago experiences „high intensity' rainfall which can cause the soil to become saturated, resulting in flooding. In as recent as May 2010, floods in Trinidad caused massive destruction to houses, infrastructure and livestock mainly in central and south Trinidad.

On the other hand, drought as described by WHO as a *prolonged dry period in natural climate cycle caused by rainfall deficit and other predisposing factors* has not been common to Trinidad and Tobago. However, in March 2010, a meteorological drought was declared by the Water and Sewage Authority of Trinidad and Tobago following low rainfall activity which began in September 2009 (Government Information Services Limited). Throughout the Caribbean, drought conditions were experienced.

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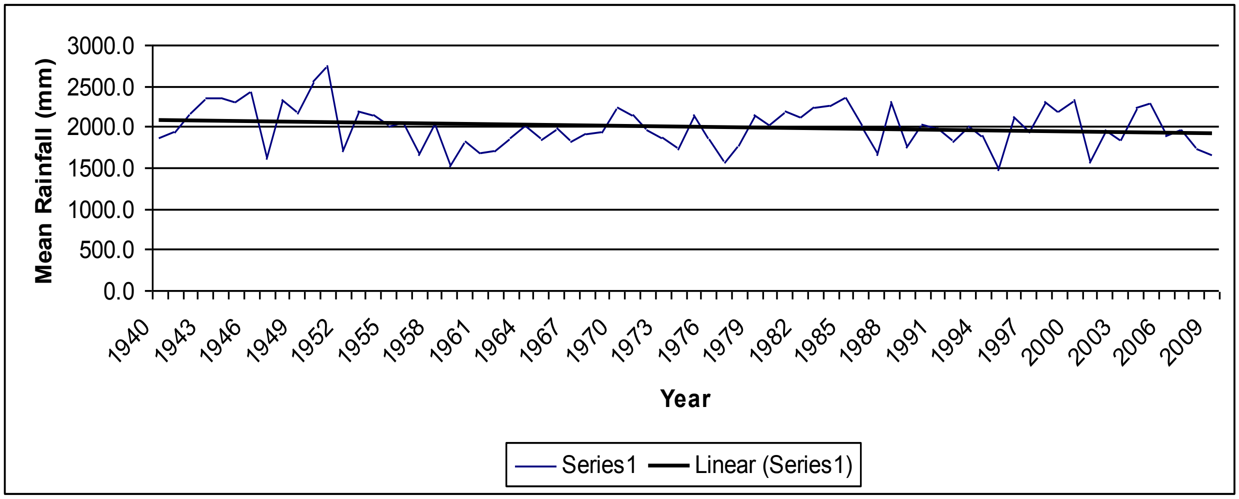
29 „Cold' days or „cold' nights are defined as the temperature below which 10% of days or nights are recorded in current climate of that region or season.
30 A „Heavy' event is defined as a daily rainfall total which exceeds the threshold that is exceeded on 5% of rainy days in current the climate of that region and season.
[31] ditto"

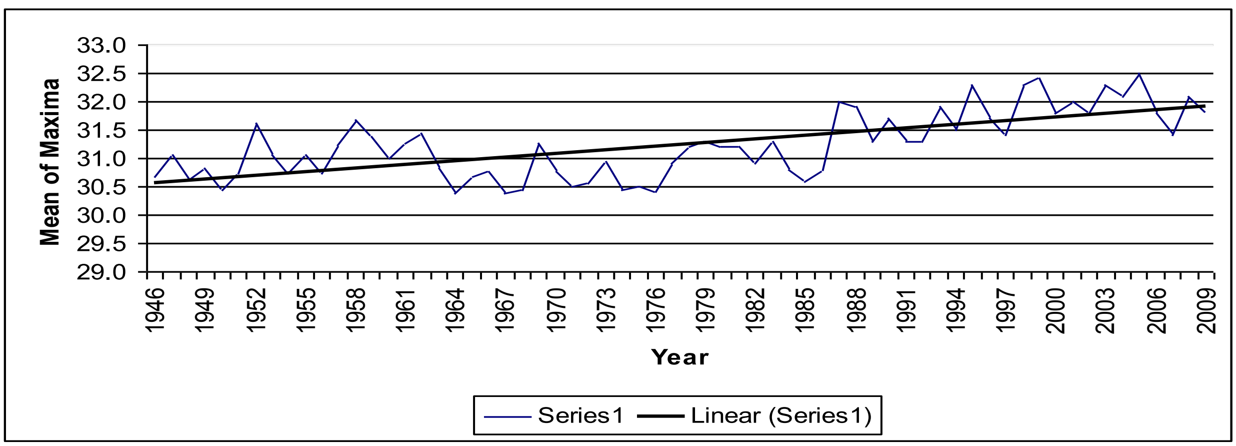
The country has been impacted by nine natural disasters during 1900 to 2010 which resulted in 45 deaths, affected 53,000 people and caused an estimated US$64million in damages (Alexander, 2010).

Figure 12: Mean rainfall in Trinidad and Tobago 1940 to 2009



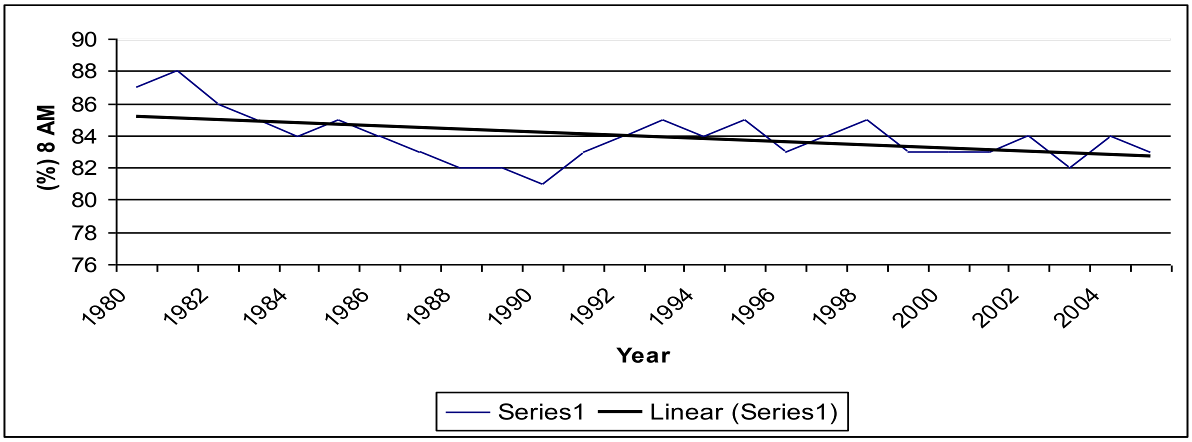
Source: Central Statistical Office of Trinidad and Tobago.

Figure 13: Mean air temperature in Trinidad and Tobago 1846 to 2009



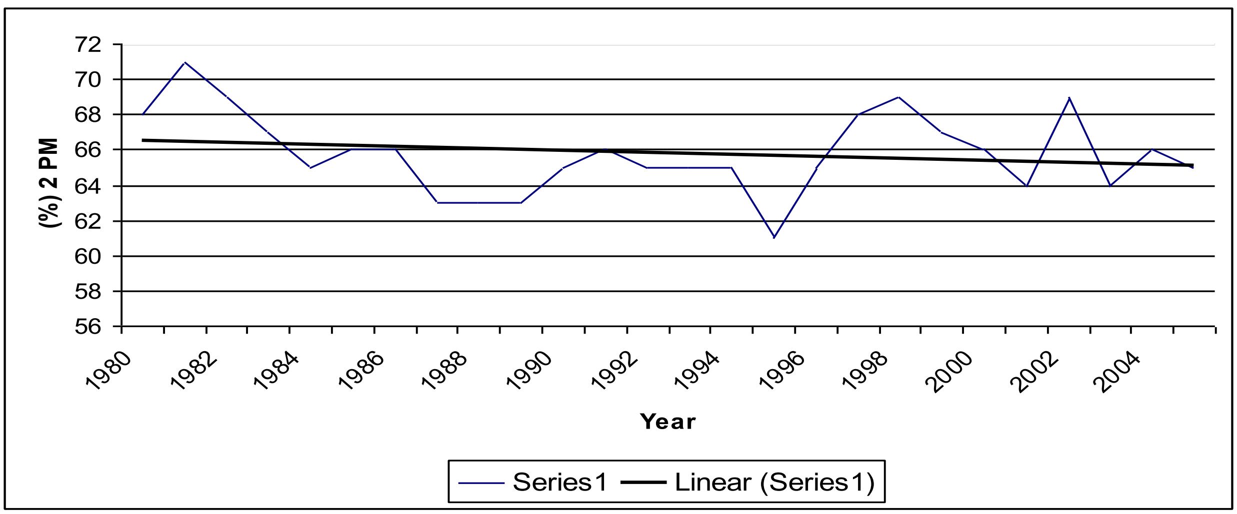
Source: Central Statistical Office of Trinidad and Tobago.

Figure 14: Annual Mean Relative Humidity at 8am 1980 to 2005



Source: Central Statistical Office of Trinidad and Tobago.

Figure 15: Annual Mean Relative Humidity at 2pm 1980 to 2005



Source: Central Statistical Office of Trinidad and Tobago.

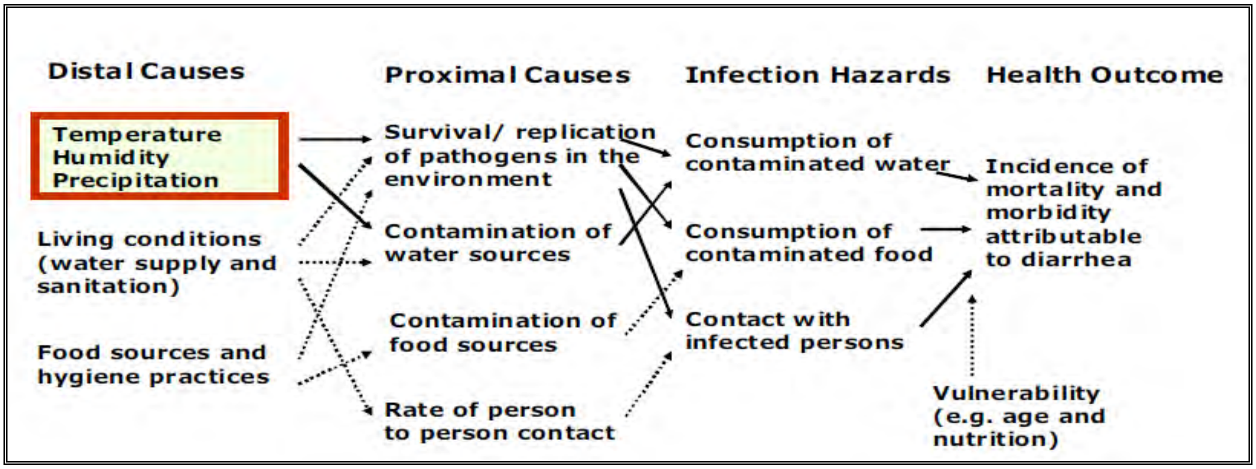
A. LINKING THE CLIMATE SITUATION TO DISEASES AND ILLNESSES IN TRINIDAD AND TOBAGO

In previous sections, the expected impact of climate variables on the incidence of diseases such as dengue fever and malaria were outlined briefly. In addition, a study by Amarakoon et al. (2007) attempted to link dengue fever incidence to rainfall and temperature in Trinidad and Tobago over a period of six years. The dengue fever outbreaks did show seasonality patterns where warming followed by rainfall preceded the outbreaks.

Projections are that temperature will increase and annual average rainfall will decrease but the occurrence of extreme events, such as „high intensity rainfall events', are likely to increase. If this is the case, then Trinidad and Tobago may continue to experience catastrophic flooding which may increase the risk of vector-borne, food-borne and water-borne illnesses. Increases in temperature can also contribute to the spread of these diseases. For example, during floods there is an increase risk of diarrhoeal illness due to water and/or food contamination with bacteria, faecal matter and rat urine. In addition, temperature increases alongside humid conditions may favour the growth of bacteria in water and food.

A depiction is presented in figure 16, which shows that climate variables can induce disease incidence, including diarrhoeal illness. Climate variables directly affect the survival and replication of pathogens in the environment and can contribute to the contamination of water sources. The consumption of contaminated food or water or contact with an infected person can increase the incidence of morbidity or mortality attributable to diarrhoea. It is important to note that living conditions and hygiene practices, as identified in the diagram, also contribute to the incidence of diarrhoeal illness.

Figure 16: Pathways through which climate change variables affect health: the example of diarrhoeal illness



Source: Ebi (2007).

From the literature, some other health outcomes are to be expected from changes in climate variables. Psychological disorders, nutritional impairment and respiratory infections and disorders can also arise in light of climate change.

This study has found that for Trinidad and Tobago nothing of significance on these other health outcomes has been published. There has been some work on Saint Lucia and Barbados which showed that diseases, such as respiratory tract infections, asthma and bronchitis, exhibited seasonal patterns and correlations of data for these diseases and climate data showed significant associations with temperature, relative humidity and Sahara Dust (Amarakoon, Stennett and Chen, 2004). In addition, the preliminary results of the incidences of the three most common diseases in Grenada, influenza, viral conjunctivitis and gastroenteritis, showed a close correlation with July and annual precipitation. Also, significant positive correlations were observed for August precipitation and the incidence of viral conjunctivitis and influenza (UNFCCC, 2005).

For Trinidad and Tobago, an analysis of the impact of climate change on these diseases may not be prudent at this time since data on these diseases at a country level are not available. For example, there are no national data sets of asthma cases. It is expected, however, that once the data become available for these diseases at the national level, the results of models designed to establish, if any, relationships between disease incidence and climate variables, may be similar to that obtained from the studies done in Saint Lucia and Barbados.

VI. PRELIMINARY CLIMATE CHANGE IMPLICATIONS FOR TRINIDAD AND TOBAGO

Though the warming of the earth's atmosphere by solar energy can be described as the natural greenhouse effect, human activity has stretched the rate of global climate change. The discussion on mitigation has arisen out of Trinidad and Tobago's seventh place ranking in the world based on carbon emissions per capita in 2007. In spite of this, the country only accounts for less than 1% of absolute global greenhouse gases (GOVTT 2009). It can be argued that climate change in Trinidad and Tobago, as well as that of other SIDS, occurs as a result of worldwide anthropogenic activities that increase the atmospheric concentrations of GHG such as carbon dioxide[32], methane, chlorofluorocarbons and nitrous oxide.

What is not in doubt is that if worldwide GHG emissions are not controlled, the cost to Trinidad and Tobago in addressing hazards that may occur could be quite significant. Bueno et al. (2008) presented a preliminary analysis of the potential costs to the island nations of the Caribbean on the condition that GHG emissions continue unchecked. Their findings for Trinidad and Tobago are presented in table 16 below.

Table 16: Net impact of climate change on the economic system

	2025	2050	2075	2100
Projected Growth in Current GDP[33]	7.1	6	5.7	5.7
Cost of inaction on Climate Change, % of Current GDP (Bueno et al. 2008)	4	8	12	16
Net Impact	3.1	-2	-6.3	-10.3

Source: Author's calculations, Bueno et al. (2008).

Without any intervention by the Government of Trinidad and Tobago, the GDP growth can deteriorate over the 90-year period. Although the effects of this on health outcomes will be discussed later, it is worth highlighting at this point that with the value of GDP reducing yearly, the private and public expenditure to the health sector can be expected to decrease.

Table 13 above paints a grim picture. The indications are that by 2025 the loss in GDP due to climate change will be 4%; in 2008 the level of national spending on health care was just above 4% of GDP. When faced with the prediction that by 2100 the loss in GDP resulting from inaction on climate change will be around 16%, the situation is clearly one that cannot be ignored. With a projected decreasing trend in GDP growth alongside increasing GDP losses from the impacts of climate change, the net impact on the economy is expected to be negative and should worsen post-2050.

Although mitigation cannot be completely ignored given Trinidad and Tobago's drive to become an industrialised State, its high level of carbon emissions per capita and the expected increase in its emission portfolio, it is adaptation that has to be given serious consideration. This is because it is expected that there will be inevitable impacts on the climate resulting from past emissions even if there is an immediate reduction in GHG, where, small islands like Trinidad and Tobago are expected to be impacted the most, given their existing vulnerabilities.

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[32] The most important anthropogenic greenhouse gas (IPCC 2007a).
[33] Estimated using Autoregressive Integrated Moving Average (ARIMA) modelling.

The study by the Caribbean Catastrophe Risk Insurance Facility (2010) showed that for pilot countries,[34] 90% of the expected damage of climate change can be avoided through cost-effective adaptation measures. Adaptation measures may be taken before the impacts are felt, during or after the impacts and may be taken as a matter of course, or deliberately. What will be involved is an assessment of the country's vulnerability to climate change as well as to other possible hazards. It will then be for public policy to create the necessary systems to support the implementation of appropriate measures.

VII. TRINIDAD AND TOBAGO: THE ECONOMIC BACKDROP OF CLIMATE CHANGE

A. THE MACROECONOMY

In order to better understand the seriousness of GDP loss estimates mentioned above, it will be useful to provide a brief review of the economic backdrop of the potential impact. On the face of it, the Trinidad and Tobago economy is strong and well poised. With a population of 1.3 million, the GDP per capita for 2008 was close to US$24 billion, which represents more than a doubling of real income when compared with 1995. The economy is basically driven by its energy sector, with gas and petroleum being the major earners of foreign exchange and being responsible for most of the growth in the economy. Over the past two decades, Trinidad and Tobago has experienced virtually unbroken growth with real GDP growth rates reaching double digits in 2003 and 2006.

The country has accumulated external reserves in excess of US$12 billion while its debt to GDP ratio is below 50%. What this has meant is that when the recent (2008-2009) global recession occurred, Trinidad and Tobago was well placed to weather the storm. Rates of unemployment which had fallen to less than 5% just prior to the recession have been projected to rise to 7%, but with social programmes in place, and with the government prepared to live with budget deficits for the next couple of years, the social impact of the expected rise in unemployment is expected to be minimal. The poverty rate which was estimated in 2005 to be 16.7% had been projected to fall to 13% by 2008 (Scott and Theodore 2008). Official poverty data for 2008 are not yet available.

B. THE ECONOMIC THREAT OF CLIMATE CHANGE

It is generally agreed that such economic prosperity may be threatened by climate change. However, there is some controversy in the literature of how the impact of climate change will affect economic growth.

Frankhauser and Tol (2005) argued that in addition to the direct impact of climate change on future welfare, the damages also impact economic growth via changes in capital accumulation and the propensity to save. The use of theoretical analysis led the authors to conclude that climate change will always have a negative effect on the absolute capital stock. If savings behaviour changes, the capital-labour ratio could decrease. A similar effect on the capital-labour ratio is expected if health effects are the dominant impact of climate change and savings remain fixed. This might be the case in vulnerable least developing countries.

Mendelsohn (2009) had a completely different view on the impact of climate change on economic growth. In fact, he describes statements that indicate that economic growth and well-being may be threatened in the absence of reduced emissions of GHG, as *"alarming and misleading"*. In his

[34] Anguilla, Antigua and Barbuda, Barbados, Bermuda, the Cayman Islands, Dominica, Jamaica, and St. Lucia.

explanation, he recognized that climate change is a serious problem that warrants attention, but states there is a very low probability that given society's current behaviour, the catastrophic consequences predicted will occur as these will require a century or more of no mitigation and/or adaptation. In fact, the author states that with adaptation, the predicted potential impacts may never occur.

Though Trinidad's mainstay is oil and gas, for Tobago, tourism is the main source of GDP. According to the World Travel Tourism Council (2009), 37% of GDP is attributed to the travel and tourism economy with nearly 50% of employment being travel related. For Tobago, climate change impacts threaten key tourism activities and resources; loss of key resources and infrastructure during extreme events while increases in ocean temperature may cause further damage to coral reefs. These impacts will definitely have direct implications for economic growth, and welfare.

Without sustainable GDP growth, the income of the Government of Trinidad and Tobago and expenditure on health may be at risk. Government's expenditure for 2008 was US$6.7 billion, or 28% of GDP. Of this, health expenditure was US$0.6 billion, which was just over 8% of total expenditure. It is interesting to note that the average share of health spending held between 6% and 8% for the past few decades. This public sector spending on health has been estimated to be a little more than half the national spending on health. In other words, private spending on health in Trinidad and Tobago is very also significant.

While the entire economy is negatively affected, the encounters of individuals and their personal income can also be influenced. This is especially so for women who according to the Draft National Gender Policy and Action Plan,

> *"…continue to comprise the majority of the unemployed, underpaid in every sector of employment, except when employed by the state, and in every occupational group."*
> (Centre for Gender and Development Studies, 2004, 35)

C. THE DEVELOPMENT IMPLICATIONS OF CLIMATE CHANGE

It has been noted that there are cross-cutting issues in the relationship between climate change and health. This is because apart from direct effects on GDP, there are issues in respect of coastal settlements, food security and water supply. What this means is that climate change has the potential to affect not only certain aspects of the Trinidad and Tobago economy, but also the country's overall development. This is seen most clearly if there is a focus on human development. The Human Development Report (HDR, 2007) identified climate change as one of the defining forces shaping prospects for human development during the twenty-first century through its impacts on ecology, rainfall, temperature and weather systems. In addition, global warming was projected to directly affect all countries, but at varying degrees, since some countries are more vulnerable than others. The 2007, HDR stated that significant strides have been made globally regarding human development since 1990 and described the situation as one where climate change will be superimposed upon a world marked by large human development deficits.

Human development impacts will vary as changes in climate patterns interact with existing social and economic vulnerabilities. While uncertainties surround the timing, nature and magnitude of impacts, global warming is expected to reverse major human development progress and magnify existing disadvantages. Emerging risks will fall disproportionally on countries already characterized by high levels of poverty, low levels of nutrition, high levels of child mortality and significant health problems. In fact, currently the risks and vulnerabilities are more skewed towards the world's poorest people. In the context of human health, the report pointed out that those least equipped to respond to changing health threats will bear the brunt of the health setbacks, in a time when ill-health limits human development for poor households.

This means that with a 2005 poverty rate of 16.7% and a vulnerability rate of 9% (Kairi Consultants, 2007), Trinidad and Tobago may suffer from loss of productivity because the poor, whether employed or unemployed, may be unable to cope with, and recover from, natural hazards and disasters[35].

There is some expectation that the poor will be impacted the most by climate change given their already existing vulnerabilities. The gender dimension of the discussion also enters the discussion, especially since in Trinidad and Tobago it is estimated that 38% of poor households are being headed by women (Survey of Living, 2005). The ability of these households to cope with, and adapt to, the projected impact of climate change remains a grey area.

VIII. THE IMPACT OF CLIMATE CHANGE ON HEALTH OUTCOMES IN TRINIDAD AND TOBAGO: A SUGGESTED APPROACH

A. INTRODUCTION

This section will seek to present a framework for understanding the factors affecting the country's vulnerability as well as its resilience in respect of the human health impact of climate change. In the case of the present study, given time and data limitations, the focus of analysis will be on the health impact of climate change as seen through the lens of a few selected diseases, namely dengue fever, leptospirosis, and food-borne illnesses.

The analysis makes use of a framework which enables us to monitor the ability of the health system to respond to the increasing risk of infectious diseases induced by climate change. For policy makers, it would be important to know the channels through which the country's health status can be adversely affected by climate change – its vulnerability exposure. However, it would be equally important to know the capacity or ability of the country's health system to respond to the health impacts – its resilience potential. While vulnerability depends mainly on factors beyond our control, resilience is most often a matter of public policy. In the case of the health system, resilience will depend on policy effectiveness at the systems level, the organizational level, the community and individual level or personal level.

Figure 17 introduces a model which portrays the mechanisms through which both vulnerability as well as resilience associated with climate change can affect health outcomes. While inspired by the literature on resilience and vulnerability, the model itself is an innovation. It seeks to capture the fact that climate change is one of the many factors impacting the economic and health systems. Given the link between climate and the spread of infectious diseases as outlined in previous sections, permanent changes in climate can, therefore, have severe impacts on disease incidence. The model portrays that the higher the disease incidence, the higher the expected demand for health services to treat with the increase in infected cases. In these circumstances focus will turn to the capacity of the health system to respond to the increased demand for health services following the spike in disease incidence. It is the combined impact of the increase in the demand for health services and the response capacity of the health system which will determine the resulting health outcomes.

[35] Kjellstrom et al. (2008) predicted that under A2 conditions the productivity of labour in the Caribbean will drop by 11.4 – 26.9 %.

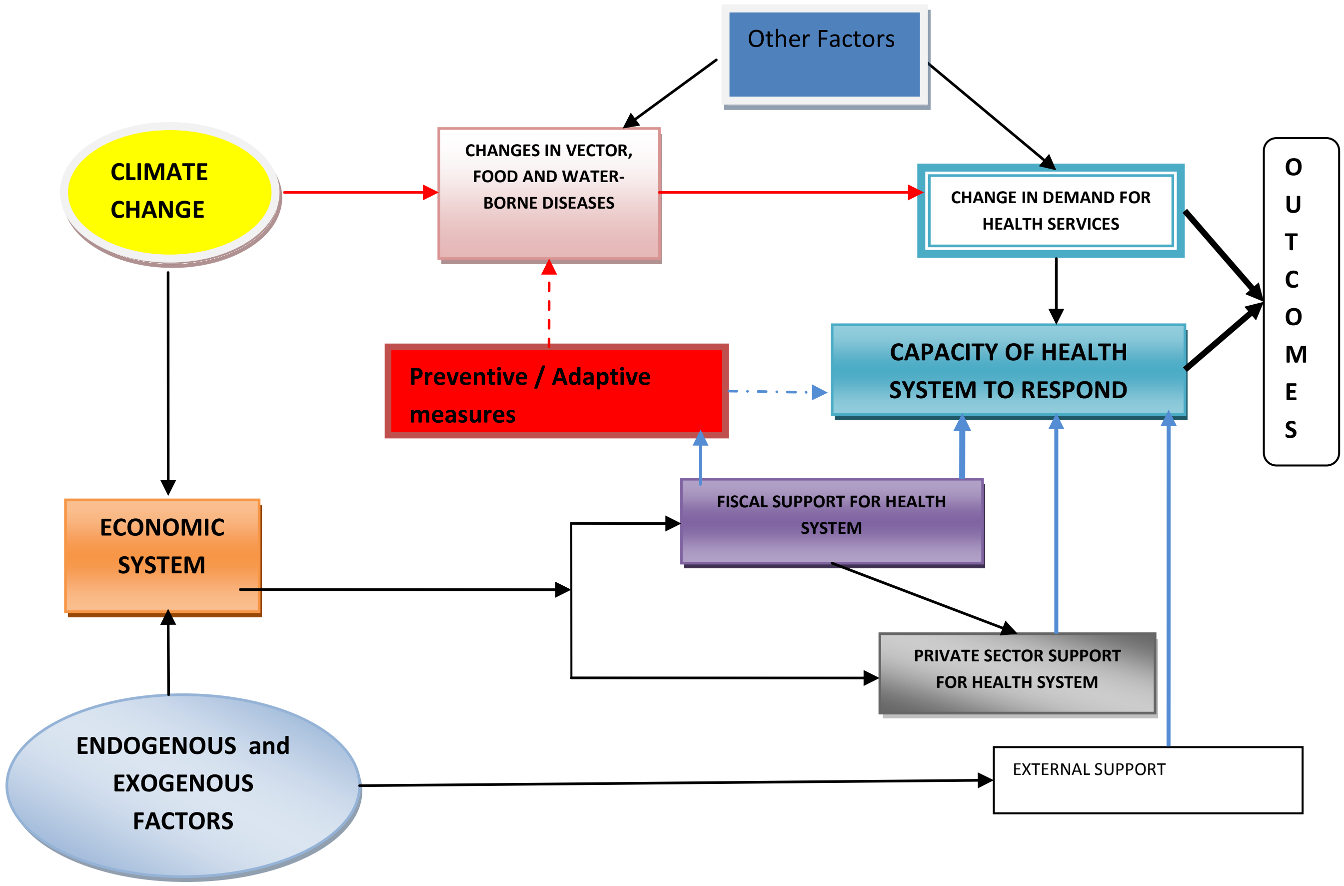
The model highlights the potential double impact of climate change – a direct impact by increasing the demand for health services and an indirect impact by limiting the capacity of the health system to respond. Since the health system draws on the economic system for its inputs from fiscal or private sources, the negative impacts of climate change on the economic system can compromise the ability of the health system to respond to an increase in climate-induced disease incidence.

It is this scenario which makes adaptive interventions imperative. Included in the possible adaptive measures will certainly be those preventive measures taken to reduce the incidence of infectious diseases. These would, of course, complement other adaptive measures undertaken to build health system capacity to respond to likely increases in disease incidence (figure 17 illustrates).

The upper part of figure 17 portrays the vulnerability channel flowing from climate change through disease incidence and changes in demand for health services on health outcomes. This channel reflects a combination of monotonic influences. The lower part of figure 17 seeks to capture the resilience channel. However, because of the vulnerability of the entire economic system to climate change, the resilience effects will depend on the balance between negative and positive influences on the economic system.

In the estimations that will follow only the top left hand section of the model, where the links between climate change and disease incidence are portrayed, will be employed. Fitting the entire model remains work to be done.

Figure 17: Modelling the impact of climate change on health outcomes - monitoring vulnerability and resilience



Source: Data compiled by Author

B. The Model – Vulnerability and Resilience

In evaluating a country's vulnerability exposure to the health impact of climate change and the resilience of its health sector to respond, the following variables would be useful.

➢ **Variable names:**

- VWFD : vector and water borne diseases
- CC: climate change
- AM: adaptation measures
- FS: fiscal support for health sector
- EF – Endogenous Factors (mainly human capital)
- DH: demand for health services
- OF: other determinants of health needs (mainly lifestyle and living conditions)
- GDP: Gross domestic product
- XF: exogenous determinants of income (mainly energy sector earnings)
- PI : level of personal incomes, private sector support for health system
- HSCAP: capacity of the health system
- HOUT: population health outcomes

- EAS: external agency support

- **Variables defined:**

1. VWFD = V(CC,MM,OF) $V_1>0, V_2<0, V_3$
2. AM = A(FS) $A_1>0$
3. DH = D(VWFD, OF) $D_1>0, D_2$
4. GDP = G(CC, EF, XF) $G_1<0, G_2>0, G_3>0$
5. FS = F(GDP) $F_1>0$
6. PI = P(GDP, FS) $P_1>0, P_2<0$
7. HSCAP= S(FS, PI, EAS) $S_1>0, S_2>0, S_3>0$
8. HOUT = H(HSCAP/DH) $H_1>0$

- **Discussion**

A number of points need to be noted:

- The first point is that the model does not present an exhaustive set of determinants of health. Of the three main determinants that concern the economist - behaviour, living conditions and the health system – the model focuses mainly on the health system, while leaving room for elaborating on behaviour or lifestyle.
- With relevant substitutions, the *capacity equation* can be rewritten as

$$HSCAP = S\{FS(GDP(CC, EF, XF)), P(GDP(CC,EF, XF))\}$$

This highlights the fact that health system capacity depends on the negative and positive influences on the national income of the country.

Also highlighted is the link between health outcomes and the quantum of fiscal support on the one hand, as well as the quality (S_1) of the fiscal support, on the other.

- The second main capacity determinant in the system would be the level of private incomes, which can be taken as a spending or standard of living indicator.
- The model seeks to capture the joint responsibility of the public and private sectors in the adaptation to climate change. Ensuring that the capacity to respond is adequate is not a matter for the government alone.
- It should be noted that if a direct link between fiscal support and the adaptive capacity of the health system is assumed, the focus on fiscal support is virtually coterminous with a focus on the adaptive factors indicated in the model.
- Finally, the use of the ratio of *capacity* to *demand for services* as the determinant of health outcomes highlights the service quality challenge facing the health system. In this respect, there is usually a tendency for the situation to worsen as demand or utilization increases and to improve as the capacity of the system expands.
- Improvement, therefore, requires that capacity changes continue to outstrip utilization demands.

IX. EMPIRICAL DETERMINATION OF THE IMPACT OF CLIMATE CHANGE ON DISEASE INCIDENCE IN TRINIDAD AND TOBAGO

A. DATA AND METHOD

Using the Engle-Granger Two-Step Algorithm Testing and Error Correction Modelling[36] via EVIEWS 7 and EVIEWS 4, the impact of climate variables on the disease incidence levels was examined. With reference to the framework portrayed in Figure 17, the regression modelling will focus on the vulnerability of the health sector to climate change. Data were sourced from the Caribbean Epidemiology Centre, the Central Statistical Office of Trinidad and Tobago, the National Surveillance Unit, Ministry of Health and the World Bank. Due to the limited availability of time series data of some variables, simple linear extrapolation was used to achieve a complete dataset[37]. A time series spanning 27 years, from 1980 to 2007 was used in the analysis. Given data limitations only a few diseases were examined namely dengue fever, leptospirosis, food-borne illnesses and gastroenteritis. These diseases were chosen due to the availability of the length of time series data. Though limited information for other diseases were available, the years for which the data extended were not sufficient for any meaningful econometric estimation.

As discussed in Section 4, the literature indicates that apart from climate, there are a number of other factors influencing the emergence and spread of infectious diseases. As such, in estimating the impact of climate on disease incidence, a number of non-climate variables were also considered.

B. THE MODEL –DENGUE FEVER

1. Functional form selection and Variables' a priori expectations

The independent variables outlined in table 17 were selected to be considered in modelling the impact of climate variables on dengue fever incidence in Trinidad and Tobago. Given the literature and our own interpretation, the *a priori* expectations of the variables to the power of 1 (that is non-polynomial) to be considered are expressed below.

[36] It is relevant to note that Negative Binomial Regressions or Poisson Regressions were not used upon discussions with other researchers. Due to their experience in the statistical field, count data methods were not observed as the best process for a project such as this.

[37] In this procedure, the missing years of data were calculated by finding the difference in the values between the two years of data available. For example, if data for 1994 and 1998 was available, but data for 1995 to 1997 was missing, the difference in the values between 1998 and 1994 would be calculated. Following this step, the figure found was divided by the number of missing years of data plus 1. The incremental value discovered was added to the base year (for example 1994) and was continuously added each year for which data was missing until the last year for which data was actually available (for example 1998).

Table 17: A priori expectations – Dengue fever

Independent Variables	Expected Relationship
Rain Dummy[38]	***Positive***
Improved water source, rural (% of rural population with access)	***Negative***
Improved sanitation facilities, total (% of urban population with access)	***Negative***
Population size	***Positive***
Temperature - Mean of Maxima	***Positive***
Relative Humidity	***Positive***

Source: Data compiled by Author

Of course, the relationship of certain variables may not take a form that is simply linear. Prior to the determination of the model, Microsoft Word and Excel were used to determine the individual relationships between the dependent variable and each independent variable. It was found that some relationships were not linear in functional form. The best functional form was used in the final model given the functional form of the other variables by practicing stepwise induction as developed by Chatterjee and Sarkar (2009)[39].

2. Results

In the first stage of the Engle-Granger procedure attempts were made at achieving a best linear unbiased estimator (BLUE) model through Ordinary Least Squares regression. The best result from the best model is shown below.

Dengue Fever Incidence

$$DENGUE = (-2.076932)*TEMP\_MAX^3 + (93.58991)*TEMP\_MAX^2$$
$$\quad\quad (-2.5) \quad\quad\quad\quad (2.4)$$

$$(-452.52)*IMPROVE\_SANIT\_TOT + (-308.18)*IMPROVE\_WATER\_RURAL + (.02)*POP +$$
$$\quad\quad (-3.92) \quad\quad\quad\quad (-6.27) \quad\quad\quad\quad (6.27)$$
$$(919.12)*RAIN\_DUMMY + (0.012920)*HUMIDITY\_8^3$$
$$\quad\quad (2.56) \quad\quad\quad\quad (2.26)$$

R-Squared Adjusted= .75 DW= 1.9

Where,
DENGUE: Dengue fever incidence
TEMP_MAX: Temperature-Mean of Maxima
RAIN_DUMMY: Notes the years in which precipitation was above average
IMPROVE_WATER_RURAL: Improved water source, rural (% of rural population with access)
IMPROVE_SANIT_TOTAL: Improved sanitation facilities, total (% of total population with access)
POP: Population size[40]
HUMIDITY_8: Relative humidity at 8 a.m

[38] This dummy observes above average rainfall as "1" and below average rainfall as the value "0".
[39] Chatterjee and Sankar (2009) applied the multi-step polynomial regression method to malaria in India.
[40] In Trinidad and Tobago, some areas are sparsely populated, while in other areas this is not the case. Hence, in modelling, population size and not population density was used .

3. Discussion of Results

According to the adjusted R-squared, the model explains 75% of the variation in the dependent variable. The independent variables were significant at the 5% and 10% levels of significance. At a 75% adjusted R-squared, the expectation of bias affecting the model has not been realised. While there is always a risk of excluding variables, certain variables were selected based on the framework of analysis developed from an overview of the literature the author's interpretation as well as data availability.[41]

The population variable "POP", the climate variable "RAIN_DUMMY", and the non-climate variables "IMPROVE_SANIT_TOT" and "IMPROVE_WATER_RURAL" had outcomes that were anticipated. The population coefficient indicates that with an increase in the population by 1 person, the rise in the number of cases of dengue will equate to .02 persons. Also, an increase in the percentage of persons with access to improve sanitation facilities by 1 will result in the number of dengue fever cases being reduced by 453 persons. A similar result is observed for the "IMPROVE_WATER_RURAL" variable; a 1% increase in access reduces dengue fever incidence by 308 cases. The positive sign of the rain dummy points to above average rainfall adding to the number of dengue fever cases per year.

From analyzing the temperature variable, it was found that the polynomial representations had an increasing effect on "DENGUE". This means that the slope of the quadratic temperature relationship is a steadily rising one. Calculating the change in "Dengue" given the actual temperature values, it was observed that a rise in temperature resulted in the change in dengue fever being positive. This means as temperature increases so, too, does the incidence of dengue fever. Annex VII shows the change in dengue fever cases given temperature changes. The relative humidity variable also showed a similar effect on the dependent variable but at a rate of change that is lower thus resulting in a flatter slope. Annex VII also shows the yearly change in dengue fever cases given relative humidity levels.

It is known that in econometric analyses a problem arises that can limit the viability of the results and, hence, the applicability of any policy recommendations. The problem of unit roots can indicate spurious regression in which there are no established causal relationships between the dependent variable and the independent variables. Through the Engle Granger Cointegration Procedure, once variables are cointegrated, an adjusted model can be used. For the present study, it was found that the variables are cointegrated. This led to the use of Error Correction Modelling to address the problem of non-stationarity. In this way the analysis can be carried out without underlying bias.

4. The Error Correction Model

Ordinary Least Squares regression is again used and this model incorporates both the long-run and short-run relationships of "DENGUE".

Change in Dengue Fever Incidence

$$D(DENGUE)= (-17.29)*D(TEMP\_MAX^{3}) + (819)*D(TEMP\_MAX^{2})$$
$$(-1.866) \qquad (1.866)$$

$$(37.57)*D(IMPROVE\_SANIT\_TOT) + (20.49)*D(IMPROVE\_WATER\_RURAL)$$
$$(.27) \qquad (.47)$$
$$+ (-.003)*D(POP) + (296)*D(RAIN\_DUMMY) + (-.0002)*(HUMIDITY\_8^{3})$$
$$(-.23) \qquad (1.38) \qquad (-.04)$$

[41] This is applicable to all diseases discussed. There is always some anticipated bias and the author acknowledges this. As long as the R-Squared is large, given the goals of this paper and the vulnerability aspect of the developed framework, bias does not influence the results.

+ (-.91)* DENG_RESID_POLY (-1)[42]
(.-3.97)
R-Squared Adjusted= .49 DW= 1.9

Though the originally specified variables have been differenced, some of the *a priori* expectations are sustained from the model in Section B.2, for example, rainfall. With an adjusted goodness of fit of .49 and other pre-tests and post-tests supporting the model (see Annex I), one can derive conclusions such as those presented in the following section.

5. Conclusions

Though employing a simple procedure, the model has highlighted the importance of climate and non-climate variables to the spread of dengue fever in Trinidad and Tobago. Above average rainfall levels can lead to an outbreak of cases. Temperature and relative humidity also positively influences the number of dengue fever cases.

Access to sanitation facilities and improved water sources were also found to play significant roles in determining dengue fever incidence levels. Without underestimating the considerable impact of the climate variables, from the model it is evident that infrastructure levels are also important in determining dengue fever incidence levels in Trinidad and Tobago. In fact, the lack of pipe-borne water[43] in Trinidad and Tobago has been found to be fuelling dengue fever in Trinidad and Tobago, according to the Chief Medical Officer (La Rose, 2011). Increased access to improved water sources, therefore, seems like a solution in minimizing dengue fever incidence in Trinidad and Tobago. The variable "IMPROVE_WATER_RURAL" supports this hypothesis as a negative coefficient is attained in the model. Increasing access to improved sanitation facilities also showed an inverse relationship with dengue fever incidence as improvements may target poor living conditions which may have been contributing to dengue fever. From the discussion above, any climate change adaptation response in Trinidad and Tobago must take into account improvements in sanitation facilities and water sources.

The population variable sustains expectation as densely populated areas may tend to have higher incidence rates of dengue fever. Brown et al. (1996), in a study on dengue fever in Trinidad, established that for the number of cases that were studied,

> "*The highest proportion of these 154 confirmed cases (46%) occurred in the most densely populated county of St. George, in which the capital, Port-of-Spain, is situated."* (Brown et al. 1996, 9)

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[42] Note that the residual series of dengue is the actual cases of dengue minus the model derived in Section 9.2.2. This shows that the coefficients in 9.2.2 does apply to the new model and even though the model may not show differenced terms as significant or may not carry the coefficient signs of the first OLS procedure, the main purpose is to highlight that the 9.2.2 model can be used and interpreted and does apply to some final outcome, that is, the change in dengue cases. This point should be remembered when inspecting the leptospirosis and food-borne illnesses models.

[43] 80 per cent of the population does not receive pipe-borne water continuously during the day and the storage of water is contributing to the breeding of the Aedes Aegypti mosquito which spreads dengue fever (La Rose 2011).

C. THE MODEL - LEPTOSPIROSIS

1. Variables

The independent variables outlined in table 18 were selected to be considered in modelling the impact of climate variables on leptospirosis incidence in Trinidad and Tobago. Given the theory and our own interpretation, the *a priori* expectations of the variables are expressed in table 18.

Table 18: A priori expectations - Leptospirosis

Independent Variables	Expected Relationship
Rainfall	***Positive***
Improved sanitation facilities, total (% of urban population with access)	***Negative***
Temperature-Mean of Maxima	***Positive***
Forest area(% of land area in Trinidad and Tobago)	***Negative***

Source: Data compiled by Author

2. Results: Original and Error correction models

The results from the BLUE model are presented below.

Leptospirosis

LEPTO= (69.14)*TEMP_MAX + (-26.15)*FORESTAREA + (.05)*RAINFALL(-1) +
(7.87) (-6.55) (2.2)

(-10.4) *IMPROV_SANIT_TOTAL(-4) + (-.61) * AR(2)
(-4.9) (-2.9)
R-Squared Adjusted= .46 DW= 1.43

Where;
LEPTO: The number of leptospirosis cases
TEMP_MAX: Temperature-Mean of maxima
IMPROV_SANIT_TOTAL: Improved sanitation facilities, total (% of total population with access)
FORESTAREA: The percentage of land area covered in Trinidad and Tobago by forested land
RAINFALL: Represents the level of precipitation
AR: Autoregressive term to correct the problem of autocorrelation that arose in examination of the model.

As was explained in Section B.3, the issue of unit roots was addressed given that the dependent variable and independent variables are cointegrated (observe Annex II) and the following error correction model was attained:

Change in Leptospirosis cases

D(LEPTO)= (8.49)*D(TEMP_MAX) + (-45.33)*D(FORESTAREA) + (.04)*D(RAINFALL(-1)) +
(1.07) (-1.77) (4.01)
(-2.6) *D(IMPROV_SANIT_TOTAL(-4)) + (.15) * LEPTO_RESID + (-.76)*AR(2)
(-.53) (1.3) (-4.43)
R-Squared Adjusted= .62 DW= 1.3

3. Discussion of Results

The adjusted R-squared is approximately 46% which indicates that the variables in the model are useful in explaining the variation in the incidence of leptospirosis. All the independent variables were significant at 5% and 10%.

A lagged autoregressive term of 2 was included in the model to address the problem of autocorrelation. Despite the possibility of bias, this method was used for the purpose of simplicity. Other procedures, for example the Cochrane Orcutt process, are iterative and time-consuming and logically were not chosen.

Consistent with the literature and as expected, the model shows a positive relationship between "RAINFALL(-1)" and the number of new cases of leptospirosis. A rise in rainfall by 1 millimetre results in .05 new cases of leptospirosis. In addition, as "IMPROVE_SANIT_TOT" increases by %, the model shows that the incidence of leptospirosis decreases by 10.4 cases.

As predicted, the model shows a negative relationship between "FORESTAREA" and leptospirosis incidence with a coefficient of -26.15, that is, a reduction of leptospirosis cases by 26.15. This relationship could be explained in two ways. Firstly, as "FORESTAREA" decreases, the cleared land is assumed to be used for productive reasons (agriculture, construction of homes, or other infrastructure) thereby increasing food and shelter for rodent populations. Secondly, forested areas serve as habitats for rodents and destruction of such habitats would mean that rodent populations may have to seek new homes, thus possibly increasing their contact with humans. Moreover, as anticipated, the coefficient of TEMP_MAX was positive. An increase in temperature by 1 degree leads to an increase in leptospirosis incidence by 69 cases.

4. Conclusions

Rats can swim and survive in water. Hilton, 2010 states that,

> " *...rats infected with leptospirosis can swim in rivers, drink from open drains and swim in flash flood waters going about their business as usual, passing urine and faeces that could be infected with leptospirosis spirochaetes. Once you know this, you understand how you can get leptospirosis by wading in floodwaters or paddling, barefoot, in a puddle.*" (Hilton, 2010)

The argument here is that leptospirosis can spread across Trinidad and Tobago through a number of ways. Above average rainfall which results in flooding can displace rodent populations leaving them to seek higher ground in homes. In addition, unsafe practices by individuals during floods such as, wading, paddling or walking barefooted in flood waters can increase the risk of contracting leptospirosis. A decrease in forest area is also a contributory factor. The increased contact with rodent populations can also expose humans to rodent-borne diseases such as encephalitis which further emphasizes the need to take steps to inhibit rodents. Based on results of the model which focussed on leptospirosis, improving sanitation facilities is a potential solution. This will be discussed in the section on adaptation options.

D. The Model - Food-borne Illnesses

1. Functional form selection and Variables' a priori expectations

In conceptualising the model for food-borne illnesses incidence levels two independent variables were evaluated. These are presented below in table 19, along with their *a prori* expectations.

Table 19: A priori expectations - food-borne illnesses

Independent Variables	Expected Relationship
Relative Humidity	***Positive***
Rainfall	***Positive***

Source: Data compiled by Author

Due to the high likelihood that the relationship of these variables with food-borne illnesses cases may not be linear, Microsoft Excel was used to determine a polynomial form and was applied in the statistical process.

2. Results: Original and Error correction models

The outcomes of the model are displayed as follows:

Food-borne Illnesses

$$FOODBORNE = \underset{(-2.6)}{(-.003)} * HUMIDTY\_8^3 + \underset{(-3.6)}{(-.0006)} * RAINFALL^2 + \underset{(3.7)}{(2.67)} * RAINFALL$$

R-Squared Adjusted= .2   DW= 1.8

Where;

FOODBORNE: the incidence of food-borne illnesses in Trinidad and Tobago

HUMIDTY_8: Relative Humidity at 8 a.m

RAINFALL: Represents the level of precipitation

With the model being statistically acceptable according to post tests and with the variables having some degree of cointegration, the error correction model is defined as,

Change in Food-borne Illnesses cases

$$D(FOODBORNE) = \underset{(-1.6)}{(-.002)} * D(HUMIDTY\_8^3) + \underset{(-.88)}{(-.0003)} * D(RAINFALL^2)$$

$$+ \underset{(.83)}{(1.45)} * D(RAINFALL) + \underset{(4.14)}{(.9)} FOOD\_POLY\_ERROR(-1)$$

R-Squared Adjusted= .44   DW= 1.89

3. Discussion of Results

With an adjusted R-squared of 20%, the effects of the relative humidity variable and the rainfall variable vary.

The relative humidity variable has an increasing effect on food-borne illnesses which means the slope of the relationship between the two variables are increasing. The outcome, however, is that of a cumulative positive relationship as with a rise in relative humidity the change in food-borne illnesses are positive, that is, as relative humidity increases so, too, do the number of cases of food-borne illnesses. This is consistent with the links identified in the literature since high relative humidity means that the air is saturated with *moisture*, a key factor in the growth of mould and bacteria (Dincer 1997). In modelling, it was found that temperature was insignificant although it was identified in the literature as a contributory factor.

For "RAINFALL" however, the result has been a combined diminishing effect. Theoretically, for the first year of data (1980), a 1 millimetre increase in rainfall increases food-borne diseases by 2.67. The aforementioned does not happen cumulatively over the time period. As rainfall increases, the incidence of food-borne diseases decreases since a rise in rainfall results in a negative change in the number of cases (Annex VII). In Trinidad and Tobago, according to the 2000 Census, people still make use of spring rivers and other forms of water supply. High levels of rainfall, therefore, could mean increased use of private catchments for household purposes and less use of more risky forms of water supply such as rivers. This phenomenon could help explain the relationship between rainfall and food-borne illnesses. It should also be noted that, although increased rainfall was expected to be linked positively to food-borne illnesses, increased rainfall does not necessarily mean that flooding occurred to the extent that water courses have been contaminated.

The variable, increase in access to improved water sources, were found to be insignificant in the model. As indicated in Section 4, the data series "food-borne illnesses" also includes diseases that are "water-borne". The ratio of the number of cases of food-borne illnesses to the number of cases of water-borne illnesses may however be disproportionate in favour of food borne illnesses. As such, this may have resulted in the water access variable being insignificant in this context.

4. Conclusions

The conclusion here is that the model has found climate variables in particular relative humidity and rainfall to be linked to the incidence of food-borne diseases in Trinidad and Tobago. However, it is quite clear from the adjusted R-squared that there are other important variables that were not considered owing solely to the unavailability of data. In the context of food-borne illnesses, one very important factor which could not be quantified relates to food hygiene practices. In the literature, this was found to be one of the major drivers of food-borne illnesses but could not be included in our model. Despite this, however, one clear implication of the results from the study that should be stressed, concerns the food health and safety practices of individuals and institutions. This can be justified since as indicated in an earlier section, most of the food-borne disease outbreaks in the Caribbean have been linked to poor food safety practices.

E. THE MODEL - GASTROENTERITIS

1. Variables

In attempting to specify the model, the following were expected. Table 20 illustrates.

Table 20: A priori expectations – Gastroenteritis

Independent Variables	**Expected Relationship**
Relative Humidity	***Positive***
Improved water source, rural (percent of rural population with access)	***Negative***

Source: Data compiled by Author

2. Gastroenteritis results: Original and Error correction models

The model produced the following outcome

Gastroenteritis

GASTROENTERITIS = (-6327099) + (2625.183)*IMPROVE_WATER_RURAL
(-2.3) (2.08)
+(-.13)*IMPROVE_WATER_RURAL^4 + (148883.7) *HUMIDITY_8 + (-892.4)* HUMIDTY_8^2
(-1.12) (2.3) (-2.3)
R-Squared Adjusted= .24 DW= 1.9

Where;
GASTROENTERITIS: the incidence of gastroenteritis in Trinidad and Tobago
IMPROVE_WATER_RURAL: Improved water source, rural (percent of rural population with access)
HUMIDITY_8: Relative humidity at 8 a.m
With the model being statistically acceptable according to post tests and with the variables having some degree of cointegration, the error correction model is defined as,

Change in Gastroenteritis

GASTROENTERITIS = (59.7) + (2016.15)*D(IMPROVE_WATER_RURAL)
(.1) (2.6)
+(-.104)*D(IMPROVE_WATER_RURAL$^{4)}$ + (111327.7)*D(HUMIDITY_8)
(-2.5) (2.5)
+ (-667.3)*D(HUMIDTY_8^2) + (-1)*GASTRO_POLY_ERROR(-1)
(-2.5) (-3.06)
R-Squared Adjusted= .53 DW= 1.7

3. Discussion of Results

According to the adjusted R-squared, the model explains 24% of the variation in the dependent variable. From a technical standpoint, a 1% rise in improved water access in rural areas from 1990 to 1991 increased gastroenteritis incidence by 2,625 cases. Although an increase in access to water sources coincides with an increase in gastroenteritis cases, the effects of "IMPROVE_WATER_RURAL" was found to be diminishing which is a positive indication for Trinidad and Tobago. Hence, even though the number of gastroenteritis cases was rising alongside increases in access to improved water sources, it doing so at a decreasing rate. This proves the importance of the improvements in water sources.

The cumulative outcome of relative humidity also showed that it had a positive relationship as expected with gastroenteritis, but only up to a certain level (this is known as the turning point). It is at this level (83) that the quadratic relationship changes. For the first year of data (1980), a 1 degree rise in relative humidity can result in increase in gastroenteritis incidence by 148883.7 cases. For the other years, the change in gastroenteritis, given relative humidity levels are shown in Annex VII.

Improved access to sanitation facilities was included in the model but was found insignificant. Again, further research is needed for all food-borne diseases.

4. Conclusions

A conclusion similar to that of food-borne illnesses applies in the case of gastroenteritis as well since there were important qualitative factors that could not be included in the model which may have affected the fit of the model.

F. Links to the Vulnerability /Resilience Model

Before closing this section, it is useful to point out that the empirical results obtained are directly related to the vulnerability component of the model described in figure 17. The results of Section IX actually show that with climate change, vector, food and water-borne diseases can increase. This, therefore, points to rising health services demand which may further stress health system capacities. In addition, given that climate change also puts a strain on the economic system, the capacity of the health system will also be limited. Of course if there is a rise in demand for health services caused by an increased incidence of disease due to climate change, and there is a limited health system capacity, again due to the effects of climate change, then a negative result in respect of the “Health Outcomes” depicted in figure 17 would be expected. The issue of the demand for health services and health services capacity is addressed in the next section.

X. THE DEMAND FOR HEALTH SERVICES AND HEALTH SERVICES CAPACITY

Assuming that population growth is a good indicator of change in the demand for health services, this variable was used as an appropriate proxy over the period 1990 to 2003.[44] During this period, the demand for health services is estimated to have increased by 14%.[45]

[44] See 1) Joyce CM, S Wimalaratne, and JJ McNeil. 2003. "Future demand for general practice services: effects of population change and trends in service use". *Australian Health Review: a Publication of the Australian Hospital Association.* 26 (2): 26-33 and 2) David Achanfuo Yeboah. Wntr 2007. “Impact of population variables on health services demand in the UAE”. Arab Studies Quarterly.

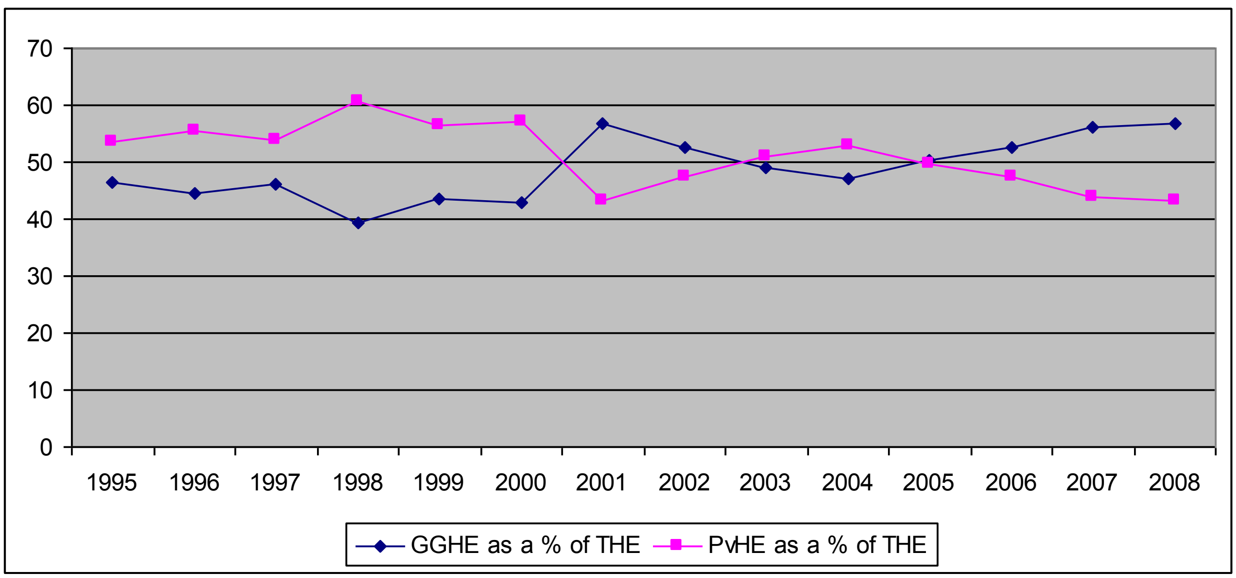
[45] The increase in population over 60 years was used as proxy for the change in health services demand. Moreover, the expansion in health sector personnel was used to determine growth in health system capacity.

With respect to capacity, the rate of expansion in key inputs of the health system (physicians, dentists, and nurses) was used as a proxy. In this regard, as noted in table 7, health system data suggest that in 2005, important dimensions of health service capacity reflected an average increase of 96% over what it was in 1996. This virtual doubling of capacity speaks to the resilience of the health system since it allows hospitals and health centres to treat with increasing levels of illnesses in the population. According to figure 17 which models the impact of climate change on health outcomes, the change in demand for health services is seen as the challenge to the capacity of the health system.

Other proxies are possible, the share of health and the number and size of existing health facilities, for example, but the rate of expansion of key inputs seemed to capture best the specific aspects of capacity that would matter in case of a sudden surge in demand.

In Trinidad and Tobago, although the capacity of the health system is assumed to depend largely on fiscal support, the role of the private sector should not be underestimated. In fact, private health expenditure as a percentage of total health spending outstripped government expenditure on health for most of the period 1995 to 2008 (figure 18). However, in more recent years, government spending on health as a percent of total spending on health has exceeded private spending, and it appears that this gap is widening. The importance of the public health system cannot, therefore, be overestimated.

Figure 18: Government and private expenditure on health as a percent of total health expenditure



Source: World Health Organization: Trinidad and Tobago - National Expenditure on Health.

Data from WHO from 1995 to 2008 show that out-of-pocket health expenditure comprises mainly private health expenditure (over 80%). Moreover, out-of-pocket health expenditure as a per cent of GDP has been almost equal to government's expenditure on health as a per cent of GDP over 1995 to 2008 (2%-3%). Given that out-of-pocket expenditure on health is as important as government's own investment in health, the incomes of citizens and residents come into question. Of greater importance is the income of the Government of Trinidad and Tobago since the loss of earnings could translate into a reduction in the capacity of the health system and a decrease in government's expenditure on health per capita, which stood at approximately US$524 in 2008 (WHO). By using GDP as an indicator to signify the income earnings of Trinidad and Tobago, climate change can compromise the response ability of the health system.

XI. SCENARIO ANALYSIS

A. IPCC SCENARIOS

The future impact of climate change depends largely on future emissions of GHG which are the product of very dynamic systems determined by driving forces such as demographic, socio-economic and technological development. Given the degree of uncertainty surrounding future events, scenarios were developed as possible images of how the future will unfold. The scenarios developed by IPCC assist in analyzing how driving forces may influence future emissions and in assessing associated uncertainties. It should be noted, however, that this set of scenarios excludes outlying „surprise' or „disaster' scenarios and any scenario is open to various interpretations since it includes subjective elements. The scenarios are not assigned any probability of occurrence nor should they be interpreted as policy recommendations. (IPCC 2000)

In developing the scenarios, four different storylines (A1, A2, B1 and B2) were developed with each storyline reflecting different emission driving forces and allows for the quantification of scenarios. Different scenarios were developed for each storyline using different modelling approaches to examine the range of outcomes arising from a range of models that use similar assumptions about driving forces. IPCC SRES are outlined in table 21. (IPCC 2000)

In this study, the A2 and B2 emissions trajectories will be utilized as well as a BAU scenario which uses past trends in driving forces (historical trends) to forecast changes in the variable under consideration, in this case, disease incidence[46]. The BAU scenario, however, is not an emissions trajectory and in reality a BAU scenario will never exist as changes will always take place. Annex V provides an outline of how the BAU scenario was constructed for this study.

The BAU, A2 and B2 scenarios will seek to make projections of disease incidence for dengue fever, leptospirosis, food-borne illnesses and gastroenteritis to 2050 using variables outlined in Section IX. However, the values that the variables take in A2 and B2 will, of course, depend on the emissions driving forces in each scenario.

[46] These were the scenarios specifically indicated in the Terms of Reference for this study.

Table 21: IPCC Special Report on Emissions Scenarios (SRES)

Scenario	Characteristics
A1	The A1 storyline and scenario family describe a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B).
A2	The A2 storyline and scenario family describe a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which result in continuously increasing global population. Economic development is primarily regionally oriented and per capita economic growth and technological change are more fragmented and slower than in other storylines.
B1	The B1 storyline and scenario family describes a convergent world with the same global population that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.
B2	The B2 storyline and scenario family describe a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with continuously increasing global population at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels.

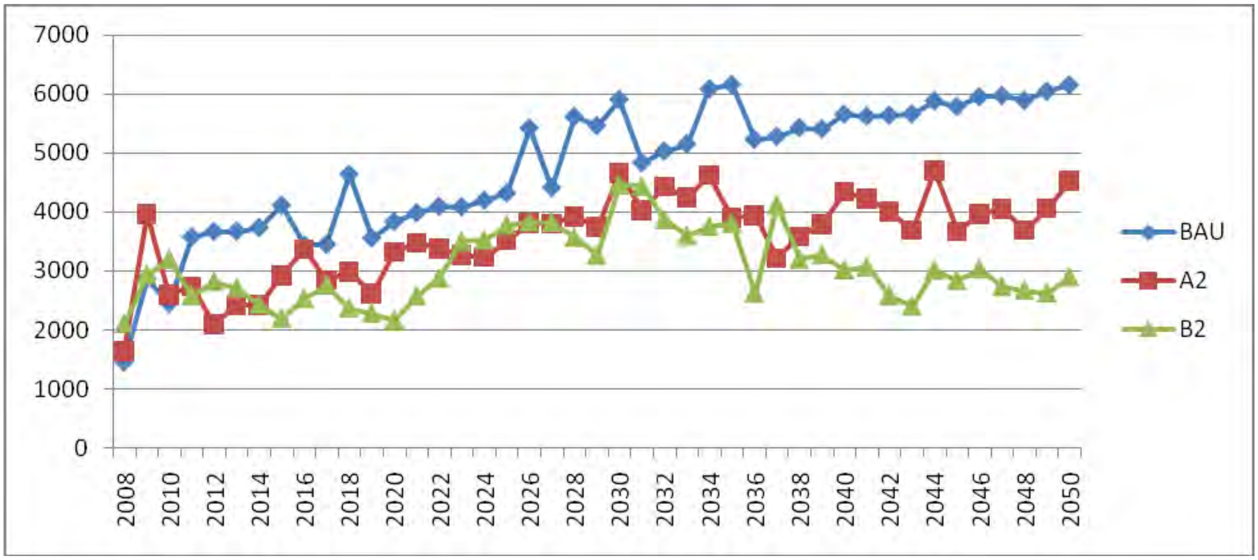
Source: IPCC (2000).

B. DENGUE FEVER – BAU, A2, B2[47]

The simulation in figure 19 below shows the trend in dengue fever incidence for the BAU, A2 and B2 scenarios. Dengue fever incidence levels are particularly higher in the BAU scenario for the most part of 2008 to 2050. The B2 scenario is the lowest impact scenario in terms of incidence levels. Total number of new cases for the period 2008 to 2050 was 204,786 in BAU, 153,725 in A2 and 131,890 in B2.

[47] For dengue, as well as the other diseases, the A2 and B2 values for the independent variables were entered into EVIEWS. Regressed against the BAU dependent variable values, the fit of the A2 and B2 models were not ideal. This is expected given the unavailability of A2 and B2 disease incidence levels.

Figure 19: Dengue fever scenarios

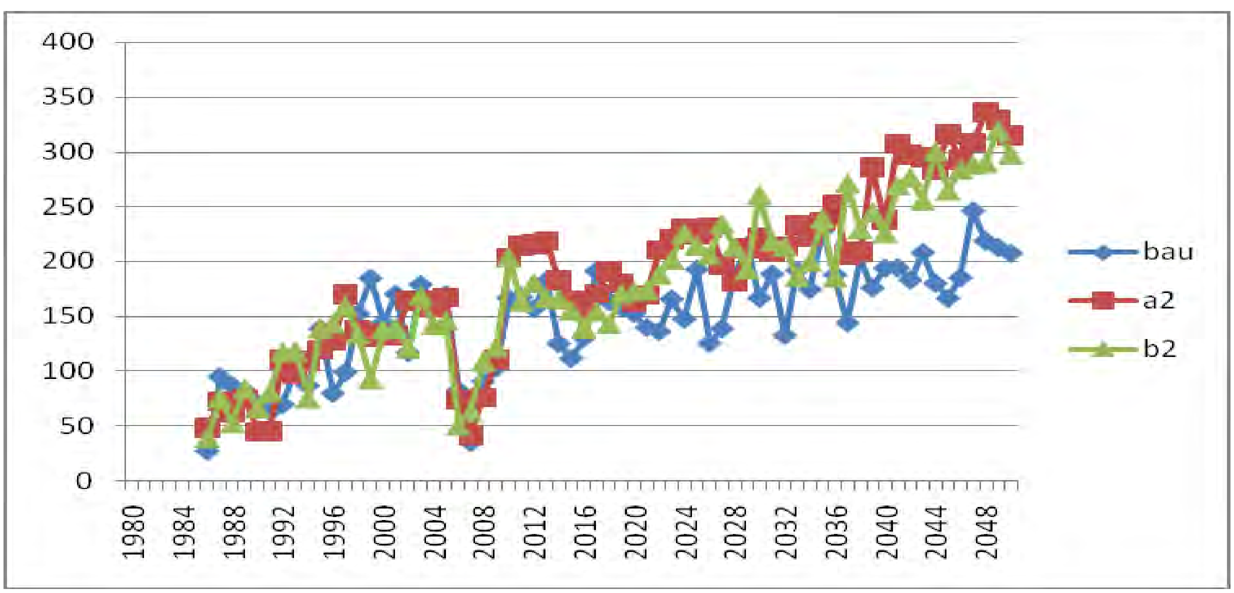


Source: Data compiled by Author

C. LEPTOSPIROSIS – BAU, A2, B2

Figure 20 establishes the scenarios of leptospirosis. A2 and B2 seem to be following a similar path with total number of new cases in A2 being 9,727 and 9,218 cases in B2. Although incidence levels in the BAU scenario coincided with those of A2 and B2 prior to 2020, they became somewhat lower post 2020. Total number of new cases of leptospirosis in the BAU scenario for the period under consideration amounted to 7,338**.** This is an unexpected result and most probably point to the need for further investigation.

Figure 20: Leptospirosis scenarios

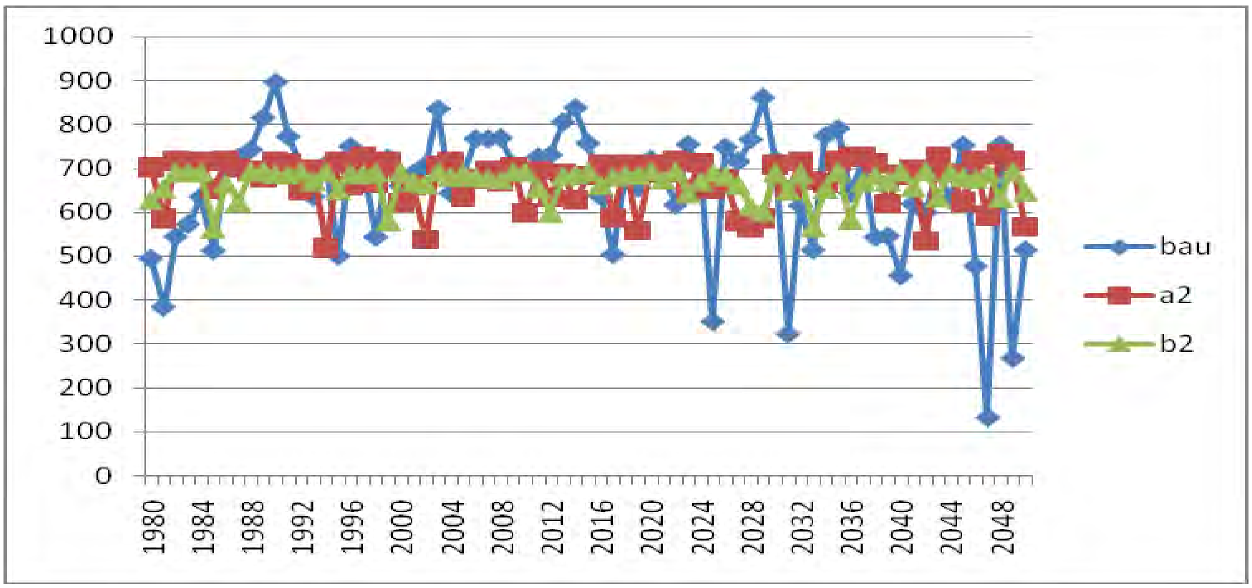


Source: Data compiled by Author

D. FOOD-BORNE ILLNESSES – BAU, A2, B2

The scenarios as they relate to food-borne illnesses are presented in figure 21 bearing in mind that values for the variables used in the model determine the trends in incidence. It is obvious that, for the most part of the period, all three scenarios seem to be following along similar paths, with the exception of the few outliers in the BAU scenario. In this case, the BAU scenario recorded 27,537 new cases, the fewest of the scenarios, with the A2 scenario recording 28,568 new cases and the B2, 28,679 new cases. Although the difference between the BAU and the other scenarios is small, this in itself seems to warrant new approaches to estimation.

Figure 21: Food-borne illnesses scenarios

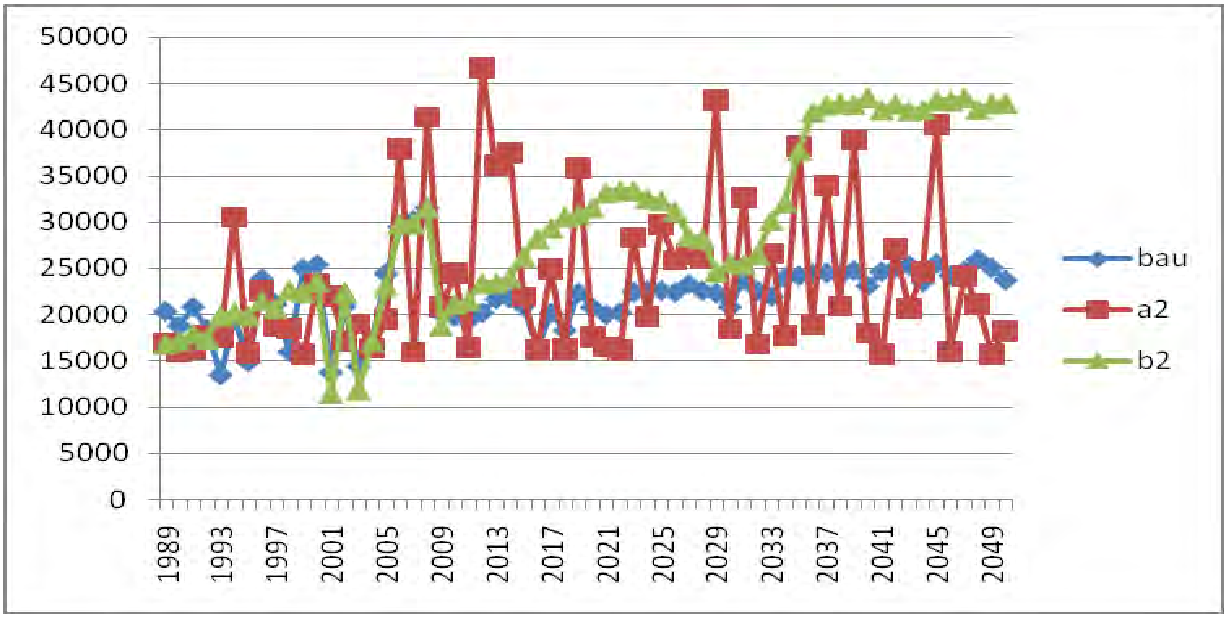


Source: Data compiled by Author

E. GASTROENTERITIS – BAU, A2 AND B2

Figure 22 shows the trend in gastroenteritis incidence for the BAU, A2 and B2 scenarios. The picture is similar to that of food-borne illnesses and leptospirosis where the BAU scenario appears to be the most stable scenario and least impact scenario - 978,427 new cases over the period. The B2 scenario recorded a total of 1,436,346 new cases and the A2 scenario 1,093,848 new cases.

Figure 22: Gastroenteritis scenarios



Source: Data compiled by Author

XII. THE ESTIMATED IMPACT OF DISEASE INCIDENCE ON THE HEALTH SECTOR: TREATMENT COSTS TO 2050 IN BAU, A2 AND B2

A. TREATMENT COSTS

Perhaps the most important economic impact of climate change on the health sector would be the phenomenal increase in the treatment costs of the diseases arising from changes in the earth's climate. In the absence of data relating to the unit costs of treating dengue fever, leptospirosis, and food-borne illnesses in Trinidad and Tobago, proxies were used to allow for the calculation of treatment costs to 2050. All proxies used were adjusted to get 2008 starting values. A summary of the unit costs of treatment for each disease at 2008 prices is shown below in table 22.

In the case of dengue fever, an overall cost per case of US$828 has been estimated. This refers to the non-fatal ambulatory and non-fatal hospitalized cases (Suaya et al., 2009)[48]. Using this, the projected impact of an increase in dengue fever incidence on the health sector was computed as the cost per case times the number of new dengue fever cases to 2050.

In this study, it is assumed that the per unit costs of treating all food-borne illnesses are similar across the different illnesses. In other words, the unit cost of treating a case of salmonellas is similar to that of treating a case of shigellosis. The cost of treating an uncomplicated case of salmonellosis was estimated to be US$40 in 2005 (WHO Fact Sheet: Drug Resistant Salmonella). This cost will be used as

[48] The costs were determined from a study done in eight countries in 2005-2006: Brazil, El Salvador, Guatemala, Panama, Venezuela, Cambodia, Malaysia and Thailand and cited by Suaya et al. (2009).

a proxy for the per unit treatment cost of all food-borne illnesses. In estimating the impact on the health sector, it was assumed that at least 50% of all new cases of food-borne illnesses are uncomplicated and, so, require minimal medical attention while the other 50% require hospitalization for a minimum of three days. For hospitalized cases, following a WHO study (2005), an average cost per patient bed day across hospitals of US$87 was used. This excludes the cost of drugs and diagnostic testing.[49]

According to the Medical Dictionary, approximately 90% of the cases of leptospirosis are not serious and clear up on their own[50]. For costing purposes, it is assumed that all cases of leptospirosis will incur an average cost of US$36 per outpatient visit across the different hospital levels. This was the estimate derived in WHO (2005) already mentioned. It is also assumed that 10% of all leptospirosis cases would require hospitalization and intensive care treatment for at least three days. The median cost per patient per day in the Intensive Care Unit in Trinidad was estimated to be approximately US$670 during a three-month period in 2007 (Hariharan, Chen and Merritt-Charles, 2007).

In estimating the cost of gastroenteritis to the health sector, it was assumed that all new cases of gastroenteritis will incur an average cost of US$36 per outpatient visit across the different hospital levels. It is also assumed that only 10% will require hospitalization for a minimum of three days, with an average cost of US$87 per patient bed day across hospitals (excluding the cost of drugs and diagnostic testing).[51]

Table 22: Summary of unit costs of treatment at 2008 prices

Proxies	$US	Proxies inflated to get 2008 values[52] ($US)
Dengue Fever – **Overall cost per case:**	828 (2005-2006 est.)	1596
Food-borne – **Cost of an uncomplicated case:** **Avg. cost per patient bed day across hospitals[53]:**	40 (2005 est.) 87 (2005 est.)	77 168
Leptospirosis – **Avg. cost per outpatient visit:** **Median cost per patient day at ICU Trinidad:**	36 (2005 est.) 670 (2007 est.)	70 874
Gastroenteritis – **Avg. cost per outpatient visit:** **Avg. cost per patient bed day across hospitals**	36 (2005 est.) 87 (2005 est.)	70 168

Source: Data compiled by Author

The costs of treatment for dengue fever, leptospirosis, food-borne illnesses and gastroenteritis have been calculated using the 2008 unit cost estimates of providing health care service for these diseases presented in table 22 above. Tables 23, 24, 25 and 26 show the cost of treatment for each disease to 2050 in each of the scenarios. This information is summarized in table 27.

[49] WHO Estimates of Unit Cost for Patient Services for Trinidad and Tobago, 2005.
[50] The Medical Dictionary, "Leptospirosis". Available from http://medical-dictionary.thefreedictionary.com/Weils+Disease
[51] WHO Estimates of Unit Cost for Patient Services for Trinidad and Tobago, 2005
[52] These were calculated using relevant sub-indices from the Index of Retail Prices for a number of years.
[53] Excluding the cost drugs and diagnostic testing.

Table 23: Dengue fever, cost of treatment to 2008 to 2050

Scenarios	Projected Number of Cases 2008-2050	Estimated Cost of Treatment to 2050 (2008 prices) ($USM)
BAU	204,786	326.8
A2	153,725	245.3
B2	131,890	210.5

Source: Author's calculations.

Table 24: Leptospirosis, Cost of treatment to 2008 to 2050

Scenarios	Projected Number of Cases 2008-2050	Estimated Cost of Treatment to 2050 (2008 prices) ($USM)
BAU	7,338	2.4
A2	9,726	3.2
B2	9,218	3.1

Source: Author's calculation

Table 25: Food-borne illnesses, cost of treatment to 2008 to 2050

Scenarios	Projected Number of Cases 2008-2050	Estimated Cost of Treatment to 2050 (2008 prices) ($USM)
BAU	27,537	8
A2	28,568	8.3
B2	28,679	8.3

Source: Author's calculations

Table 26: Gastroenteritis, cost of treatment to 2008 to 2050

Scenarios	Projected Number of Cases 2008-2050	Estimated Cost of Treatment to 2050 (2008 prices) ($USM)
BAU	978,427	84.4
A2	1,093,848	95
B2	1,.436,346	124.6

Source: Author's calculations.

Table 27: The treatment costs in BAU, A2 and B2 for the period 2008 to 2050

Scenarios	*DENGUE FEVER (US$ M)*	*LEPTOSPIROSIS (US$ M)*	*FOOD-BORNE ILLNESSES (US$ M)*	*GASTROENTERITIS (US$M)*	*TOTAL (US$ M)*
BAU	326.8	2.4	8	84.4	**421.6**
A2	245.3	3.2	8.3	95	**351.8**
B2	210.5	3.1	8.3	124.6	**346.5**

Source: Author's calculations.

Despite the mixed results for impact of the individual diseases on the health sector across scenarios, when the overall picture is taken the analysis shows that the most costly impact on the health sector is expected to be in the BAU scenario. This was seen when the cost of treating the diseases in question was considered. The least cost impact was experienced in the B2 scenario. In other words, making the necessary corrections in the recalcitrant cases cited above will only compound the overall result that was expected.

In respect of each of the three scenarios, the question that arises concerns what can be done to reduce incidence of these diseases and, by implication, to reduce the economic impact of climate change on the health sector of the country. This leads to the matter of adaptation strategies**.**

XIII. TRINIDAD AND TOBAGO'S RESPONSE TO CLIMATE CHANGE

Trinidad and Tobago is a ratified signatory to UNFCCC and its Kyoto Protocol. Trinidad and Tobago, in 2001, submitted its National Communication on Climate Change to UNFCCC. On a regional level, Trinidad and Tobago has participated in a number of projects on climate change presided over by the Caribbean Community Secretariat.

The specific impacts of climate change vary from country to country depending on their different levels of vulnerabilities. As such, the Government of Trinidad and Tobago recognizes that there is "no-one-size-fits-all" policy for countries or even sectors in the context of climate change and that climate change policies are tailored based on national circumstances, development aspirations and sectoral and cross sectoral interactions. A Draft National Climate Change Policy was developed for Trinidad and Tobago in 2009 after a comparison of climate change policies for countries similar in development aspirations, size and geographical location. Currently, climate change is not specifically addressed in existing sectoral and national policies although broad reference to mitigation and adaptation in made in the National Environmental Policy (2006). (GOVTT 2009)

The Draft National Climate Change Policy would have implications for other sectoral policies and so they may need to be revised to integrate and contextualize issues relating to climate change[54]. The

[54] Currently there are some national policies and legislation in which climate change may have some significance Draft National Protected Areas Policy (2009), National Tourism Policy (2009), Draft National Forest Policy (2008), Draft Waste Management Rules (2008), Water Pollution Management Programme (2005), Environmentally Sensitive Areas Rules (2001), National Policy and Programme on Wetland Conservation for Trinidad and Tobago (2001)

objectives of the draft policy are to reduce or avoid GHG emissions from all emitting sectors; to enhance carbon sinks; to protect the natural environment and human health; to conserve and build resilience of human and natural systems to adapt to the adverse impacts of climate change and to enhance agricultural production and food security. (GOVTT, 2009)

Trinidad and Tobago's response to climate change is to be guided by the concept of sustainability. All government ministries are expected to be involved in the implementation of the policy. It was recognized that the response will require consultative and multi-partite approach and will be both evidence-based and precautionary in nature. Trinidad and Tobago's response to climate change focuses on both adaptation and mitigation. In the context of mitigation, the government proposes to utilize low greenhouse gas emission economic development pathways across sectors. Regarding adaptation, the policy outlines only broad options to integrate adaptation planning into national policy[55]. These are:

1. "Strengthening existing institutional arrangements for systematic observations, research and climate change modeling through cooperation with academia, NGO's and private sector;
2. Assessing sectoral vulnerability to climate change by conducting vulnerability analyses and formulating adaptation options, including technological application, in biophysical and socio-economic systems;
3. Revising sectoral policies to include consideration of climate change impacts derived from vulnerability analyses;
4. Revising national development plans to incorporate climate change vulnerability, impacts and adaptation options with a view to climate proofing new developments and retrofitting existing infrastructure;
5. Enhancing the resilience of natural biophysical systems so as to maximize ecosystem services such as the natural coastal defence properties of coral reefs and mangrove systems, through the development of a system of national protected areas, including for water catchments; and
6. Promoting community-based adaptation though expanded use of the Green Fund for capacity building and enhancing resilience."
   (GOVTT 2009, 19)

XIV. RECOMMENDATIONS TO STRENGTHEN THE RESPONSE TO CLIMATE CHANGE

A. POLICY LEVEL

Part of the response to climate change is, of course, recognition of the projected impacts of climate change and a conscious effort to mitigate future climate change as well as adapt so that the impacts can be minimized. Trinidad and Tobago has formally recognized climate change and its impacts in the National Communication on Climate Change (2001) and the Draft National Policy on Climate Change (2009). Perhaps, an important aspect of this recognition stage is the acknowledgment of the need and commitment to collect relevant data as it relates to the issues surrounding climate change and its impacts. The lack of data has been a major limitation in this study which restricted an in-depth analysis of issues surrounding the health impacts of climate change.

[55] However, in the National Communication (2001) specific sectoral adaptation measures were highlighted. In the context of human health, improvements in the management of water resources and primary health were mentioned as possible adaptation strategies.

Mainstreaming of climate change into national policies and sectoral plans may be considered a pillar of any response to climate change; in particular, those of the health sector, as they pertain to this study. As discussed earlier, some of the existing national policies will have to be reviewed to incorporate the varying faces of climate change. It is through the revision of these policies and plans, the adaptation response will be made clear. In light of this, research into adaptive options becomes of critical importance.

B. INFRASTRUCTURE AND BEHAVIOUR CHANGES

From the empirical analysis, water and sanitation have been identified as significant explanatory variables in determining disease incidence in Trinidad and Tobago. It will, therefore, be reasonable to assume that any successful adaptation to climate change in Trinidad and Tobago that is aimed at minimizing the health impacts of climate change, in particular disease incidence, will be linked to the quality of population access to water resources and sanitation facilities. The adaptation response in this context will, therefore, focus on three broad areas:

a) Water Resources;
b) Sanitation; and
c) Lifestyles, Behaviours and Attitudes.

Before discussing each of the areas, it is worth noting that adaptation measures in one area may have unintended consequences in another area.

1. Water resources

Indications are that non-piped sources of water and water storage activities (of piped or non-piped water) can significantly increase the risk of a number of infectious diseases. The Chief Medical Officer, in a newspaper article, stated that most of the dengue fever cases recorded occurred in semi-rural areas where water is not properly stored in barrels for domestic and other purposes (La Rose, 2011). Although the ultimate solution to this problem is the universal coverage of piped treated water, this initiative is costly and will take time. While the government pursues this objective, there are other short- to medium-term initiatives that could be undertaken to minimize the risk of infection resulting from contaminated water.

a) Water storage practices

Water storage has been found to be quite common across Trinidad and Tobago, whether due to lack of access to pipe-borne water or deficiencies in supply of piped-water. Although there may have been improvements in access to potable water over the last few decades, the fact is that only 20% of the population receives a 24-hour supply, while the other 80% has to engage in some degree of storage of water (piped or non-piped) during the day (La Rose 2011). This may be linked to the phenomenal increase in the number of dwellings using private catchments not piped over the period 1990 to 2000 (see table 28).

Investigations show that most of the dwellings using private catchments not-piped were from rural and semi-rural areas[56]; these areas were described by the Public Utilities Minister as the worst served areas in terms of supply of pipe-borne water (Choy 2010). From table 28, in 2000 at least 35% of the dwellings were expected to engage in some form of water storage. Given the link between water storage and disease incidence, this finding paints a very worrying picture.

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[56] Mayaro/Rio Claro, Sandre Grande, Penal/Debe, Princes Town, Siparia, Point Fortin.

Table 28: Water supply sources, 1990 and 2000

	1990 Census	2000 Census
Total dwellings	**271,871**	**300,844**
Source of Water Supply		
Public piped into dwelling	**149,570**	**182,115**
Public piped into yard	**32,925**	**26,348**
Private piped into dwelling	**11,509**	**13,430**
Private catchments not piped	**14,012**	**25,156**
Public stand pipe	**40,881**	**28,827**
Truck-borne	**11,628**	**6,239**
Spring river	**4,222**	**4,527**
Other	**5,788**	**12,370**
Not stated	**1,336**	**1,832**

Source: Trinidad and Tobago Census 1990, 2000.

The proposed recommendation is that, a programme on *„safe water storage practices'* that seeks to build awareness and influence behaviour of those, particularly in rural and semi-rural areas be initiated to help in reducing the incidence of vector and water-borne illnesses. For example, an estimated US$86,000 was spent by the private sector in 1992 on cholera-related advertisements and private announcements on health education regarding cholera in two leading newspapers. This had the effect of contributing significantly to keeping cholera prevention in the public's eye (Hospedales et al., 1993). It makes sense to assume that a similar approach could be utilized for other health problems, strengthening the public-private health drive in the context of public health interests.

A similar education drive could be developed that promotes safe water storage practices, such as:

(a) Regular cleaning of storage containers which may help destroy mosquito larvae,
(b) Covering of water storage containers to prevent entry of flies, cockroaches and rodents, all of which are considered major transporters of pathogens and
(c) Boiling of water to kill harmful bacteria.

It has been suggested that advice on the types of containers to be used for water storage at the community level could help in reducing the incidence of dengue fever (La Rose 2011).[57] As part of its self help and other programmes, the Ministry of the People is even considering distributing "proper water containers" which may help eliminate breeding sites for mosquitoes (Pickford-Gordon 2011). Apart from ads and announcements, schools could be used as a major channel for disseminating information on safe water storage practices. The point has been made that education programmes have been used in the past to achieve behavioural control in children, since according to him, it is difficult to get adults to understand (Pickford-Gordon 2011).[58] Such an education drive will require a multi-sectoral approach which may be spearheaded by the Ministry of Health.

[57] A comment by Dr. Cumberbatch (Chief Medical Officer, Ministry of Health)
[58] *Ditto*

b) Water supply schedules in semi-rural and rural areas

Given that water is a scarce resource, it is hardly likely that all parts of Trinidad and Tobago will be able to have a continuous supply of pipe-borne water. It is for this reason that water supply schedules have been developed. The suggestion here is that, changes to water supply schedules for semi-rural and rural areas of Trinidad may help to do two things:

a) Reduce the extent of water storage in these areas, thereby reducing habitats for Vectors, especially the Aedes Aegypti mosquito and the risk of other water-borne illnesses such as Leptospirosis; and

b) Increase the number of times barrels and other storage containers are washed and re-filled, thus interrupting the life-cycle of mosquitoes.

An analysis of the water supply situation in Trinidad and Tobago (see tables 29 and 30) shows that there has been a significant decrease (>60%) in the population receiving class 1 supply (168 hours per week or a continuous supply). In addition, the percentage of the population receiving less than 84 hours per week (3.5 days) increased from 30% in 2000 to 49% in 2010. Of even greater importance to this study is that in 2010, of those receiving less than an 84-hour supply, 72% is from the south of the island where most of the rural and semi rural areas are located. A change to water schedules in these areas may actually make a difference with respect to disease incidence.

For example, assuming these areas get a three-day water supply per week, a change to the scheduling may be to provide a 24-hour supply every two days rather than an uninterrupted three-day water supply. The latter will mean that there will be a four-day period in which water may be stored in barrels without being re-filled; the period in which, with the right conditions, some vector species can go through its entire life-cycle[59]. Of course, in times of drought such schedules may need to change to reflect water rationing.

[59] The egg, larvae and pupae stages depend on temperature and species characteristics as to how long it takes for development. Some species have naturally adapted to go through their entire life cycle in as little as four days or as long as one month. http://www.mosquitoes.org/LifeCycle.html, http://www.wuvcd.org/mosquito/lifecycle.html (accessed, January 26th, 2011).

Table 29: Water supply 2000

June 2000							
Class	Population			Total			
	North	South	Tobago		Percent Population	Factor	Full Service Equivalent Calculation
1	318087	31777	13714	363578	31	1	0.31
2	47349	166740	1782	215871	18	0.71	0.13
3	126440	117571	2919	246930	21	0.5	0.1
4	98881	32179	9657	140717	12	0.29	0.03
5	80620	123143	19558	223321	18	0	0
Total	671377	471410	47630	1190417			0.57

Source: WASA.

Table 30: Water supply 2010

March 2010							
Class	Population			Total			
	North	South	Tobago		Percent Population	Factor	Full Service Equivalent Calculation
1	139906	8533	5408	153847	12	1	0.12
2	214062	100828	5832	320722	26	0.71	0.18
3	96012	38819	19330	154161	12	0.5	0.06
4	57725	284168	6805	348698	28	0.29	0.08
5	93505	155108	10254	258867	21	0	0
Total	601210	587456	47629	1236295	100		0.45

Source: WASA.

SCALE	
CLASS 1	168 HOURS PER WEEK OR CONTINOUS SUPPLY
CLASS 2	120-168 HOURS PER WEEK
CLASS 3	84-120 HOURS PER WEEK
CLASS 4	48-84 HOURS PER WEEK
CLASS 5	LESS THAN 48 HOURS PER WEEK

Source: Data compiled by Author

c) Water supply: Quantity and quality

Earlier empirical work has shown that improving the supply of pipe-borne water to semi-rural and rural areas is likely to reduce disease incidence considerably. Trinidad and Tobago's main source of water supply is from rivers (surface water), although ground water sources exist throughout the country. Demand for water has increased considerably over the last few decades on both islands with domestic demand being the major driving force. In Trinidad, estimates for 2000 show that demand for water in Trinidad had outstripped production (CSO). Given this spike in demand for water, the goal of the government is to ensure that every community has a water supply of at least two days per week and has allocated US$206 million for the achievement this goal through:

1. “the installation of mobile packaged water treatment plants,
2. the accelerated development of new groundwater sources,
3. additional capacity to provide security of supply through service reservoirs,
4. the upgrading of water treatment plants in north and south Trinidad,
5. the replacement of critical segments of the transmission and distribution network and the improved management of the water scheduling operations.”

(Choy, 2010)

The empirical results for dengue fever show that a 1% increase in access to improved water sources in rural areas could reduce dengue fever incidence by approximately 306 cases. Since there are no empirical studies on Trinidad and Tobago which can guide us on this matter, this study will assume that there is a unit elastic relationship between an increase in *total expenditure* on improved water sources in rural areas and an increase in access, a 1% increase in access will require at least a 1% increase in total expenditure.[60] As such, an outlay of 1% of the expenditure allocated by the government (US$206 million) to improve water supply to communities could contribute to reducing dengue fever incidence, assuming, as public programmes often do, that there is a direct link between access and utilization.

The following policy recommendations are consistent with the goals of the government, identified above. It is anticipated that through improvements in water supply, especially to semi-rural and rural areas in Trinidad and Tobago, the incidence of water and vector-borne diseases may be minimized.

2. Sanitation

Poor sanitation facilities (excreta disposal facilities) may be linked to faecal pollution. In fact, closeness of toilets or latrines to water sources has been identified by Welsh et al. (2000) as a possible source for water contamination. Ground water sources may also be polluted from leaking pit latrines and septic tanks. A cross-sectional study by Welsh et al., (2000) highlighted that a substantial proportion of rural households (in the northeastern part of Trinidad) were found to have drinking water considered unfit for human consumption as 79% of household water samples tested positive for coliforms and 61.1% for faecal coliforms. The study revealed that in Matura a latrine was less than 27 metres from a river from which some households collect drinking water. Given their findings, the authors concluded that a great potential exists for waterborne gastroenteritis in Trinidad.

The 2000 Census showed that approximately 27% of the dwellings in Trinidad and Tobago still use pit latrines. Although this marked a decrease in the use of pit latrines when compared to 1990, this estimate is still quite high. Latrines encourage rodents who carry faecal matter and with it potential diseases and serves as a breeding ground for certain species of flies and mosquitoes (PAHO, Guide to Sanitation in Shelters and Camps).

The empirical results of the dengue fever, leptospirosis and gastroenteritis models show that disease incidence is quite sensitive to the sanitation situation. The estimates show that for every 1% increase in the population with access to improved sanitation facilities, there would be a reduction in the incidence of dengue fever by 453 cases and of leptospirosis incidence by 10.44 cases.

[60] The assumption of a log-linear relationship between the variables in question, which seems reasonable, will point to a constant elasticity. To open the discussion the present assumption represents a special case.

Supply side policies	Comments
Increase storage capacity by building reservoirs and dams	In 2008, Trinidad and Tobago signed agreement with CBCL Ltd of Nova Scotia, Canada, to design four new reservoirs at Mamoral, Bades Trace in Rio Claro, Arena and Tortuga (Chouthi 2008). To date, these have not been built. Consideration should be given to the building of these reservoirs. This may assist in satisfying household demand for water and improving supply to semi-rural and rural areas in South Trinidad; thereby reducing the need for private catchments and water storage in these areas
Desalination of sea water	Since 2002, the Point Lisas Industrial Estate utilizes low-cost high-quality water 24 hours a day from the largest seawater reverse osmosis (SWRO) system in the Western Hemisphere[61]. Expansion in desalination activity could help WASA meet the increasing industrial and agricultural demand for water in Trinidad, freeing up rainwater sources for household use.
Reduce pollutants in water sources	Solids (measured as total suspended solids), organics (measured by biological oxygen demand), oil and grease and nitrogen and phosphorous are the major pollutants found in Trinidad and Tobago surface water systems (CSO). Welsh et al.(2000) did a study on the microbial quality of water in rural areas of Trinidad and it was found that water used for drinking by rural residents were not suitable for human consumption as faecal coliforms were present. *E. coli* was also detected in two-thirds of the water sampled. Given the level of pollution identified in main water sources and its impact on disease incidence, a conscious effort should be made to ensure that the level of pollution is minimized. This will best be done through a public-private partnership initiative. Line ministries involved will be The Ministry of the Environment, The Ministry of Health, The Ministry of Public Utilities and the Ministry of Local Government. The business sector and NGO's are also key stakeholders that should form part of this group.
Demand-side policy	
Promote water conservation	Water remains a scare resource. As such, water conservation should be promoted even in light of improvements in water supply and expansions in water resources.

Although the data used in the empirical analysis refers to sanitation facilities in the context of excreta disposal facilities, improvements in sanitation in its general sense[62] may help in reducing disease incidence. For example, proper solid waste disposal may eliminate possible breeding grounds for mosquitoes and get rid of possible habitats for rodents.

[61]Highbeam Business, "SWRO desalination plant supplies high-quality water in Trinidad: innovative seawater reverse osmosis design coupled with proven pretreatment technology produces affordable water supply for Trinidad.(Seawater Reverse Osmosis)". Available from http://business.highbeam.com/411917/article-1G1-112167749/swro-desalination-plant-supplies-highquality-water (accessed June 20, 2011).

[62] "*Basic sanitation is the lowest-cost technology ensuring hygienic excreta and sullage disposal and a clean and healthful living environment both at home and in the neighbourhood of users"* (World Health Organization).

It is in this context we recommend the following.

Policies / Strategies	Comments
Upgrade / replace sanitation facilities in rural areas.	Although the household use of contaminated water with faecal coliform has been found to be quite prevalent in the northeastern part of Trinidad, this finding may actually reflect most of the rural areas in Trinidad since many of the dwellings in these areas still use pit latrines which may be contaminating water sources during normal conditions and more so, during floods. Given that at least 27 percent of the dwellings still use pit latrines (2000 est.), this policy should be urgently pursued. Upgrading would mean from a simple latrine to a ventilated latrine or to a pour flush latrine. A replacement for example could be the use of flush toilets connected to sewer as opposed to ventilated latrine (Hutton and Haller 2004). Whatever the option, financial assistance may need to be provided to most households, especially in the rural areas. In addition, the efficient functioning of improved excreta facilities (for example, flush toilets connected to septic tanks) may require a continuous supply of water, which is itself a challenge in Trinidad and Tobago. Above all, such an initiative will necessitate the support of those in rural areas. As such, appropriate „buy-in' techniques may have to be used. In Latin America and the Caribbean, the annual cost for improvements on a per-person-reached basis for the installation of septic tanks was estimated to be $US 12.39 in 2000 (Hutton and Haller 2004). This was inflated to get the per-person-reached cost in 2008 which was estimated to be $US 15.6.
Strengthen sanitation drive of Municipal Corporations.	These corporations to a large extent engage in public health and sanitation services[63]. Some of their responsibilities include collection and disposal of garbage cleaning of cesspits and septic tanks provision and maintenance of minor water courses cleaning of public spaces insect vector, rodent and canine control provision and maintenance and regulation of public retail markets, slaughter-houses Using the unit elasticity analysis discussed in Section 14.2.1 above, a 1 percent increase in access will require at least a 1 percent increase in total expenditure. 1 percent of expenditure allocation to Municipal Corporations is approximately $US 1.87 m per annum (based on Draft Expenditure Estimates 2011). This same outlay may also contribute to reducing leptospirosis incidence. Other investments may also have to be made to get the desired 1 percent increase in access to improved sanitation and the full impact of disease incidence. To achieve a reduction in disease incidence however, the increase expenditure must be allocated specifically to improving sanitation for example, regular cleaning of cesspits and cesspools, consistent maintenance of public toilet facilities, rigorous cleaning of markets and proper and timely disposal of garbage.
Making judicious use of the Community-based	CEPEP plays a key role in environment sanitation throughout Trinidad and Tobago. A major part of work involves the removal of garbage from public spaces. Given the scope of work, the programme complements the activities of the Municipal Corporations.

[63] Government of the Republic of Trinidad and Tobago, Ministry of Local Government, "Functions of Municipal Bodies". Available from http://www.localgov.gov.tt/function_of_municipal_bodies.html (accessed June 20, 2011).

Environment Protection and Enhancement Programme (CEPEP).	In the most recent past, CEPEP workers have been used in clean-up efforts following heavy flooding throughout the country (Dowlat 2010). Trinidad and Tobago has had a history of flooding which has caused major damage to homes, livestock and infrastructure. Post-disaster or post-flooding activities are of critical importance in preventing the spread of infectious diseases. In summary, its role in improving sanitation across Trinidad and Tobago, its contribution to post-flooding efforts, and with a budget equivalent of less than 1 percent of GDP in 2011 ($US 51 as per Draft Expenditure Estimates 2011), any increase in CEPEP labour, especially in the rural and semi-rural areas may help alleviate the problem of dengue fever and leptospirosis incidence.
Strengthening the work of the Environmental Management Agency (EMA).	The expectation here is that the EMA continue to focus attention on influencing changes in behaviour and attitudes with the aim of improving sanitation[64]. Educational programmes should be expanded to ensure that information on the proper disposal of waste and the impacts of pollution on the environment and health are disseminated at all levels. Currently the EMA education programmes target schools. The result of such an education initiative could reduce the risk of pollution, thereby reducing disease incidence. Given the negative relationship between forest area and leptospirosis incidence identified from our empirical analysis it may useful that one of the agencies function be, the protection of areas marked for forestry.

3. Attitudes, behaviours and lifestyles

The most important adaptation strategy as it relates to disease incidence in Trinidad and Tobago may be effecting lifestyle, behaviour and attitude changes. Policies and initiatives like those outlined above may prove ineffective if current practices continue to prevail. Pollution of main water courses, unsafe storage of water and poor food safety practices are only some of the many factors contributing to disease incidence in Trinidad and Tobago. It is only through a change in attitudes that behaviour and lifestyle changes can be made. A change in attitude may come about when individuals are informed of the consequences of their actions and the likely impacts on their lives. For example, rural communities should be made aware of the risks associated with improper storage of water and the likely impacts on their health. In this context, the role of education and information dissemination in influencing attitude change should not be underestimated. For example, the Government of Trinidad and Tobago, under its Dengue Prevention and Eradication Programmes launched in 2010, incorporated into Standard 4 Primary School curriculum information about the life cycle of mosquitoes, the dangers of dengue fever and how to eliminate mosquito breeding places around the homes and schools[65].

C. Summarizing the Costs of Adaptation Measures Recommended

What the study revealed is that a 1% increase in the percentage of the population with access to improved water sources is expected to reduce dengue fever incidence by 308 cases and a 1% increase in the percentage of population with access to improved sanitation facilities is expected to decrease the incidence of dengue fever by 453 cases and leptospirosis by 10.44 cases. In addition, the increases in access to improved water sources causes a decrease in the rate at which gastroenteritis is increasing. Clearly, increases in access to improved water sources and sanitation facilities have significant benefits.

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[64] The functions and powers of the authority (EMA) can be found on the following website: http://www.ema.co.tt/cms/index.php?option=com_content&task=view&id=130&Itemid=127 (accessed, February 2, 2011).

[65] The Government of the Republic of Trinidad and Tobago, Ministry of Health, “2010: End of Year Report”, 31 December 2010. Available from http://www.health.gov.tt/news/newsitem.aspx?id=203 (accessed June 20, 2011).

In costing our adaptation measures, it was assumed that there is a unit elastic relationship between an increase in *total expenditure* on improved water sources and sanitation facilities and an increase in access. As such, our adaptation measures in most cases represent a 1% change in expenditure allocated to improving access to improved sanitation facilities and improved water sources in different contexts. It is worth noting at this point that the list of measures listed in table 31 is not an exhaustive list and, so, there may still be areas where increases in expenditure may be needed to get the desired 1% increase in access and the full impact on diseases incidence in terms of the decrease in the number of cases indicated above. From this study, it was difficult to tell by how much each adaptation measure will impact disease incidence, since this will require an investigation into the relationship between expenditure on each of the measures and disease incidence. What this study revealed from the relationships between the variables in the models was that improvements in sanitation and water sources will reduce disease incidence. This means that the adaptation measures identified in table 28, are all expected to contribute in some way to this reduction.

The adaptation measures recommended relate largely to increasing access to improved water sources and sanitation facilities and influencing behaviour changes since, in this study, these were found to be major drivers of the selected diseases in Trinidad and Tobago.

Table 31: Adaptation costs of measures identified ($USM) to 2050 at 1 percent, 2 percent and 4 percent discount rates

Adaptation Measures	*Cost per annum (2008)*	*Cost to 2050*	*Cost to 2050 @ 1 percent DR*	*Cost to 2050 @ 2 percent DR*	*Cost to 2050 @ 4 percent DR*
Replace sanitation facilities[1]	**0.2**	**8.4**	**5.53**	**3.66**	**1.62**
Strengthening the sanitation drive of the Municipal Corporations[2]	**1.85**	**77.2**	**50.83**	**33.61**	**14.87**
Expanding CEPEP[3]	**0.46**	**19.32**	**12.72**	**8.41**	**3.72**
Enhancing capacity of the Solid Waste Management Company (SWMCOL)[4]	**0.11**	**4.62**	**3.04**	**2.01**	**0.89**
Improving water supply, especially to the rural area[5]	**2.06**	**86.52**	**56.97**	**37.66**	**16.66**
Enhancing Environmental Awareness[6]	**0.43**	**18.06**	**11.89**	**7.86**	**3.48**
Health Promotion - to reduce risky behaviour[7]	**2.06**	**86.52**	**56.97**	**37.66**	**16.66**
Strengthening the work of the Environmental Management Agency[8]	**0.10**	**4.2**	**2.77**	**1.83**	**0.81**
Forestry preservation[9]	**0.10**	**4.2**	**2.77**	**1.83**	**0.81**
TOTAL	**7.17**	**309.04**	**203.48**	**134.53**	**59.51**

Notes to table:

[1]: Replace pit latrines with septic tanks (1 percent of the population).
[2]: 1 percent of 2008 actual expenditure allocation to Municipal Corporations.
[3]: 1 percent of 2010 expenditure allocation to CEPEP (estimated), deflated to get the value for 2008.
[4]: 1 percent of 2009 actual expenditure to SWMCOL, deflated to get the value for 2008.
[5]: 1 percent of the total amount allocated in 2010 to improve water supply, deflated to get the value for 2008.
[6]: The amount allocated to the Ministry of Housing and the Environment for Promotions, Publicity, Printing, Conferences, Seminars and Others Functions in 2008 was used as a proxy for this estimate.
[7]: The 2008 actual expenditure allocation to the Ministry of Health for Promotions, Publicity, Printing, Conferences, Seminars and Others Functions was used as a proxy for this estimate.
[8]: 1 percent of 2009 expenditure allocation to EMA (estimated), deflated to get the value for 2008.
[9]: 1 percent of the total amount allocated to Forestry in 2008 was used as a proxy for this estimate.
Source: Draft Expenditure Estimates 2011 and 2010, Choy (2010), Author's calculations.

XV. ADAPTATION COST VS. TREATMENT COST IN BAU, A2 AND B2

The cost calculations have been carried out at 1%, 2% and 4% discount rates. The basic result is that ***the treatment costs exceed cost of adaptation*** in all scenarios (see table 32). In other words, adaptation makes economic sense.

From table 31, it certainly cannot be inferred that, if the recommended adaptation investment is made, the entire cost of treatment will be avoided. This is because the adaptation investment includes only *some* of what is needed to reduce incidence. As such, even if the adaptation measures are made, there may still be cases of infectious diseases which will incur treatment costs. In addition, as it relates to influencing behaviour changes, even if these measures are adopted, and current behaviour patterns prevail, disease incidence may still be quite high. Table 32 indicates, however, the *possibility* of reducing the high cost of treatment that is associated with increased disease incidence following investments in adaptation measures. Of course, this is on the assumption that measures prove to be effective.

Bearing this in mind, it is useful then to take a look at how the treatment cost and the adaptation cost relate to each other in the different scenarios; A2, B2 and BAU. Table 32 indicates. The implications are unambiguous: in the face of the climate change effects that can be expected regarding disease incidence in particular, it makes sense to undertake adaptation measures, mainly because of the welfare benefits of less morbidity amongst the population, even if in all instances our models were not able to demonstrate savings in monetary terms.

Table 32: Comparison of cost of treatment and cost of adaptation 2008 to 2050 ($USM)

Scenario	Total Cost to 2050	Total Cost to 2050 @ 1 percent DR	Total Cost to 2050 @ 2 percent DR	Total Cost TO 2050 @ 4 percent DR
BAU				
Cost of Treatment	422	278	183	81
Cost of Adaptation	309	203	135	60
A2				
Cost of Treatment	352	232	153	68
Cost of Adaptation	309	203	135	60
B2				
Cost of Treatment	347	228	151	67
Cost of Adaptation	309	203	135	60

Source: Author's calculations.

XVI. GENERAL CONCLUSION

As the study concludes, it is important to point out that although the Terms of Reference spoke to an *"assessment of the likely economic impacts of climate change on the health sector of Trinidad and Tobago",* analysis has been restricted to the impacts as seen through different sources of morbidity: dengue fever, leptospirosis and food-borne diseases. The main reason for the limited purview of the study was understandably the availability of data. However, since the approach taken in the study was to highlight the vulnerability and resilience dimensions of the problem, it is clear that once data become available in respect of other climate-related sources of morbidity, the models employed in the study will have wider applicability.

The focus on the selected sources of morbidity has highlighted the fact that the vulnerability of the country's health sector to climate change does not depend solely on the extent of the exogenously derived impacts, but also on the behaviours and practices among the population. What this means is that, adaptation measures will not simply require adequate human and financial resources, but they will require an emphasis on behaviour change which should have positive spill-over effects on the entire health system. The implication here is that policy makers in Trinidad and Tobago do not have to wait until a comprehensive cost-benefit climate change study is done on the entire health system before they begin to put certain adaptation measures in place. This is because the vulnerability which became evident in the analysis of the impacts on dengue fever, leptospirosis and food-borne illnesses is certainly not restricted to these disease conditions. To the extent that this vulnerability stems from propensities in the population which increase the exposure to certain harmful outcomes, the country will do well to take the lessons learnt from the disease conditions analysed in the present study.

ANNEXES

ANNEX I- DENGUE FEVER

A. *THE ORIGINALLY SPECIFIED MODEL*

1. The Model

Dependent Variable: DENGUE
Method: Least Squares
Date: 05/05/11 Time: 13:03
Sample (adjusted): 1980 2005
Included observations: 26 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
TEMP_MAX*TEMP_MAX*TEMP_MAX	-2.076932	0.820643	-2.530861	0.0204
TEMP_MAX*TEMP_MAX	93.58991	38.23964	2.447458	0.0243
POP	0.027812	0.004435	6.270621	0.0000
IMPROVE_WATER_RURAL	-308.1894	49.11587	-6.274743	0.0000
IMPROVE_SANIT_TOT	-452.5213	115.2844	-3.925262	0.0009
RAIN_DUMMY	919.1248	358.5224	2.563647	0.0190
HUMIDITY_8*HUMIDITY_8*HUMIDITY_8	0.012920	0.005712	2.261747	0.0356

R-squared	0.812866	Mean dependent var	1141.769
Adjusted R-squared	0.753772	S.D. dependent var	1554.700
S.E. of regression	771.4640	Akaike info criterion	16.35926
Sum squared resid	11307978	Schwarz criterion	16.69798
Log likelihood	-205.6704	Hannan-Quinn criter.	16.45680
Durbin-Watson stat	1.919112		

2. Test of Misspecification

Ramsey RESET Test
Equation: EXPERIMENT
Specification: DENGUE (TEMP_MAX*TEMP_MAX*TEMP_MAX) (TEMP_MAX*TEMP_MAX) POP IMPROVE_WATER_RURAL IMPROVE_SANIT_TOT RAIN_DUMMY HUMIDITY_8*HUMIDITY_8 *HUMIDITY_8
Omitted Variables: Squares of fitted values

	Value	df	Probability
t-statistic	0.646969	18	0.5258
F-statistic	0.418569	(1, 18)	0.5258
Likelihood ratio	0.597677	1	0.4395

F-test summary:

	Sum of Sq.	df	Mean Squares

Test SSR	256978.1	1	256978.1
Restricted SSR	11307978	19	595156.8
Unrestricted SSR	11051000	18	613944.5
Unrestricted SSR	11051000	18	613944.5

LR test summary:

	Value	df
Restricted LogL	-205.6704	19
Unrestricted LogL	-205.3716	18

Unrestricted Test Equation:
Dependent Variable: DENGUE
Method: Least Squares
Date: 05/05/11 Time: 14:35
Sample: 1980 2005
Included observations: 26

Variable	Coefficient	Std. Error	t-Statistic	Prob.
TEMP_MAX*TEMP_MAX*TEMP_MAX	-1.428791	1.303204	-1.096368	0.2874
TEMP_MAX*TEMP_MAX	63.58934	60.48715	1.051287	0.3070
POP	0.022673	0.009132	2.482863	0.0231
IMPROVE_WATER_RURAL	-218.8429	146.8338	-1.490412	0.1534
IMPROVE_SANIT_TOT	-351.2785	195.4443	-1.797332	0.0891
RAIN_DUMMY	766.7401	433.6742	1.768009	0.0940
HUMIDITY_8*HUMIDITY_8*HUMIDITY_8	0.010391	0.006996	1.485322	0.1548
FITTED^2	5.26E-05	8.14E-05	0.646969	0.5258

R-squared	0.817119	Mean dependent var	1141.769
Adjusted R-squared	0.745999	S.D. dependent var	1554.700
S.E. of regression	783.5461	Akaike info criterion	16.41320
Sum squared resid	11051000	Schwarz criterion	16.80030
Log likelihood	-205.3716	Hannan-Quinn criter.	16.52467
Durbin-Watson stat	1.856296		

3. Test of Autocorrelation

Date: 05/05/11 Time: 15:00
Sample: 1980 2005
Included observations: 26

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
. *| .		. *| .		1	-0.072	-0.072	0.1509	0.698
.	.		. *| .		2	-0.062	-0.068	0.2691	0.874
. |**.		. |**.		3	0.318	0.312	3.4756	0.324
. *| .		. *| .		4	-0.157	-0.133	4.2873	0.369

. | . |	. |* . |	5	0.046	0.079	4.3603	0.499
. | . |	. *| . |	6	-0.057	-0.193	4.4778	0.612
.**| . |	. *| . |	7	-0.207	-0.127	6.1266	0.525
. | . |	. | . |	8	0.053	-0.035	6.2384	0.621
. | . |	. | . |	9	-0.045	0.030	6.3241	0.707
. *| . |	. | . |	10	-0.117	-0.049	6.9462	0.731
. |* . |	. | . |	11	0.096	0.068	7.3962	0.766
. | . |	. | . |	12	-0.042	-0.046	7.4900	0.824

4. Test of Autocorrelation

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.646037	Prob. F(2,17)	0.5365
Obs*R-squared	1.836526	Prob. Chi-Square(2)	0.3992

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Date: 05/17/11 Time: 12:13
Sample: 1980 2005
Included observations: 26
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
TEMP_MAX*TEMP_MAX*TEMP_MAX	0.306803	0.925095	0.331645	0.7442
TEMP_MAX*TEMP_MAX	-12.93928	42.40447	-0.305139	0.7640
POP	0.001083	0.004660	0.232313	0.8191
IMPROVE_WATER_RURAL	17.11809	55.88823	0.306292	0.7631
IMPROVE_SANIT_TOT	-16.13769	119.8991	-0.134594	0.8945
RAIN_DUMMY	50.93574	376.1235	0.135423	0.8939
HUMIDITY_8*HUMIDITY_8*HUMIDITY_8	0.003233	0.006513	0.496408	0.6260
RESID(-1)	-0.074959	0.278652	-0.269004	0.7912
RESID(-2)	-0.361233	0.317813	-1.136624	0.2715

R-squared	0.070636	Mean dependent var	-0.275591
Adjusted R-squared	-0.366712	S.D. dependent var	672.5467
S.E. of regression	786.2506	Akaike info criterion	16.43985
Sum squared resid	10509230	Schwarz criterion	16.87535
Log likelihood	-204.7181	Hannan-Quinn criter.	16.56526
Durbin-Watson stat	1.938360		

5. Test for Homoscedasticity

Heteroskedasticity Test: White

F-statistic	0.781624	Prob. F(7,18)	0.6110
Obs*R-squared	6.060814	Prob. Chi-Square(7)	0.5327
Scaled explained SS	4.327294	Prob. Chi-Square(7)	0.7414

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 05/05/11 Time: 14:36
Sample: 1980 2005
Included observations: 26

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-2317858.	47465796	-0.048832	0.9616
(TEMP_MAX*TEMP_MAX*TEMP_MAX)^2	-0.014989	0.092463	-0.162104	0.8730
(TEMP_MAX*TEMP_MAX)^2	20.78386	138.3716	0.150203	0.8823
POP^2	3.33E-06	1.83E-06	1.817048	0.0859
IMPROVE_WATER_RURAL^2	-253.1281	307.1159	-0.824210	0.4206
IMPROVE_SANIT_TOT^2	-791.8893	609.8509	-1.298496	0.2105
RAIN_DUMMY^2	531146.8	352645.8	1.506177	0.1494
(HUMIDITY_8*HUMIDITY_8*HUMIDITY_8)^2	1.41E-06	4.65E-06	0.304162	0.7645

R-squared	0.233108	Mean dependent var	434922.2
Adjusted R-squared	-0.065127	S.D. dependent var	725280.1
S.E. of regression	748525.4	Akaike info criterion	30.13726
Sum squared resid	1.01E+13	Schwarz criterion	30.52436
Log likelihood	-383.7844	Hannan-Quinn criter.	30.24873
F-statistic	0.781624	Durbin-Watson stat	2.282679
Prob(F-statistic)	0.611047		

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	0.762484	Prob. F(7,18)	0.6251
Obs*R-squared	5.946342	Prob. Chi-Square(7)	0.5460
Scaled explained SS	4.245563	Prob. Chi-Square(7)	0.7511

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 06/24/11 Time: 10:21
Sample: 1980 2005
Included observations: 26

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-19407649	1.87E+08	-0.103775	0.9185
TEMP_MAX*TEMP_MAX*TEMP_MAX	-1803.122	11705.01	-0.154047	0.8793
TEMP_MAX*TEMP_MAX	82230.28	554060.0	0.148414	0.8837
POP	7.774085	4.321493	1.798935	0.0888
IMPROVE_WATER_RURAL	-36884.29	48593.08	-0.759044	0.4577
IMPROVE_SANIT_TOT	-140164.5	114383.7	-1.225389	0.2362
RAIN_DUMMY	527093.6	353697.2	1.490240	0.1535
HUMIDITY_8*HUMIDITY_8*HUMIDITY_8	1.904662	5.616486	0.339120	0.7384

R-squared	0.228705	Mean dependent var	434922.2
Adjusted R-squared	-0.071242	S.D. dependent var	725280.1
S.E. of regression	750671.0	Akaike info criterion	30.14298
Sum squared resid	1.01E+13	Schwarz criterion	30.53009
Log likelihood	-383.8588	Hannan-Quinn criter.	30.25446
F-statistic	0.762484	Durbin-Watson stat	2.309798
Prob(F-statistic)	0.625149		

Heteroskedasticity Test: Harvey

F-statistic	1.465895	Prob. F(7,18)	0.2411
Obs*R-squared	9.440231	Prob. Chi-Square(7)	0.2226
Scaled explained SS	7.330866	Prob. Chi-Square(7)	0.3953

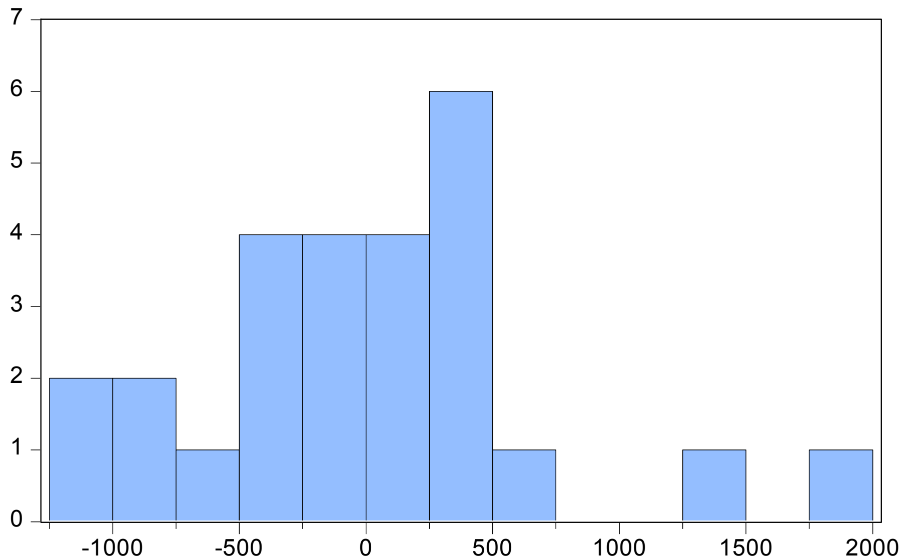
Test Equation:
Dependent Variable: LRESID2
Method: Least Squares
Date: 06/24/11 Time: 10:21
Sample: 1980 2005
Included observations: 26

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	583.0610	467.7795	1.246444	0.2286
TEMP_MAX*TEMP_MAX*TEMP_MAX	0.033633	0.029278	1.148778	0.2657
TEMP_MAX*TEMP_MAX	-1.573579	1.385860	-1.135454	0.2711
POP	1.47E-05	1.08E-05	1.357580	0.1914
IMPROVE_WATER_RURAL	-0.235357	0.121545	-1.936381	0.0687
IMPROVE_SANIT_TOT	-0.663589	0.286106	-2.319382	0.0323
RAIN_DUMMY	0.818477	0.884696	0.925151	0.3671
HUMIDITY_8*HUMIDITY_8*HUMIDITY_8	3.74E-06	1.40E-05	0.266450	0.7929

R-squared	0.363086	Mean dependent var	11.63742
Adjusted R-squared	0.115397	S.D. dependent var	1.996355
S.E. of regression	1.877639	Akaike info criterion	4.345567

Sum squared resid	63.45950	Schwarz criterion	4.732674
Log likelihood	-48.49237	Hannan-Quinn criter.	4.457040
F-statistic	1.465895	Durbin-Watson stat	2.229279
Prob(F-statistic)	0.241077		

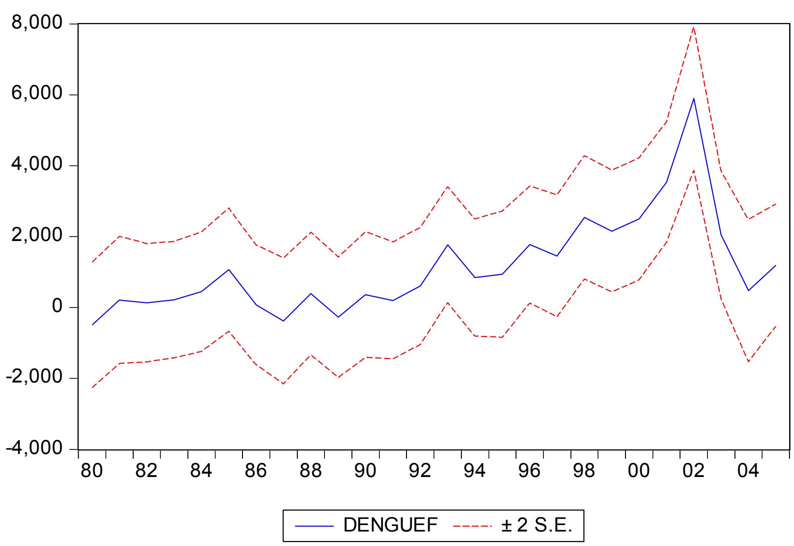
6. Test of Normality



Series: Residuals
Sample 1980 2005
Observations 26

Mean	-0.275591
Median	-35.68349
Maximum	1810.683
Minimum	-1115.724
Std. Dev.	672.5467
Skewness	0.581344
Kurtosis	3.674932
Jarque-Bera	1.957992
Probability	0.375688

7. Forecasting Abilities



Forecast: DENGUEF
Actual: DENGUE
Forecast sample: 1980 2009
Adjusted sample: 1980 2005
Included observations: 26

Root Mean Squared Error	659.4863
Mean Absolute Error	502.4832
Mean Abs. Percent Error	1170.796
Theil Inequality Coefficient	0.178649
Bias Proportion	0.000000
Variance Proportion	0.051909
Covariance Proportion	0.948091

8. *COMMENTS*
The model proved to be valid but with all the variables being of 1 unit root except population (which had 2 unit roots), cointegration was done. One may suggest that the Engle-granger procedure requires all the variables to have the same unit roots. This is not true, however, as Charemza and Deadman(1992) states:

"*If only two variables appear in the long run relation, both have to be of the same order of integration. If the number of variables are greater than two(that is if there is more than one explanatory variable), the order of integration of any of the explanatory variables. Moreover, there must be none or at least two explanatory variables integrated to an identical order higher than the order of integration of the dependent variable.*" (Charemza and Deadman 1992, 149)

The model has also been tested for multicollinearity of which there is no large degree.

B. *TESTING RESIDUALS FOR COINTEGRATION*

1. ACF Test

Date: 05/05/11 Time: 15:02
Sample: 1980 2009
Included observations: 26

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
. | . |	. | . |	1	0.003	0.003	0.0002	0.989
. *| . |	. *| . |	2	-0.196	-0.196	1.1662	0.558
. | . |	. | . |	3	-0.055	-0.056	1.2630	0.738
. |* . |	. | . |	4	0.080	0.043	1.4730	0.831
. *| . |	.**| . |	5	-0.195	-0.226	2.7916	0.732
. |* . |	. |**. |	6	0.186	0.227	4.0570	0.669
. |* . |	. | . |	7	0.109	0.028	4.5140	0.719
***| . |	***| . |	8	-0.388	-0.402	10.613	0.225
. | . |	. |* . |	9	-0.054	0.105	10.737	0.294
. |* . |	. | . |	10	0.177	-0.019	12.160	0.274
. *| . |	. *| . |	11	-0.107	-0.200	12.712	0.313
.**| . |	.**| . |	12	-0.285	-0.207	16.923	0.153

2. Augmented dickey Fuller Test for Unit roots

Null Hypothesis: DENG_RESID_POLY has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.691749	0.0010
Test critical values:	1% level	-3.724070	
	5% level	-2.986225	
	10% level	-2.632604	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(DENG_RESID_POLY)
Method: Least Squares
Date: 05/05/11 Time: 15:02
Sample (adjusted): 1981 2005
Included observations: 25 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DENG_RESID_POLY(-1)	-0.995820	0.212249	-4.691749	0.0001
C	-20.11030	138.8173	-0.144869	0.8861
R-squared	0.489031	Mean dependent var	-51.03998	
Adjusted R-squared	0.466815	S.D. dependent var	949.4769	
S.E. of regression	693.3036	Akaike info criterion	15.99743	
Sum squared resid	11055406	Schwarz criterion	16.09494	
Log likelihood	-197.9679	Hannan-Quinn criter.	16.02448	
F-statistic	22.01251	Durbin-Watson stat	1.926107	
Prob(F-statistic)	0.000100			

3. Residual Equation

Dependent Variable: D(DENG_RESID_POLY)
Method: Least Squares
Date: 05/05/11 Time: 15:20
Sample (adjusted): 1981 2005
Included observations: 25 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DENG_RESID_POLY(-1)	-0.997281	0.207641	-4.802916	0.0001
R-squared	0.488565	Mean dependent var	-51.03998	
Adjusted R-squared	0.488565	S.D. dependent var	949.4769	
S.E. of regression	679.0156	Akaike info criterion	15.91834	
Sum squared resid	11065494	Schwarz criterion	15.96710	
Log likelihood	-197.9793	Hannan-Quinn criter.	15.93187	
Durbin-Watson stat	1.922214			

4. *Comments*
By observing the CDRW statistic as well as the correlogram, the error tem appears to be absent of unit roots and hence the model is cointegrated.

C. *THE ERROR CORECTION MODEL*

1. The Model

Dependent Variable: D(DENG_RESID_POLY)
Method: Least Squares

Date: 05/05/11 Time: 15:22
Sample (adjusted): 1981 2005
Included observations: 25 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(TEMP_MAX*TEMP_MAX*TEMP_MAX)	-17.29141	9.262352	-1.866849	0.0793
D(TEMP_MAX*TEMP_MAX)	819.6972	439.9302	1.863244	0.0798
D(POP)	-0.003074	0.013049	-0.235600	0.8166
D(IMPROVE_WATER_RURAL)	20.49243	42.97475	0.476848	0.6395
D(IMPROVE_SANIT_TOT)	37.57410	137.4729	0.273320	0.7879
D(RAIN_DUMMY)	296.4832	214.6417	1.381294	0.1851
D(HUMIDITY_8*HUMIDITY_8*HUMIDITY_8)	-0.000238	0.005285	-0.044969	0.9647
DENG_RESID_POLY(-1)	-0.911532	0.229247	-3.976195	0.0010

R-squared	0.642245	Mean dependent var	-51.03998
Adjusted R-squared	0.494934	S.D. dependent var	949.4769
S.E. of regression	674.7739	Akaike info criterion	16.12097
Sum squared resid	7740437.	Schwarz criterion	16.51101
Log likelihood	-193.5121	Hannan-Quinn criter.	16.22915
Durbin-Watson stat	1.910541		

2. Test for Autocorrelation

Date: 05/06/11 Time: 13:11
Sample: 1981 2005
Included observations: 25

<table>
<tr><th>Autocorrelation</th><th>Partial Correlation</th><th></th><th>AC</th><th>PAC</th><th>Q-Stat</th><th>Prob</th></tr>
<tr><td>. | . |</td><td>. | . |</td><td>1</td><td>-0.007</td><td>-0.007</td><td>0.0014</td><td>0.970</td></tr>
<tr><td>. *| . |</td><td>. *| . |</td><td>2</td><td>-0.196</td><td>-0.196</td><td>1.1311</td><td>0.568</td></tr>
<tr><td>. |*** |</td><td>. |*** |</td><td>3</td><td>0.440</td><td>0.455</td><td>7.0787</td><td>0.069</td></tr>
<tr><td>. |* . |</td><td>. | . |</td><td>4</td><td>0.091</td><td>0.027</td><td>7.3436</td><td>0.119</td></tr>
<tr><td>. | . |</td><td>. |* . |</td><td>5</td><td>-0.051</td><td>0.150</td><td>7.4311</td><td>0.190</td></tr>
<tr><td>. *| . |</td><td>***| . |</td><td>6</td><td>-0.173</td><td>-0.475</td><td>8.4928</td><td>0.204</td></tr>
<tr><td>. | . |</td><td>. | . |</td><td>7</td><td>-0.049</td><td>-0.043</td><td>8.5842</td><td>0.284</td></tr>
<tr><td>. |**. |</td><td>. |* . |</td><td>8</td><td>0.238</td><td>0.135</td><td>10.835</td><td>0.211</td></tr>
<tr><td>.**| . |</td><td>. | . |</td><td>9</td><td>-0.254</td><td>-0.004</td><td>13.562</td><td>0.139</td></tr>
<tr><td>. *| . |</td><td>. |* . |</td><td>10</td><td>-0.102</td><td>0.158</td><td>14.029</td><td>0.172</td></tr>
<tr><td>. |* . |</td><td>.**| . |</td><td>11</td><td>0.142</td><td>-0.238</td><td>14.996</td><td>0.183</td></tr>
<tr><td>. *| . |</td><td>. *| . |</td><td>12</td><td>-0.200</td><td>-0.182</td><td>17.076</td><td>0.147</td></tr>
</table>

3. Misspecification Test

Ramsey RESET Test
Equation: DENG_POLY_ECM

Specification: D(DENG_RESID_POLY) D(TEMP_MAX*TEMP_MAX
*TEMP_MAX)D(TEMP_MAX*TEMP_MAX)D(POP)
D(IMPROVE_WATER_RURAL)D(IMPROVE_SANIT_TOT)
D(RAIN_DUMMY)D(HUMIDITY_8*HUMIDITY_8*HUMIDITY_8)
DENG_RESID_POLY(-1)
Omitted Variables: Squares of fitted values

	Value	df	Probability
t-statistic	1.681621	16	0.1121
F-statistic	2.827848	(1, 16)	0.1121
Likelihood ratio	4.068709	1	0.0437

F-test summary:

	Sum of Sq.	df	Mean Squares
Test SSR	1162575.	1	1162575.
Restricted SSR	7740437.	17	455319.8
Unrestricted SSR	6577862.	16	411116.4
Unrestricted SSR	6577862.	16	411116.4

LR test summary:

	Value	df
Restricted LogL	-193.5121	17
Unrestricted LogL	-191.4778	16

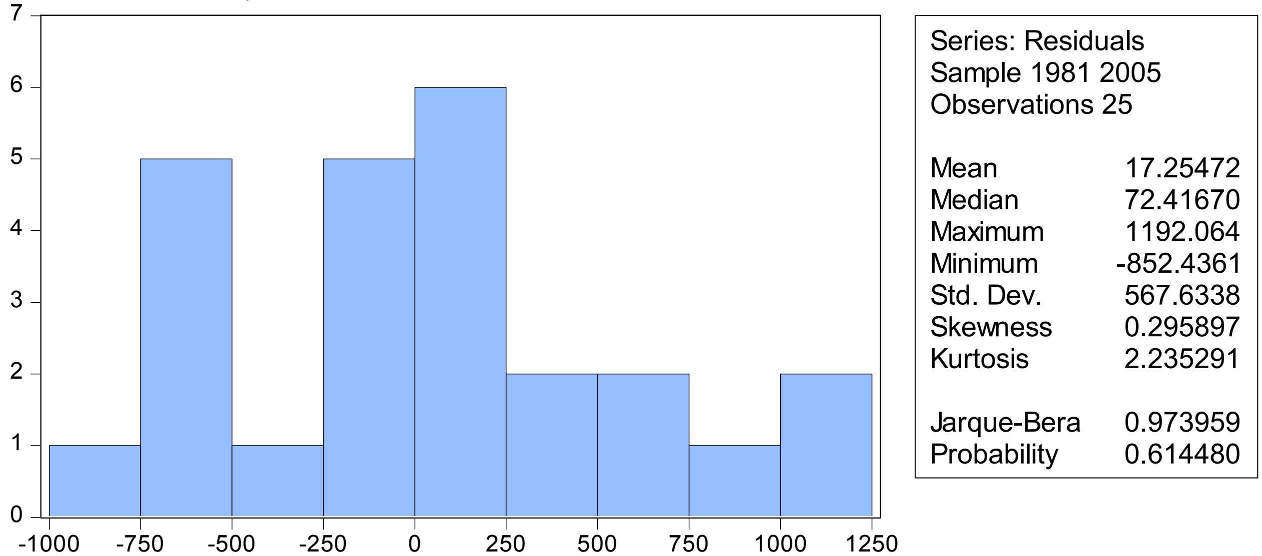
Unrestricted Test Equation:
Dependent Variable: D(DENG_RESID_POLY)
Method: Least Squares
Date: 05/06/11 Time: 13:09
Sample: 1981 2005
Included observations: 25

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(TEMP_MAX*TEMP_MAX*TEMP_MAX)	-11.22962	9.510861	-1.180715	0.2550
D(TEMP_MAX*TEMP_MAX)	534.3711	451.1524	1.184458	0.2535
D(POP)	-0.014601	0.014168	-1.030574	0.3181
D(IMPROVE_WATER_RURAL)	33.37366	41.54769	0.803262	0.4336
D(IMPROVE_SANIT_TOT)	61.22676	131.3846	0.466012	0.6475
D(RAIN_DUMMY)	365.0670	207.9946	1.755176	0.0984
D(HUMIDITY_8*HUMIDITY_8*HUMIDITY_8)	-0.000207	0.005022	-0.041152	0.9677
DENG_RESID_POLY(-1)	-1.117042	0.249775	-4.472199	0.0004
FITTED^2	0.000277	0.000165	1.681621	0.1121

R-squared	0.695978	Mean dependent var	-51.03998
Adjusted R-squared	0.543967	S.D. dependent var	949.4769
S.E. of regression	641.1836	Akaike info criterion	16.03822
Sum squared resid	6577862.	Schwarz criterion	16.47702
Log likelihood	-191.4778	Hannan-Quinn criter.	16.15992

Durbin-Watson stat	1.873153

4. Test for Normality



5. Test for Autocorrelation

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.242569	Prob. F(2,15)	0.7876
Obs*R-squared	0.759922	Prob. Chi-Square(2)	0.6839

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Date: 05/06/11 Time: 13:10
Sample: 1981 2005
Included observations: 25
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(TEMP_MAX*TEMP_MAX*TEMP_MAX)	2.097574	10.19668	0.205712	0.8398
D(TEMP_MAX*TEMP_MAX)	-100.0906	484.5763	-0.206553	0.8391
D(POP)	0.001156	0.013804	0.083770	0.9343
D(IMPROVE_WATER_RURAL)	-5.733045	47.69808	-0.120194	0.9059
D(IMPROVE_SANIT_TOT)	-59.18320	168.4680	-0.351302	0.7302
D(RAIN_DUMMY)	-14.48173	245.1734	-0.059067	0.9537
D(HUMIDITY_8*HUMIDITY_8*HUMIDITY_8)	0.001347	0.005924	0.227305	0.8233
DENG_RESID_POLY(-1)	-0.148574	0.497410	-0.298695	0.7693

RESID(-1)	0.190072	0.600687	0.316425	0.7560
RESID(-2)	-0.195662	0.330410	-0.592179	0.5626

R-squared	0.030397	Mean dependent var	17.25472
Adjusted R-squared	-0.551365	S.D. dependent var	567.6338
S.E. of regression	707.0094	Akaike info criterion	16.24914
Sum squared resid	7497935.	Schwarz criterion	16.73669
Log likelihood	-193.1142	Hannan-Quinn criter.	16.38437
Durbin-Watson stat	2.078692		

6. Test for Homescedasticity

Heteroskedasticity Test: White

F-statistic	0.741461	Prob. F(8,16)	0.6556
Obs*R-squared	6.761552	Prob. Chi-Square(8)	0.5626
Scaled explained SS	1.990683	Prob. Chi-Square(8)	0.9813

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 05/06/11 Time: 13:10
Sample: 1981 2005
Included observations: 25

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	186078.6	279311.9	0.666204	0.5148
(D(TEMP_MAX*TEMP_MAX*TEMP_MAX))^2	0.922234	1.464313	0.629806	0.5377
(D(TEMP_MAX*TEMP_MAX))^2	-2082.429	3275.352	-0.635788	0.5339
(D(POP))^2	-0.000525	0.000848	-0.619197	0.5445
(D(IMPROVE_WATER_RURAL))^2	-609.5211	2210.885	-0.275691	0.7863
(D(IMPROVE_SANIT_TOT))^2	-3014.606	20892.08	-0.144294	0.8871
(D(RAIN_DUMMY))^2	168662.1	178397.5	0.945429	0.3585
(D(HUMIDITY_8*HUMIDITY_8*HUMIDITY_8))^2	0.000150	0.000139	1.077139	0.2974
DENG_RESID_POLY(-1)^2	0.036591	0.112845	0.324254	0.7499

R-squared	0.270462	Mean dependent var	309617.5
Adjusted R-squared	-0.094307	S.D. dependent var	356593.8
S.E. of regression	373029.7	Akaike info criterion	28.77042
Sum squared resid	2.23E+12	Schwarz criterion	29.20921
Log likelihood	-350.6302	Hannan-Quinn criter.	28.89212
F-statistic	0.741461	Durbin-Watson stat	2.204179
Prob(F-statistic)	0.655645		

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	1.337840	Prob. F(8,16)	0.2944
Obs*R-squared	10.02025	Prob. Chi-Square(8)	0.2636
Scaled explained SS	2.950085	Prob. Chi-Square(8)	0.9375

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 06/24/11 Time: 10:22
Sample: 1981 2005
Included observations: 25

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	518220.5	146317.0	3.541764	0.0027
D(TEMP_MAX*TEMP_MAX*TEMP_MAX)	-3690.427	4644.202	-0.794631	0.4385
D(TEMP_MAX*TEMP_MAX)	170721.1	220595.5	0.773910	0.4503
D(POP)	-20.65600	13.52943	-1.526745	0.1463
D(IMPROVE_WATER_RURAL)	-8986.931	21602.59	-0.416012	0.6829
D(IMPROVE_SANIT_TOT)	-2160.000	69838.46	-0.030929	0.9757
D(RAIN_DUMMY)	232811.1	107598.1	2.163710	0.0460
D(HUMIDITY_8*HUMIDITY_8*HUMIDITY_8)	-1.663408	2.648784	-0.627989	0.5389
DENG_RESID_POLY(-1)	62.01143	115.5797	0.536526	0.5990

R-squared	0.400810	Mean dependent var	309617.5
Adjusted R-squared	0.101215	S.D. dependent var	356593.8
S.E. of regression	338066.1	Akaike info criterion	28.57358
Sum squared resid	1.83E+12	Schwarz criterion	29.01238
Log likelihood	-348.1698	Hannan-Quinn criter.	28.69529
F-statistic	1.337840	Durbin-Watson stat	2.368862
Prob(F-statistic)	0.294372		

Heteroskedasticity Test: Harvey

F-statistic	1.046988	Prob. F(8,16)	0.4434
Obs*R-squared	8.590352	Prob. Chi-Square(8)	0.3780
Scaled explained SS	4.247378	Prob. Chi-Square(8)	0.8341

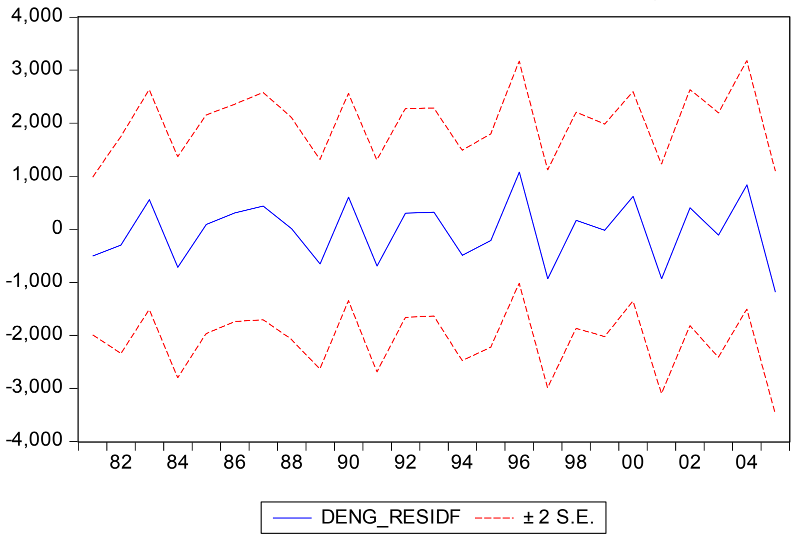
Test Equation:
Dependent Variable: LRESID2
Method: Least Squares
Date: 06/24/11 Time: 10:27
Sample: 1981 2005
Included observations: 25

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	12.91323	0.684657	18.86089	0.0000

D(TEMP_MAX*TEMP_MAX*TEMP_MAX)	-0.005974	0.021731	-0.274892	0.7869
D(TEMP_MAX*TEMP_MAX)	0.267957	1.032225	0.259591	0.7985
D(POP)	-0.000122	6.33E-05	-1.929366	0.0716
D(IMPROVE_WATER_RURAL)	0.009183	0.101084	0.090843	0.9287
D(IMPROVE_SANIT_TOT)	0.225405	0.326793	0.689749	0.5002
D(RAIN_DUMMY)	0.709289	0.503480	1.408772	0.1780
D(HUMIDITY_8*HUMIDITY_8*HUMIDITY_8)	-3.73E-06	1.24E-05	-0.300733	0.7675
DENG_RESID_POLY(-1)	0.000275	0.000541	0.507610	0.6187

R-squared	0.343614	Mean dependent var	11.75547
Adjusted R-squared	0.015421	S.D. dependent var	1.594242
S.E. of regression	1.581902	Akaike info criterion	4.028845
Sum squared resid	40.03861	Schwarz criterion	4.467641
Log likelihood	-41.36057	Hannan-Quinn criter.	4.150549
F-statistic	1.046988	Durbin-Watson stat	2.676726
Prob(F-statistic)	0.443387		

7. Forecasting Abilities



Forecast: DENG_RESIDF	
Actual: D(DENG_RESID_POLY)	
Forecast sample: 1980 2009	
Adjusted sample: 1981 2005	
Included observations: 25	
Root Mean Squared Error	743.1615
Mean Absolute Error	595.2436
Mean Abs. Percent Error	285.7161
Theil Inequality Coefficient	0.486996
Bias Proportion	0.000207
Variance Proportion	0.206056
Covariance Proportion	0.793736

ANNEX II- LEPTOSPIROSIS

A. *THE ORIGINALLY SPECIFIED MODEL*

1. The Model

Dependent Variable: LEPTO
Method: Least Squares
Date: 05/13/11 Time: 13:15
Sample (adjusted): 1986 2009
Included observations: 24 after adjustments
Convergence achieved after 8 iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
IST(-4)	-10.80319	2.198862	-4.913080	0.0001
TEMP_MAX	69.14452	8.775009	7.879709	0.0000
FORESTAREA	-26.51515	4.044333	-6.556124	0.0000
RAINFALL(-1)	0.057151	0.025964	2.201165	0.0403
AR(2)	-0.613233	0.209730	-2.923914	0.0087

R-squared	0.555999	Mean dependent var	106.1667
Adjusted R-squared	0.462525	S.D. dependent var	51.06915
S.E. of regression	37.44015	Akaike info criterion	10.26642
Sum squared resid	26633.54	Schwarz criterion	10.51184
Log likelihood	-118.1970	Hannan-Quinn criter.	10.33153
Durbin-Watson stat	1.430159		

2. Test of Mispecification

Ramsey RESET Test
Equation: POLY_LEPTO_NEW
Specification: LEPTO IST(-4) TEMP_MAX FORESTAREA RAINFALL(-1) AR(2)
Omitted Variables: Squares of fitted values

	Value	df	Probability
t-statistic	0.893650	18	0.3833
F-statistic	0.798610	(1, 18)	0.3833
Likelihood ratio	1.041869	1	0.3074

F-test summary:

	Sum of Sq.	df	Mean Squares
Test SSR	1131.457	1	1131.457
Restricted SSR	26633.54	19	1401.765
Unrestricted SSR	25502.08	18	1416.782
Unrestricted SSR	25502.08	18	1416.782

LR test summary:

	Value	df

Restricted LogL	-118.1970	19
Unrestricted LogL	-117.6761	18

Unrestricted Test Equation:
Dependent Variable: LEPTO
Method: Least Squares
Date: 05/13/11 Time: 13:16
Sample: 1986 2009
Included observations: 24
Convergence achieved after 8 iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
IST(-4)	3.454685	4.064999	0.849861	0.4066
TEMP_MAX	-33.84672	20.41958	-1.657562	0.1147
FORESTAREA	18.08233	14.23162	1.270574	0.2201
RAINFALL(-1)	0.001347	0.036322	0.037082	0.9708
FITTED^2	0.003903	0.001276	3.060058	0.0067
AR(2)	0.576648	0.185125	3.114910	0.0060

R-squared	0.574861	Mean dependent var	106.1667
Adjusted R-squared	0.456767	S.D. dependent var	51.06915
S.E. of regression	37.64017	Akaike info criterion	10.30634
Sum squared resid	25502.08	Schwarz criterion	10.60085
Log likelihood	-117.6761	Hannan-Quinn criter.	10.38447
Durbin-Watson stat	1.143050		

Inverted AR Roots	.76	-.76

3. Test of Autocorrelation

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	1.578349	Prob. F(2,17)	0.2351
Obs*R-squared	3.758549	Prob. Chi-Square(2)	0.1527

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Date: 05/13/11 Time: 13:17
Sample: 1986 2009
Included observations: 24
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
IST(-4)	2.257070	2.558483	0.882191	0.3900
TEMP_MAX	-10.78586	10.79305	-0.999334	0.3316
FORESTAREA	3.376807	4.377785	0.771351	0.4511
RAINFALL(-1)	-0.010390	0.026417	-0.393289	0.6990

AR(2)	-0.464298	0.405138	-1.146024	0.2677
RESID(-1)	0.407187	0.264611	1.538814	0.1423
RESID(-2)	0.523247	0.476562	1.097962	0.2875

R-squared	0.156606	Mean dependent var	0.047447
Adjusted R-squared	-0.141062	S.D. dependent var	34.02907
S.E. of regression	36.35002	Akaike info criterion	10.26276
Sum squared resid	22462.51	Schwarz criterion	10.60636
Log likelihood	-116.1531	Hannan-Quinn criter.	10.35392
Durbin-Watson stat	1.966105		

4. Test of Autocorrelation

Date: 05/13/11 Time: 13:18
Sample: 1986 2009
Included observations: 24
Q-statistic probabilities adjusted for 1 ARMA term(s)

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
. |**. |	. |**. |	1	0.265	0.265	1.8983	
. |* . |	. | . |	2	0.093	0.025	2.1446	0.143
. | . |	. | . |	3	0.028	-0.002	2.1686	0.338
. | . |	. | . |	4	0.033	0.026	2.2035	0.531
. | . |	. | . |	5	0.028	0.014	2.2295	0.694
. *| . |	. *| . |	6	-0.118	-0.141	2.7090	0.745
.**| . |	.**| . |	7	-0.292	-0.252	5.8289	0.443
. | . |	. |* . |	8	0.038	0.211	5.8862	0.553
. *| . |	.**| . |	9	-0.167	-0.235	7.0513	0.531
. *| . |	. | . |	10	-0.106	-0.015	7.5506	0.580
***| . |	***| . |	11	-0.365	-0.370	13.930	0.176
.**| . |	. *| . |	12	-0.297	-0.124	18.505	0.071

5. Test for Homoscedasticity

Heteroskedasticity Test: White

F-statistic	1.912133	Prob. F(15,8)	0.1786
Obs*R-squared	18.76583	Prob. Chi-Square(15)	0.2245
Scaled explained SS	5.869981	Prob. Chi-Square(15)	0.9818

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares

Date: 05/13/11 Time: 13:16
Sample: 1986 2009
Included observations: 24

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-48023.67	49457.39	-0.971011	0.3600
GRADF_01^2	15.88923	39.89044	0.398322	0.7008
GRADF_01*GRADF_02	209.5053	382.1053	0.548292	0.5985
GRADF_01*GRADF_03	-195.3016	184.2179	-1.060167	0.3200
GRADF_01*GRADF_04	-0.565182	0.406387	-1.390748	0.2018
GRADF_01*GRADF_05	2.501021	1.940321	1.288973	0.2334
GRADF_02^2	-524.9552	737.1502	-0.712141	0.4966
GRADF_02*GRADF_03	373.7046	401.1010	0.931697	0.3788
GRADF_02*GRADF_04	-0.606559	1.025787	-0.591311	0.5706
GRADF_02*GRADF_05	-33.92613	11.74105	-2.889531	0.0202
GRADF_03^2	31.84061	138.7898	0.229416	0.8243
GRADF_03*GRADF_04	1.856749	0.881386	2.106623	0.0682
GRADF_03*GRADF_05	16.13284	6.446609	2.502531	0.0368
GRADF_04^2	-0.003126	0.002640	-1.184052	0.2704
GRADF_04*GRADF_05	0.055795	0.049659	1.123563	0.2938
GRADF_05^2	0.299318	0.227890	1.313431	0.2255

R-squared	0.781909	Mean dependent var	1109.731
Adjusted R-squared	0.372989	S.D. dependent var	1132.574
S.E. of regression	896.8170	Akaike info criterion	16.67030
Sum squared resid	6434246.	Schwarz criterion	17.45567
Log likelihood	-184.0436	Hannan-Quinn criter.	16.87866
F-statistic	1.912133	Durbin-Watson stat	2.229586
Prob(F-statistic)	0.178558		

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	1.594668	Prob. F(4,19)	0.2166
Obs*R-squared	6.032158	Prob. Chi-Square(4)	0.1968
Scaled explained SS	1.886869	Prob. Chi-Square(4)	0.7566

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares

Date: 06/24/11 Time: 10:28
Sample: 1986 2009
Included observations: 24

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-53285.92	40340.41	-1.320907	0.2022
IMPROVE_SANIT_TO T(-4)	12.80483	113.7001	0.112619	0.9115
TEMP_MAX	1431.861	640.8133	2.234443	0.0377
FORESTAREA	137.1665	401.7619	0.341412	0.7365
RAINFALL(-1)	0.751268	0.921253	0.815485	0.4249

R-squared	0.251340	Mean dependent var	1109.731
Adjusted R-squared	0.093727	S.D. dependent var	1132.574
S.E. of regression	1078.191	Akaike info criterion	16.98701
Sum squared resid	22087438	Schwarz criterion	17.23244
Log likelihood	-198.8441	Hannan-Quinn criter.	17.05212
F-statistic	1.594668	Durbin-Watson stat	2.337813
Prob(F-statistic)	0.216577		

Heteroskedasticity Test: Harvey

F-statistic	1.720736	Prob. F(4,19)	0.1870
Obs*R-squared	6.382221	Prob. Chi-Square(4)	0.1724
Scaled explained SS	5.208448	Prob. Chi-Square(4)	0.2666

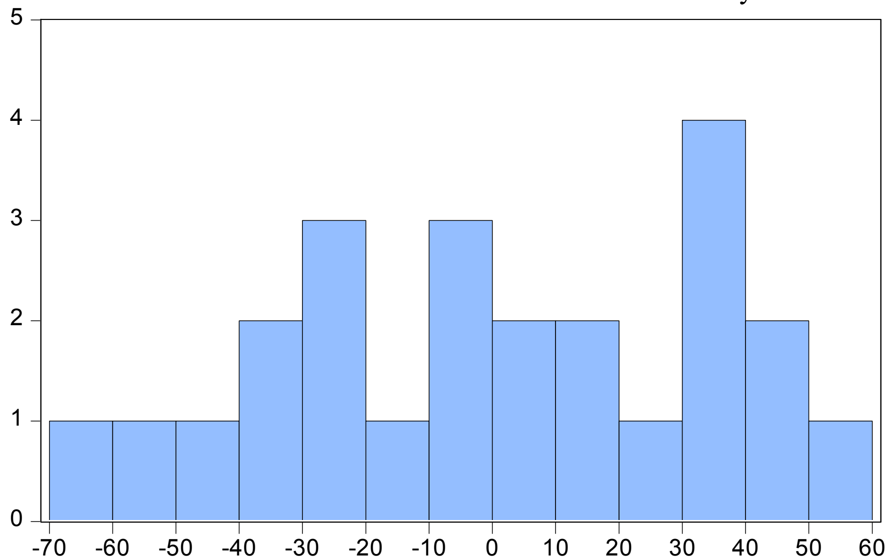
Test Equation:
Dependent Variable: LRESID2
Method: Least Squares
Date: 06/24/11 Time: 10:28
Sample: 1986 2009
Included observations: 24

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-45.11572	72.30133	-0.623996	0.5401
IMPROVE_SANIT_TO T(-4)	0.086269	0.203783	0.423337	0.6768
TEMP_MAX	1.859483	1.148517	1.619030	0.1219
FORESTAREA	-0.301912	0.720070	-0.419282	0.6797
RAINFALL(-1)	-0.001304	0.001651	-0.789870	0.4394

R-squared	0.265926	Mean dependent var	5.991830
Adjusted R-squared	0.111384	S.D. dependent var	2.049957
S.E. of regression	1.932422	Akaike info criterion	4.338477
Sum squared resid	70.95081	Schwarz criterion	4.583905
Log likelihood	-47.06172	Hannan-Quinn criter.	4.403589
F-statistic	1.720736	Durbin-Watson stat	2.685992

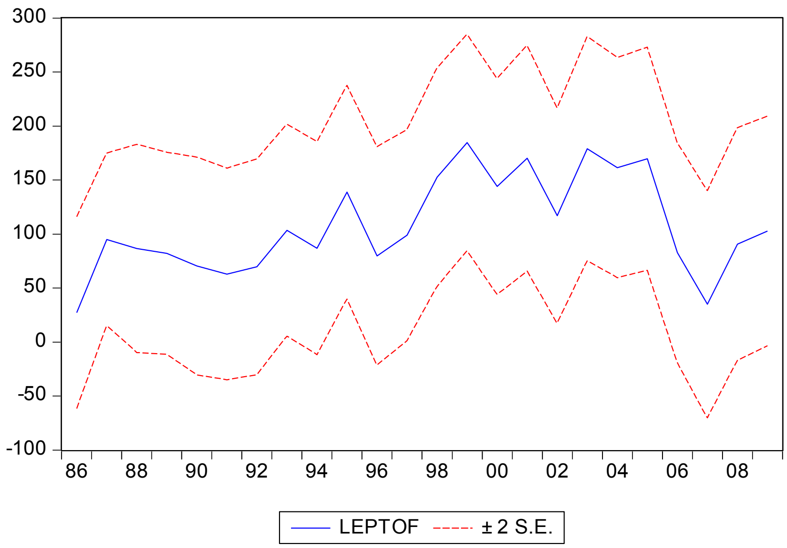
Prob(F-statistic)	0.187003

6. Test of Normality



Series: Residuals	
Sample 1986 2009	
Observations 24	
Mean	0.047447
Median	-0.099950
Maximum	58.59161
Minimum	-61.14577
Std. Dev.	34.02907
Skewness	-0.134966
Kurtosis	1.998957
Jarque-Bera	1.074949
Probability	0.584222

7. Forecasting Abilities



Forecast: LEPTOF	
Actual: LEPTO	
Forecast sample: 1980 2009	
Adjusted sample: 1986 2009	
Included observations: 24	
Root Mean Squared Error	39.07309
Mean Absolute Error	32.44056
Mean Abs. Percent Error	42.05750
Theil Inequality Coefficient	0.167054
Bias Proportion	0.002161
Variance Proportion	0.024744
Covariance Proportion	0.973094

8. *COMMENTS*

Multicollinearity is not a problem for this model.The model is only considered normal for a significance level of 1%. All variables are of 1 unit root except “FORESTAREA” which has two unit roots. A.1.8 comment on unit roots applies here.

B. *TESTING RESIDUALS FOR COINTEGRATION*

1. ACF Test

Date: 05/13/11 Time: 13:27
Sample: 1980 2009
Included observations: 26

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
. |*** |	. |*** |	1	0.364	0.364	3.8645	0.049
. |* . |	. | . |	2	0.187	0.062	4.9209	0.085
. | . |	. *| . |	3	0.028	-0.068	4.9456	0.176
. | . |	. | . |	4	-0.046	-0.055	5.0159	0.286
. |* . |	. |* . |	5	0.109	0.177	5.4298	0.366
. | . |	. | . |	6	0.065	-0.012	5.5831	0.471
. *| . |	.**| . |	7	-0.118	-0.218	6.1210	0.526
. | . |	. |* . |	8	0.066	0.208	6.2967	0.614
. *| . |	.**| . |	9	-0.175	-0.237	7.6126	0.574
. *| . |	. | . |	10	-0.123	-0.062	8.3045	0.599
***| . |	***| . |	11	-0.412	-0.443	16.528	0.123
***| . |	. | . |	12	-0.397	-0.033	24.715	0.016

2. Augmented dickey Fuller Test for Unit roots

Null Hypothesis: POLY_LEPTO_ERROR has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.941163	0.0548
Test critical values:	1% level	-3.724070	
	5% level	-2.986225	
	10% level	-2.632604	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(POLY_LEPTO_ERROR)
Method: Least Squares
Date: 05/17/11 Time: 14:44
Sample (adjusted): 1981 2005
Included observations: 25 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
POLY_LEPTO_ERROR(-1)	-0.596202	0.202710	-2.941163	0.0073
C	-3.565011	6.989463	-0.510055	0.6149
R-squared	0.273312	Mean dependent var	-2.266826	

Adjusted R-squared	0.241717	S.D. dependent var	40.05257
S.E. of regression	34.87756	Akaike info criterion	10.01818
Sum squared resid	27978.22	Schwarz criterion	10.11569
Log likelihood	-123.2273	Hannan-Quinn criter.	10.04523
F-statistic	8.650441	Durbin-Watson stat	1.931372
Prob(F-statistic)	0.007334		

3. Residual Equation

Dependent Variable: D(POLY_LEPTO_ERROR)
Method: Least Squares
Date: 05/13/11 Time: 13:28
Sample (adjusted): 1981 2005
Included observations: 25 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
POLY_LEPTO_ERROR (-1)	-0.589673	0.199162	-2.960764	0.0068

R-squared	0.265092	Mean dependent var	-2.266826
Adjusted R-squared	0.265092	S.D. dependent var	40.05257
S.E. of regression	34.33577	Akaike info criterion	9.949430
Sum squared resid	28294.68	Schwarz criterion	9.998185
Log likelihood	-123.3679	Hannan-Quinn criter.	9.962953
Durbin-Watson stat	1.923820		

C. *THE ERROR CORECTION MODEL*

1. The Model

Dependent Variable: D(LEPTO)
Method: Least Squares
Date: 05/13/11 Time: 13:31
Sample (adjusted): 1987 2006
Included observations: 20 after adjustments
Convergence achieved after 9 iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(IST(-4))	-2.697917	5.025658	-0.536829	0.5998
D(TEMP_MAX)	8.496855	7.882998	1.077871	0.2993
D(FORESTAREA)	-45.33906	25.52890	-1.775989	0.0975
D(RAINFALL(-1))	0.041117	0.010232	4.018353	0.0013
POLY_LEPTO_ERROR (-1)	0.158779	0.121871	1.302840	0.2137
AR(2)	-0.765056	0.172403	-4.437616	0.0006

R-squared	0.722170	Mean dependent var	4.950000
Adjusted R-squared	0.622945	S.D. dependent var	34.58091
S.E. of regression	21.23435	Akaike info criterion	9.192443
Sum squared resid	6312.568	Schwarz criterion	9.491162
Log likelihood	-85.92443	Hannan-Quinn criter.	9.250756
Durbin-Watson stat	1.345852		

2. Test for Autocorrelation

Date: 05/13/11 Time: 13:34
Sample: 1987 2006
Included observations: 20
Q-statistic probabilities adjusted for 1 ARMA term(s)

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
.**| . |	.**| . |	1	-0.240	-0.240	1.3300	
. | . |	. | . |	2	0.000	-0.060	1.3300	0.249
. *| . |	. *| . |	3	-0.106	-0.128	1.6219	0.444
. | . |	. *| . |	4	-0.059	-0.127	1.7163	0.633
. | . |	. *| . |	5	-0.054	-0.123	1.8029	0.772
. | . |	. | . |	6	0.030	-0.046	1.8319	0.872
. | . |	. | . |	7	0.035	-0.003	1.8734	0.931
.**| . |	.**| . |	8	-0.283	-0.340	4.8107	0.683
. |**. |	. |* . |	9	0.255	0.085	7.4184	0.492
. | . |	. | . |	10	-0.045	-0.005	7.5077	0.584
. | . |	. *| . |	11	-0.052	-0.156	7.6397	0.664
. | . |	. *| . |	12	-0.015	-0.100	7.6515	0.744

3. Misspecification Test

Ramsey RESET Test
Equation: UNTITLED
Specification: D(LEPTO) D(IST(-4)) D(TEMP_MAX) D(FORESTAREA) D(RAINFALL(-1)) AR(2) POLY_LEPTO_ERROR(-1)
Omitted Variables: Squares of fitted values

	Value	df	Probability
t-statistic	1.002787	13	0.3343
F-statistic	1.005582	(1, 13)	0.3343
Likelihood ratio	1.490132	1	0.2222

F-test summary:

	Sum of Sq.	df	Mean Squares
Test SSR	453.2340	1	453.2340
Restricted SSR	6312.568	14	450.8977
Unrestricted SSR	5859.334	13	450.7180
Unrestricted SSR	5859.334	13	450.7180

LR test summary:

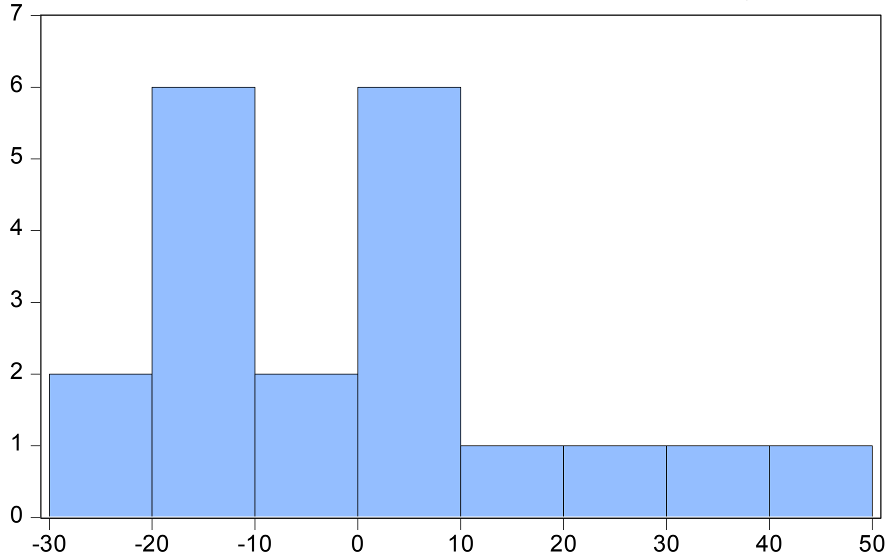
	Value	df
Restricted LogL	-85.92443	14
Unrestricted LogL	-85.17936	13

Unrestricted Test Equation:
Dependent Variable: D(LEPTO)
Method: Least Squares
Date: 05/13/11 Time: 13:32
Sample: 1987 2006
Included observations: 20
Convergence achieved after 9 iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(IST(-4))	-1.847992	5.073708	-0.364229	0.7215
D(TEMP_MAX)	7.241880	7.972107	0.908402	0.3802
D(FORESTAREA)	-17.62525	37.57799	-0.469031	0.6468
D(RAINFALL(-1))	0.038832	0.010438	3.720316	0.0026
POLY_LEPTO_ERROR (-1)	0.170149	0.122405	1.390052	0.1879
FITTED^2	0.003993	0.003982	1.002967	0.3342
AR(2)	-0.768610	0.178045	-4.316935	0.0008

R-squared	0.742118	Mean dependent var	4.950000
Adjusted R-squared	0.623095	S.D. dependent var	34.58091
S.E. of regression	21.23012	Akaike info criterion	9.217936
Sum squared resid	5859.334	Schwarz criterion	9.566442
Log likelihood	-85.17936	Hannan-Quinn criter.	9.285968
Durbin-Watson stat	1.033450		

4. Test for Normality



Series: Residuals	
Sample 1987 2006	
Observations 20	
Mean	-0.782657
Median	-2.130808
Maximum	40.45866
Minimum	-26.34432
Std. Dev.	18.20977
Skewness	0.718593
Kurtosis	2.773568
Jarque-Bera	1.763979
Probability	0.413959

5. Test for Autocorrelation

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	1.144467	Prob. F(2,12)	0.3508
Obs*R-squared	3.171124	Prob. Chi-Square(2)	0.2048

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Date: 05/17/11 Time: 14:48
Sample: 1987 2006
Included observations: 20
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(IMPROVE_SANIT_TOT(-4))	1.982884	5.611633	0.353352	0.7300
D(TEMP_MAX)	-3.054839	8.302585	-0.367938	0.7193
D(FORESTAREA)	3.596029	26.45171	0.135947	0.8941
D(RAINFALL(-1))	-0.002758	0.010512	-0.262406	0.7975
POLY_LEPTO_ERROR(-1)	0.030891	0.132377	0.233358	0.8194
AR(2)	-0.155297	0.235570	-0.659239	0.5222
RESID(-1)	0.489907	0.325624	1.504518	0.1583
RESID(-2)	0.057575	0.399816	0.144003	0.8879

R-squared	0.158556	Mean dependent var	-0.782657
Adjusted R-squared	-0.332286	S.D. dependent var	18.20977
S.E. of regression	21.01857	Akaike info criterion	9.217864
Sum squared resid	5301.362	Schwarz criterion	9.616157

Log likelihood	-84.17864	Hannan-Quinn criter.	9.295615
Durbin-Watson stat	2.196829		

6. Test for Homescedasticity

Heteroskedasticity Test: White

F-statistic	0.697823	Prob. F(6,13)	0.6564
Obs*R-squared	4.872235	Prob. Chi-Square(6)	0.5603
Scaled explained SS	1.967428	Prob. Chi-Square(6)	0.9227

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 05/13/11 Time: 13:33
Sample: 1987 2006
Included observations: 20

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-78.48480	439.2973	-0.178660	0.8610
GRADF_01^2	31.69338	38.54851	0.822169	0.4258
GRADF_02^2	-224.1965	267.2022	-0.839052	0.4166
GRADF_03^2	17399.43	11113.14	1.565663	0.1414
GRADF_04^2	0.000215	0.000486	0.442390	0.6655
GRADF_05^2	-0.068013	0.056888	-1.195561	0.2532
GRADF_06^2	-0.234291	0.136348	-1.718336	0.1094

R-squared	0.243612	Mean dependent var	315.6284
Adjusted R-squared	-0.105491	S.D. dependent var	415.7349
S.E. of regression	437.1133	Akaike info criterion	15.26748
Sum squared resid	2483885.	Schwarz criterion	15.61599
Log likelihood	-145.6748	Hannan-Quinn criter.	15.33551
F-statistic	0.697823	Durbin-Watson stat	2.842207
Prob(F-statistic)	0.656374		

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	0.355796	Prob. F(5,14)	0.8701
Obs*R-squared	2.254875	Prob. Chi-Square(5)	0.8129
Scaled explained SS	0.910528	Prob. Chi-Square(5)	0.9695

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 06/24/11 Time: 10:30

Sample: 1987 2006
Included observations: 20

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	257.7447	533.3574	0.483250	0.6364
D(IMPROVE_SANIT_TOT(-4))	-30.25608	103.9949	-0.290938	0.7754
D(TEMP_MAX)	7.699960	193.5107	0.039791	0.9688
D(FORESTAREA)	-619.6959	4515.435	-0.137239	0.8928
D(RAINFALL(-1))	0.218687	0.288844	0.757109	0.4615
POLY_LEPTO_ERROR(-1)	2.119007	3.138274	0.675214	0.5105

R-squared	0.112744	Mean dependent var	315.6284
Adjusted R-squared	-0.204133	S.D. dependent var	415.7349
S.E. of regression	456.1985	Akaike info criterion	15.32706
Sum squared resid	2913639.	Schwarz criterion	15.62578
Log likelihood	-147.2706	Hannan-Quinn criter.	15.38537
F-statistic	0.355796	Durbin-Watson stat	2.487952
Prob(F-statistic)	0.870074		

Heteroskedasticity Test: Harvey

F-statistic	0.715029	Prob. F(5,14)	0.6225
Obs*R-squared	4.068411	Prob. Chi-Square(5)	0.5396
Scaled explained SS	5.055399	Prob. Chi-Square(5)	0.4092

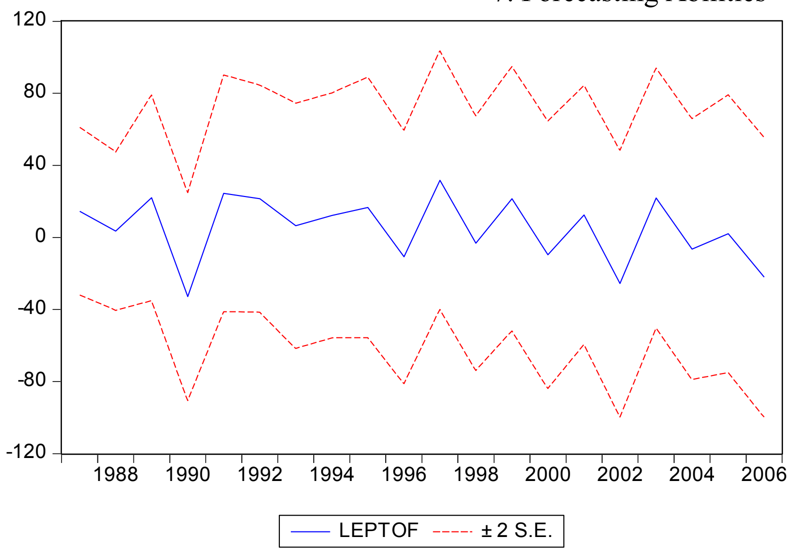
Test Equation:
Dependent Variable: LRESID2
Method: Least Squares
Date: 06/24/11 Time: 10:30
Sample: 1987 2006
Included observations: 20

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	6.024818	3.088377	1.950804	0.0714
D(IMPROVE_SANIT_TOT(-4))	-0.115068	0.602177	-0.191086	0.8512
D(TEMP_MAX)	-0.189719	1.120513	-0.169314	0.8680
D(FORESTAREA)	13.72087	26.14638	0.524772	0.6080
D(RAINFALL(-1))	0.002602	0.001673	1.555772	0.1421
POLY_LEPTO_ERROR(-1)	0.013506	0.018172	0.743220	0.4696

R-squared	0.203421	Mean dependent var	4.412232
Adjusted R-squared	-0.081072	S.D. dependent var	2.540612
S.E. of regression	2.641592	Akaike info criterion	5.023966
Sum squared resid	97.69211	Schwarz criterion	5.322685

Log likelihood	-44.23966	Hannan-Quinn criter.	5.082279
F-statistic	0.715029	Durbin-Watson stat	2.454482
Prob(F-statistic)	0.622508		

7. Forecasting Abilities



Forecast: LEPTOF	
Actual: D(LEPTO)	
Forecast sample: 1980 2009	
Adjusted sample: 1987 2006	
Included observations: 20	
Root Mean Squared Error	26.64917
Mean Absolute Error	21.34299
Mean Abs. Percent Error	133.9753
Theil Inequality Coefficient	0.507321
Bias Proportion	0.000004
Variance Proportion	0.357523
Covariance Proportion	0.642473

ANNEX III- FOOD-BORNE ILLNESSES

A. *THE ORIGINALLY SPECIFIED MODEL*

1. The Model

Dependent Variable: FOODBORNE
Method: Least Squares
Date: 05/13/11 Time: 15:11
Sample (adjusted): 1981 2004
Included observations: 24 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
HUMIDITY_8*HUMIDITY_8*HUMIDITY_8	-0.003159	0.001211	-2.608222	0.0164
RAINFALL*RAINFALL	-0.000694	0.000189	-3.665037	0.0014
RAINFALL	2.676936	0.720902	3.713314	0.0013

R-squared	0.271243	Mean dependent var	671.9583
Adjusted R-squared	0.201838	S.D. dependent var	217.5359
S.E. of regression	194.3464	Akaike info criterion	13.49363
Sum squared resid	793181.3	Schwarz criterion	13.64089
Log likelihood	-158.9236	Hannan-Quinn criter.	13.53270
Durbin-Watson stat	1.833537		

2. Test of Misspecification

Ramsey RESET Test
Equation: EXPERIMENT2
Specification: FOODBORNE HUMIDITY_8*HUMIDITY_8*HUMIDITY_8 RAINFALL*RAINFALLRAINFALL
Omitted Variables: Squares of fitted values

	Value	df	Probability
t-statistic	0.212882	20	0.8336
F-statistic	0.045319	(1, 20)	0.8336
Likelihood ratio	0.054321	1	0.8157

F-test summary:

	Sum of Sq.	df	Mean Squares
Test SSR	1793.238	1	1793.238
Restricted SSR	793181.3	21	37770.54
Unrestricted SSR	791388.1	20	39569.40
Unrestricted SSR	791388.1	20	39569.40

LR test summary:

	Value	df
Restricted LogL	-158.9236	21
Unrestricted LogL	-158.8964	20

Unrestricted Test Equation:
Dependent Variable: FOODBORNE
Method: Least Squares
Date: 05/13/11 Time: 15:14
Sample: 1981 2004
Included observations: 24

Variable	Coefficient	Std. Error	t-Statistic	Prob.
HUMIDITY_8*HUMIDITY_8*HUMIDITY_8	-0.001349	0.008593	-0.156927	0.8769
RAINFALL*RAINFALL	-0.000343	0.001660	-0.206687	0.8383
RAINFALL	1.328550	6.376789	0.208341	0.8371
FITTED^2	0.000438	0.002058	0.212882	0.8336

R-squared	0.272891	Mean dependent var	671.9583
Adjusted R-squared	0.163824	S.D. dependent var	217.5359
S.E. of regression	198.9206	Akaike info criterion	13.57470
Sum squared resid	791388.1	Schwarz criterion	13.77104
Log likelihood	-158.8964	Hannan-Quinn criter.	13.62679
Durbin-Watson stat	1.860008		

3. Test of Autocorrelation

Date: 05/13/11 Time: 15:16
Sample: 1981 2004
Included observations: 24

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
. *| . |	. *| . |	1	-0.155	-0.155	0.6542	0.419
. | . |	. | . |	2	-0.026	-0.051	0.6727	0.714
. | . |	. | . |	3	0.030	0.019	0.7000	0.873
. *| . |	. *| . |	4	-0.094	-0.090	0.9782	0.913
. *| . |	. *| . |	5	-0.162	-0.196	1.8362	0.871
. *| . |	. *| . |	6	-0.088	-0.167	2.1032	0.910
. |* . |	. | . |	7	0.123	0.071	2.6547	0.915
. *| . |	. *| . |	8	-0.082	-0.068	2.9193	0.939
. | . |	. *| . |	9	-0.057	-0.127	3.0535	0.962
. *| . |	. *| . |	10	-0.073	-0.201	3.2911	0.974
. *| . |	.**| . |	11	-0.099	-0.216	3.7629	0.976
. | . |	. | . |	12	0.030	-0.062	3.8094	0.987

4. Test of Autocorrelation

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.846751	Prob. F(2,19)	0.4444
Obs*R-squared	1.963885	Prob. Chi-Square(2)	0.3746

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Date: 05/13/11 Time: 15:15
Sample: 1981 2004
Included observations: 24
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
HUMIDITY_8*HUMIDITY_8*HUMIDITY_8	-0.000142	0.001251	-0.113242	0.9110
RAINFALL*RAINFALL	-3.97E-05	0.000196	-0.202642	0.8416
RAINFALL	0.120749	0.745512	0.161968	0.8730
RESID(-1)	-0.013566	0.250597	-0.054134	0.9574
RESID(-2)	-0.325523	0.250391	-1.300060	0.2091

R-squared	0.081829	Mean dependent var	0.564074
Adjusted R-squared	-0.111471	S.D. dependent var	185.7036
S.E. of regression	195.7804	Akaike info criterion	13.57492
Sum squared resid	728269.4	Schwarz criterion	13.82034
Log likelihood	-157.8990	Hannan-Quinn criter.	13.64003
Durbin-Watson stat	1.799681		

5. Test for Homoscedasticity

Heteroskedasticity Test: White

F-statistic	0.539947	Prob. F(6,17)	0.7708
Obs*R-squared	3.841580	Prob. Chi-Square(6)	0.6981
Scaled explained SS	4.105249	Prob. Chi-Square(6)	0.6624

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 05/13/11 Time: 15:15
Sample: 1981 2004
Included observations: 24

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2237287.	2794291.	0.800664	0.4344
(HUMIDITY_8*HUMIDITY_8*HUMI	-6.42E-06	8.42E-06	-0.762934	0.4560

DITY_8)^2				
(HUMIDITY_8*HUMIDITY_8*HUMIDITY_8)*(RAINFALL*RAINFALL)	-7.74E-08	2.39E-06	-0.032427	0.9745
(HUMIDITY_8*HUMIDITY_8*HUMIDITY_8)*RAINFALL	0.003716	0.009417	0.394610	0.6980
(RAINFALL*RAINFALL)^2	-2.95E-07	5.42E-07	-0.544008	0.5935
(RAINFALL*RAINFALL)*RAINFALL	0.001726	0.003120	0.553109	0.5874
RAINFALL^2	-3.313838	5.258918	-0.630137	0.5370

R-squared	0.160066	Mean dependent var	33049.22
Adjusted R-squared	-0.136382	S.D. dependent var	56405.92
S.E. of regression	60129.39	Akaike info criterion	25.08488
Sum squared resid	6.15E+10	Schwarz criterion	25.42848
Log likelihood	-294.0185	Hannan-Quinn criter.	25.17603
F-statistic	0.539947	Durbin-Watson stat	2.200690
Prob(F-statistic)	0.770772		

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	0.550295	Prob. F(3,20)	0.6538
Obs*R-squared	1.830006	Prob. Chi-Square(3)	0.6084
Scaled explained SS	1.955609	Prob. Chi-Square(3)	0.5817

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 06/24/11 Time: 10:31
Sample: 1981 2004
Included observations: 24

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-27952.17	788784.8	-0.035437	0.9721
HUMIDITY_8*HUMIDITY_8*HUMIDITY_8	-0.217133	0.391840	-0.554138	0.5856
RAINFALL*RAINFALL	-0.075139	0.193278	-0.388762	0.7016
RAINFALL	247.6718	756.8605	0.327236	0.7469

R-squared	0.076250	Mean dependent var	33049.22
Adjusted R-squared	-0.062312	S.D. dependent var	56405.92
S.E. of regression	58136.76	Akaike info criterion	24.93000
Sum squared resid	6.76E+10	Schwarz criterion	25.12634
Log likelihood	-295.1599	Hannan-Quinn criter.	24.98209
F-statistic	0.550295	Durbin-Watson stat	2.252437
Prob(F-statistic)	0.653764		

Heteroskedasticity Test: Harvey

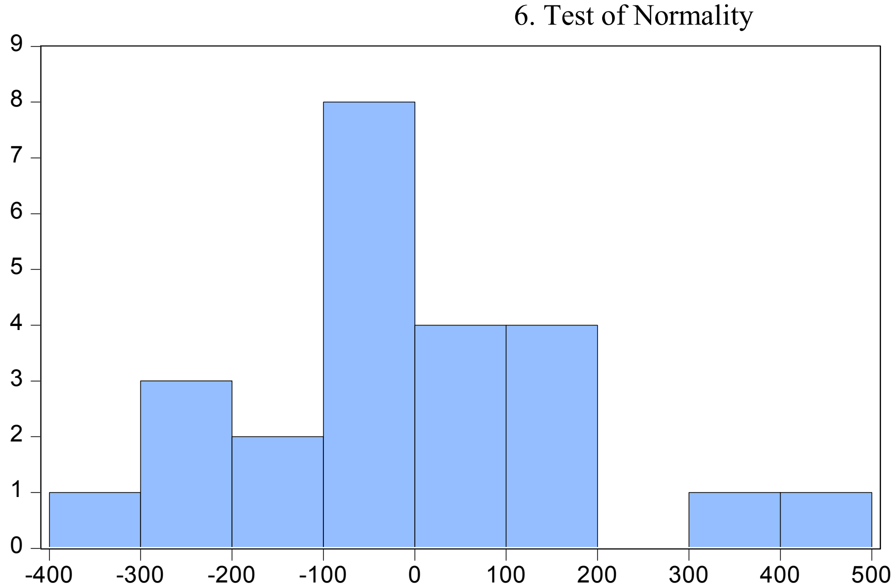
F-statistic	2.758916	Prob. F(3,20)	0.0691
Obs*R-squared	7.024922	Prob. Chi-Square(3)	0.0711
Scaled explained SS	5.931384	Prob. Chi-Square(3)	0.1150

Test Equation:
Dependent Variable: LRESID2
Method: Least Squares
Date: 06/24/11 Time: 10:32
Sample: 1981 2004
Included observations: 24

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-4.918973	25.51472	-0.192790	0.8491
HUMIDITY_8*HUMIDITY_8*HUMIDITY_8	-5.22E-06	1.27E-05	-0.411519	0.6851
RAINFALL*RAINFALL	-6.67E-06	6.25E-06	-1.066239	0.2990
RAINFALL	0.022079	0.024482	0.901848	0.3779

R-squared	0.292705	Mean dependent var	8.992650
Adjusted R-squared	0.186611	S.D. dependent var	2.085133
S.E. of regression	1.880542	Akaike info criterion	4.252009
Sum squared resid	70.72876	Schwarz criterion	4.448351
Log likelihood	-47.02411	Hannan-Quinn criter.	4.304099
F-statistic	2.758916	Durbin-Watson stat	2.327763
Prob(F-statistic)	0.069059		

6. Test of Normality



Series: Residuals
Sample 1981 2004
Observations 24

Mean	0.564074
Median	-18.10119
Maximum	492.2633
Minimum	-306.9532
Std. Dev.	185.7036
Skewness	0.858595
Kurtosis	3.780897
Jarque-Bera	3.558540
Probability	0.168761

7. Forecasting Abilities

Forecast: FOODBORNEF	
Actual: FOODBORNE	
Forecast sample: 1980 2009	
Adjusted sample: 1980 2005	
Included observations: 24	
Root Mean Squared Error	181.7944
Mean Absolute Error	137.5077
Mean Abs. Percent Error	21.71781
Theil Inequality Coefficient	0.131170
Bias Proportion	0.000010
Variance Proportion	0.294651
Covariance Proportion	0.705339

8. *COMMENTS*

Multicollinearity is low among the independent variables. Normality is accepted at 1% and no serial correlation at 5% and 1% significance.

B. *TESTING RESIDUALS FOR COINTEGRATION*

1. ACF Test

Date: 05/13/11 Time: 15:18
Sample: 1980 2009
Included observations: 24

<table>
<tr><th>Autocorrelation</th><th>Partial Correlation</th><th></th><th>AC</th><th>PAC</th><th>Q-Stat</th><th>Prob</th></tr>
<tr><td>. | . |</td><td>. | . |</td><td>1</td><td>-0.011</td><td>-0.011</td><td>0.0032</td><td>0.955</td></tr>
<tr><td>.**| . |</td><td>.**| . |</td><td>2</td><td>-0.251</td><td>-0.251</td><td>1.7881</td><td>0.409</td></tr>
<tr><td>. |* . |</td><td>. |* . |</td><td>3</td><td>0.111</td><td>0.112</td><td>2.1536</td><td>0.541</td></tr>
<tr><td>. | . |</td><td>. *| . |</td><td>4</td><td>-0.045</td><td>-0.117</td><td>2.2169</td><td>0.696</td></tr>
<tr><td>. | . |</td><td>. |* . |</td><td>5</td><td>0.064</td><td>0.135</td><td>2.3498</td><td>0.799</td></tr>
<tr><td>. |**. |</td><td>. |* . |</td><td>6</td><td>0.213</td><td>0.170</td><td>3.9292</td><td>0.686</td></tr>
<tr><td>***| . |</td><td>.**| . |</td><td>7</td><td>-0.349</td><td>-0.332</td><td>8.4017</td><td>0.299</td></tr>
<tr><td>. *| . |</td><td>. | . |</td><td>8</td><td>-0.141</td><td>-0.046</td><td>9.1735</td><td>0.328</td></tr>
<tr><td>. |* . |</td><td>. *| . |</td><td>9</td><td>0.114</td><td>-0.097</td><td>9.7135</td><td>0.374</td></tr>
<tr><td>. *| . |</td><td>. *| . |</td><td>10</td><td>-0.121</td><td>-0.108</td><td>10.365</td><td>0.409</td></tr>
<tr><td>. *| . |</td><td>. *| . |</td><td>11</td><td>-0.130</td><td>-0.182</td><td>11.181</td><td>0.428</td></tr>
<tr><td>. | . |</td><td>. *| . |</td><td>12</td><td>-0.052</td><td>-0.144</td><td>11.324</td><td>0.501</td></tr>
</table>

2. Augmented dickey Fuller Test for Unit roots

Null Hypothesis: FOOD_POLY_ERROR has a unit root

Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.169705	0.0039
Test critical values:	1% level	-3.752946	
	5% level	-2.998064	
	10% level	-2.638752	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(FOOD_POLY_ERROR)
Method: Least Squares
Date: 05/13/11 Time: 15:19
Sample (adjusted): 1981 2003
Included observations: 23 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
FOOD_POLY_ERROR(-1)	-1.014126	0.243213	-4.169705	0.0004
C	-0.669381	40.69762	-0.016448	0.9870

R-squared	0.452932	Mean dependent var	15.76340
Adjusted R-squared	0.426881	S.D. dependent var	256.6047
S.E. of regression	194.2616	Akaike info criterion	13.45923
Sum squared resid	792489.3	Schwarz criterion	13.55797
Log likelihood	-152.7811	Hannan-Quinn criter.	13.48406
F-statistic	17.38644	Durbin-Watson stat	1.749966
Prob(F-statistic)	0.000433		

3. Residual Equation

Dependent Variable: D(FOOD_POLY_ERROR)
Method: Least Squares
Date: 05/13/11 Time: 15:22
Sample (adjusted): 1981 2003
Included observations: 23 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
FOOD_POLY_ERROR(-1)	-1.013739	0.236506	-4.286316	0.0003

R-squared	0.452925	Mean dependent var	15.76340
Adjusted R-squared	0.452925	S.D. dependent var	256.6047
S.E. of regression	189.7965	Akaike info criterion	13.37229

Sum squared resid	792499.5	Schwarz criterion	13.42166
Log likelihood	-152.7813	Hannan-Quinn criter.	13.38470
Durbin-Watson stat	1.750349		

C. *THE ERROR CORECTION MODEL*

1. The Model

Dependent Variable: D(FOODBORNE)
Method: Least Squares
Date: 05/17/11 Time: 15:11
Sample (adjusted): 1982 2004
Included observations: 23 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(HUMIDITY_8*HUMIDITY_8*HUMIDITY_8)	-0.002526	0.001534	-1.646963	0.1160
D(RAINFALL*RAINFALL)	-0.000392	0.000444	-0.883928	0.3878
D(RAINFALL)	1.450979	1.728395	0.839495	0.4116
FOOD_POLY_ERROR(-1)	0.922318	0.222605	4.143303	0.0006

R-squared	0.522808	Mean dependent var	27.04348
Adjusted R-squared	0.447462	S.D. dependent var	240.9550
S.E. of regression	179.1088	Akaike info criterion	13.37063
Sum squared resid	609519.3	Schwarz criterion	13.56811
Log likelihood	-149.7623	Hannan-Quinn criter.	13.42030
Durbin-Watson stat	1.891070		

2. Test for Autocorrelation

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.238482	Prob. F(2,17)	0.7904
Obs*R-squared	0.339352	Prob. Chi-Square(2)	0.8439

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Date: 05/17/11 Time: 15:41
Sample: 1982 2004
Included observations: 23
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.

D(HUMIDITY_8*HUMIDITY_8*HUMIDITY_8)	7.63E-05	0.001706	0.044709	0.9649
D(RAINFALL*RAINFALL)	-5.52E-05	0.000482	-0.114464	0.9102
D(RAINFALL)	0.233055	1.873075	0.124424	0.9024
FOOD_POLY_ERROR(-1)	-0.026495	0.255446	-0.103722	0.9186
RESID(-1)	0.071222	0.278207	0.256004	0.8010
RESID(-2)	-0.180673	0.280271	-0.644635	0.5278

R-squared	0.014754	Mean dependent var	18.36310
Adjusted R-squared	-0.275024	S.D. dependent var	165.3871
S.E. of regression	186.7501	Akaike info criterion	13.51688
Sum squared resid	592884.9	Schwarz criterion	13.81309
Log likelihood	-149.4441	Hannan-Quinn criter.	13.59137
Durbin-Watson stat	1.981684		

3. Misspecification Test

Ramsey RESET Test
Equation: FOOD_POLY_ECM
Specification: D(FOODBORNE)D(HUMIDITY_8*HUMIDITY_8*HUMIDITY_8)D(RAINFALL*RAINFALL)D(RAINFALL) FOOD_POLY_ERROR(-1)
Omitted Variables: Squares of fitted values

	Value	df	Probability
t-statistic	1.229001	18	0.2349
F-statistic	1.510443	(1, 18)	0.2349
Likelihood ratio	1.853297	1	0.1734

F-test summary:

	Sum of Sq.	df	Mean Squares
Test SSR	47187.26	1	47187.26
Restricted SSR	609519.3	19	32079.96
Unrestricted SSR	562332.0	18	31240.67
Unrestricted SSR	562332.0	18	31240.67

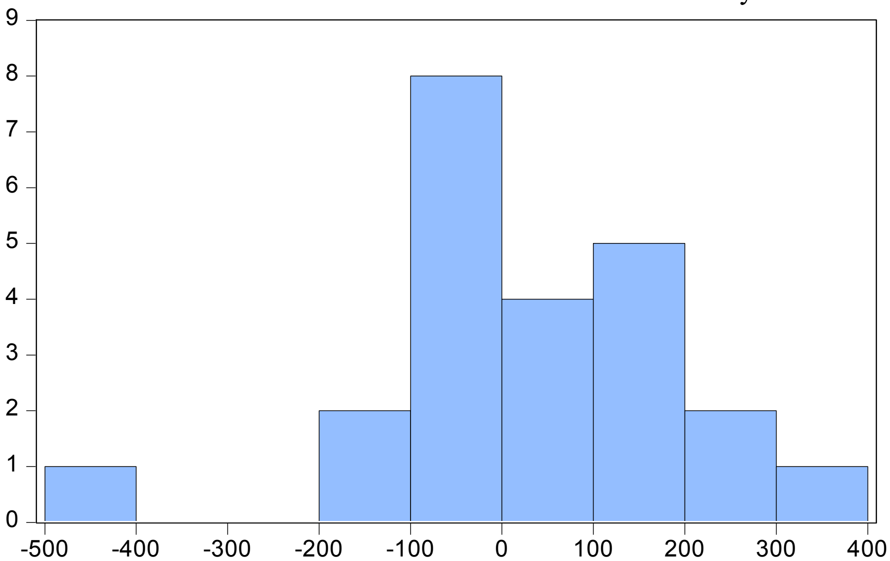
LR test summary:

	Value	df
Restricted LogL	-149.7623	19
Unrestricted LogL	-148.8357	18

Unrestricted Test Equation:
Dependent Variable: D(FOODBORNE)
Method: Least Squares
Date: 05/17/11 Time: 15:41
Sample: 1982 2004
Included observations: 23

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(HUMIDITY_8*HUMIDITY_8*HUMIDITY_8)	-0.002646	0.001517	-1.744759	0.0981
D(RAINFALL*RAINFALL)	-5.88E-05	0.000516	-0.113976	0.9105
D(RAINFALL)	0.178414	1.995330	0.089416	0.9297
FOOD_POLY_ERROR(-1)	0.761037	0.255886	2.974132	0.0081
FITTED^2	0.000907	0.000738	1.229001	0.2349
R-squared	0.559751	Mean dependent var	27.04348	
Adjusted R-squared	0.461918	S.D. dependent var	240.9550	
S.E. of regression	176.7503	Akaike info criterion	13.37701	
Sum squared resid	562332.0	Schwarz criterion	13.62386	
Log likelihood	-148.8357	Hannan-Quinn criter.	13.43909	
Durbin-Watson stat	1.953533			

4. Test for Normality



Series: Residuals
Sample 1982 2004
Observations 23

Mean	18.36310
Median	25.86322
Maximum	319.5138
Minimum	-458.7661
Std. Dev.	165.3871
Skewness	-0.759770
Kurtosis	4.369128
Jarque-Bera	4.009198
Probability	0.134714

5. Test for Autocorrelation

Date: 05/17/11 Time: 15:42
Sample: 1982 2004
Included observations: 23

<table>
<tr><th>Autocorrelation</th><th>Partial Correlation</th><th></th><th>AC</th><th>PAC</th><th>Q-Stat</th><th>Prob</th></tr>
<tr><td>. *| . |</td><td>. *| . |</td><td>1</td><td>-0.120</td><td>-0.120</td><td>0.3755</td><td>0.540</td></tr>
<tr><td>. *| . |</td><td>. *| . |</td><td>2</td><td>-0.147</td><td>-0.164</td><td>0.9684</td><td>0.616</td></tr>
<tr><td>. |* . |</td><td>. | . |</td><td>3</td><td>0.076</td><td>0.037</td><td>1.1345</td><td>0.769</td></tr>
<tr><td>. *| . |</td><td>. *| . |</td><td>4</td><td>-0.074</td><td>-0.086</td><td>1.2983</td><td>0.862</td></tr>
<tr><td>. *| . |</td><td>. *| . |</td><td>5</td><td>-0.160</td><td>-0.172</td><td>2.1208</td><td>0.832</td></tr>
<tr><td>. *| . |</td><td>.**| . |</td><td>6</td><td>-0.125</td><td>-0.213</td><td>2.6494</td><td>0.851</td></tr>
</table>

. |* . |	. | . |	7	0.123	0.028	3.1888	0.867
. *| . |	.**| . |	8	-0.172	-0.223	4.3213	0.827
. | . |	. *| . |	9	-0.047	-0.126	4.4111	0.882
. | . |	.**| . |	10	-0.014	-0.221	4.4204	0.926
. *| . |	.**| . |	11	-0.113	-0.291	5.0370	0.929
. |* . |	. *| . |	12	0.088	-0.155	5.4412	0.942

6. Test for Homescedasticity

Heteroskedasticity Test: White

F-statistic	0.213822	Prob. F(10,12)	0.9898
Obs*R-squared	3.478449	Prob. Chi-Square(10)	0.9678
Scaled explained SS	3.558141	Prob. Chi-Square(10)	0.9651

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 05/17/11 Time: 15:42
Sample: 1982 2004
Included observations: 23

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	47991.67	30286.71	1.584578	0.1390
(D(HUMIDITY_8*HUMIDITY_8*HUMIDITY_8))^2	-8.53E-06	3.00E-05	-0.283863	0.7814
(D(HUMIDITY_8*HUMIDITY_8*HUMIDITY_8))*(D(RAINFALL*RAINFALL))	-4.46E-07	1.16E-05	-0.038448	0.9700
(D(HUMIDITY_8*HUMIDITY_8*HUMIDITY_8))*(D(RAINFALL))	0.002515	0.043758	0.057471	0.9551
(D(HUMIDITY_8*HUMIDITY_8*HUMIDITY_8))*FOOD_POLY_ERROR(-1)	8.47E-05	0.004945	0.017129	0.9866
(D(RAINFALL*RAINFALL))^2	-1.50E-06	2.50E-06	-0.598846	0.5604
(D(RAINFALL*RAINFALL))*(D(RAINFALL))	0.011337	0.019297	0.587518	0.5677
(D(RAINFALL*RAINFALL))*FOOD_POLY_ERROR(-1)	0.000123	0.001372	0.089387	0.9302
(D(RAINFALL))^2	-21.40696	37.15425	-0.576165	0.5752
(D(RAINFALL))*FOOD_POLY_ERROR(-1)	-0.613824	5.520288	-0.111194	0.9133
FOOD_POLY_ERROR(-1)^2	-0.160993	0.488692	-0.329437	0.7475

R-squared	0.151237	Mean dependent var	26500.84
Adjusted R-squared	-0.556066	S.D. dependent var	46915.91
S.E. of regression	58524.01	Akaike info criterion	25.09820

Sum squared resid	4.11E+10	Schwarz criterion	25.64126
Log likelihood	-277.6293	Hannan-Quinn criter.	25.23477
F-statistic	0.213822	Durbin-Watson stat	2.018228
Prob(F-statistic)	0.989771		

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	0.411945	Prob. F(4,18)	0.7977
Obs*R-squared	1.928918	Prob. Chi-Square(4)	0.7488
Scaled explained SS	1.973110	Prob. Chi-Square(4)	0.7407

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 06/24/11 Time: 10:33
Sample: 1982 2004
Included observations: 23

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	25428.41	10493.31	2.423298	0.0261
D(HUMIDITY_8*HUMIDITY_8*HUMIDITY_8)	-0.264662	0.430892	-0.614218	0.5468
D(RAINFALL*RAINFALL)	-0.004536	0.123333	-0.036775	0.9711
D(RAINFALL)	35.72753	480.0241	0.074429	0.9415
FOOD_POLY_ERROR(-1)	-32.04105	61.75763	-0.518819	0.6102

R-squared	0.083866	Mean dependent var	26500.84
Adjusted R-squared	-0.119719	S.D. dependent var	46915.91
S.E. of regression	49644.91	Akaike info criterion	24.65284
Sum squared resid	4.44E+10	Schwarz criterion	24.89969
Log likelihood	-278.5077	Hannan-Quinn criter.	24.71492
F-statistic	0.411945	Durbin-Watson stat	1.941049
Prob(F-statistic)	0.797732		

Heteroskedasticity Test: Harvey

F-statistic	0.909992	Prob. F(4,18)	0.4792
Obs*R-squared	3.868733	Prob. Chi-Square(4)	0.4241
Scaled explained SS	4.399815	Prob. Chi-Square(4)	0.3546

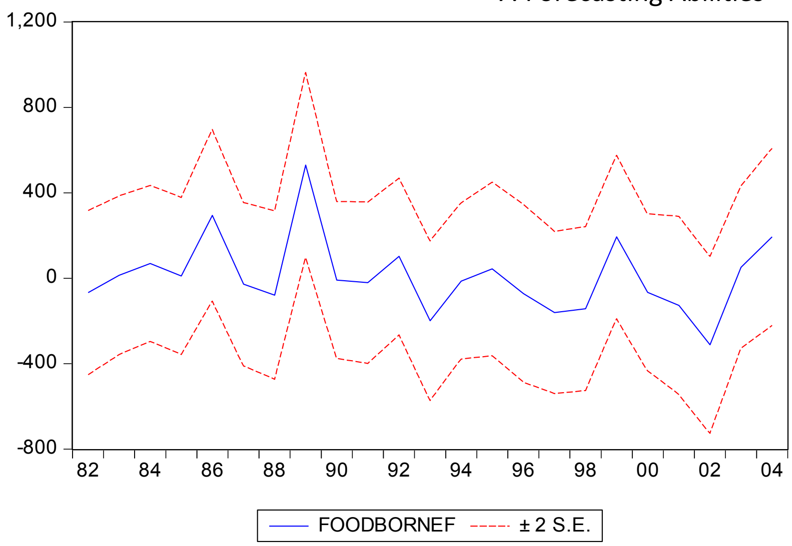
Test Equation:
Dependent Variable: LRESID2
Method: Least Squares
Date: 06/24/11 Time: 10:33
Sample: 1982 2004

Included observations: 23

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	8.664572	0.516227	16.78441	0.0000
D(HUMIDITY_8*HUMIDITY_8*HUMIDITY_8)	3.72E-06	2.12E-05	0.175359	0.8628
D(RAINFALL*RAINFALL)	-7.07E-06	6.07E-06	-1.165273	0.2591
D(RAINFALL)	0.029371	0.023615	1.243720	0.2296
FOOD_POLY_ERROR(-1)	-0.000731	0.003038	-0.240650	0.8125

R-squared	0.168206	Mean dependent var	8.646200
Adjusted R-squared	-0.016637	S.D. dependent var	2.422258
S.E. of regression	2.442324	Akaike info criterion	4.813438
Sum squared resid	107.3691	Schwarz criterion	5.060284
Log likelihood	-50.35453	Hannan-Quinn criter.	4.875519
F-statistic	0.909992	Durbin-Watson stat	2.079899
Prob(F-statistic)	0.479162		

7. Forecasting Abilities



Forecast: FOODBORNEF	
Actual: D(FOODBORNE)	
Forecast sample: 1980 2009	
Adjusted sample: 1982 2004	
Included observations: 23	
Root Mean Squared Error	162.7908
Mean Absolute Error	122.4065
Mean Abs. Percent Error	203.5569
Theil Inequality Coefficient	0.397310
Bias Proportion	0.012724
Variance Proportion	0.151439
Covariance Proportion	0.835837

ANNEX IV- GASTROENTERITIS

A. *THE ORIGINALLY SPECIFIED MODEL*

1. The Model

Dependent Variable: GASTROENTERITIS
Method: Least Squares
Date: 05/16/11 Time: 14:45
Sample (adjusted): 1989 2005
Included observations: 17 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-6327099.	2695558.	-2.347232	0.0369
IMPROVE_WATER_RURAL	2625.183	1256.738	2.088887	0.0587
IMPROVE_WATER_RURAL*IMPROVE_WATER_RURAL*IMPROVE_WATER_RURAL	-0.137512	0.064704	-2.125253	0.0550
HUMIDITY_8	148883.7	64501.34	2.308227	0.0396
HUMIDITY_8*HUMIDITY_8	-892.4333	387.3035	-2.304222	0.0399

R-squared	0.437353	Mean dependent var	17961.12
Adjusted R-squared	0.249804	S.D. dependent var	2624.299
S.E. of regression	2273.006	Akaike info criterion	18.53552
Sum squared resid	61998664	Schwarz criterion	18.78059
Log likelihood	-152.5519	Hannan-Quinn criter.	18.55988
F-statistic	2.331943	Durbin-Watson stat	1.929390
Prob(F-statistic)	0.114979		

2. Test of Misspecification

Ramsey RESET Test
Equation: UNTITLED
Specification: GASTROENTERITIS CIMPROVE_WATER_RURAL IMPROVE_WATER_RURAL*IMPROVE_WATER_RURAL *IMPROVE_WATER_RURAL HUMIDITY_8 HUMIDITY_8 *HUMIDITY_8
Omitted Variables: Squares of fitted values

	Value	df	Probability
t-statistic	0.558256	11	0.5879
F-statistic	0.311650	(1, 11)	0.5879
Likelihood ratio	0.474944	1	0.4907

F-test summary:

	Sum of Sq.	df	Mean Squares
Test SSR	1708139.	1	1708139.

Restricted SSR	61998664	12	5166555.
Unrestricted SSR	60290525	11	5480957.
Unrestricted SSR	60290525	11	5480957.

LR test summary:

	Value	df
Restricted LogL	-152.5519	12
Unrestricted LogL	-152.3145	11

Unrestricted Test Equation:
Dependent Variable: GASTROENTERITIS
Method: Least Squares
Date: 05/16/11 Time: 15:11
Sample: 1989 2005
Included observations: 17

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	18514889	44585827	0.415264	0.6859
IMPROVE_WATER_RURAL	-8464.464	19906.95	-0.425202	0.6789
IMPROVE_WATER_RURAL*IMPROVE_WATER_RURAL*IMPROVE_WATER_RURAL	0.444335	1.044388	0.425450	0.6787
HUMIDITY_8	-433887.1	1046026.	-0.414796	0.6863
HUMIDITY_8*HUMIDITY_8	2600.692	6269.916	0.414789	0.6863
FITTED^2	0.000113	0.000202	0.558256	0.5879

R-squared	0.452855	Mean dependent var	17961.12
Adjusted R-squared	0.204153	S.D. dependent var	2624.299
S.E. of regression	2341.144	Akaike info criterion	18.62523
Sum squared resid	60290525	Schwarz criterion	18.91931
Log likelihood	-152.3145	Hannan-Quinn criter.	18.65446
F-statistic	1.820871	Durbin-Watson stat	1.833478
Prob(F-statistic)	0.189232		

3. Test of Autocorrelation

Date: 05/16/11 Time: 15:12
Sample: 1989 2005
Included observations: 17

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
. | . |	. | . |	1	-0.039	-0.039	0.0310	0.860
. | . |	. | . |	2	-0.061	-0.063	0.1124	0.945
. |* . |	. |* . |	3	0.108	0.104	0.3837	0.944
. *| . |	. *| . |	4	-0.176	-0.175	1.1531	0.886
. | . |	. | . |	5	-0.011	-0.008	1.1566	0.949
. |* . |	. | . |	6	0.078	0.047	1.3363	0.970

. | . |	. | . |	7	0.008	0.047	1.3384	0.987
. **| . |	. **| . |	8	-0.241	-0.275	3.4313	0.904
. |* . |	. | . |	9	0.078	0.067	3.6755	0.931
. **| . |	. **| . |	10	-0.259	-0.309	6.7773	0.746
. *| . |	. *| . |	11	-0.136	-0.072	7.7773	0.733
. |** . |	. |* . |	12	0.247	0.105	11.733	0.467

4. Test of Autocorrelation

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.064236	Prob. F(2,10)	0.9382
Obs*R-squared	0.215634	Prob. Chi-Square(2)	0.8978

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Date: 05/16/11 Time: 15:12
Sample: 1989 2005
Included observations: 17
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-169987.9	3003531.	-0.056596	0.9560
IMPROVE_WATER_RURAL	213.1119	1555.147	0.137037	0.8937
IMPROVE_WATER_RURAL*IMPROVE_WATER_RURAL*IMPROVE_WATER_RURAL	-0.011756	0.081044	-0.145055	0.8875
HUMIDITY_8	3798.861	71866.95	0.052860	0.9589
HUMIDITY_8*HUMIDITY_8	-22.65370	431.6062	-0.052487	0.9592
RESID(-1)	-0.082415	0.368246	-0.223803	0.8274
RESID(-2)	-0.153797	0.466691	-0.329549	0.7485

R-squared	0.012684	Mean dependent var	-1.70E-09
Adjusted R-squared	-0.579705	S.D. dependent var	1968.481
S.E. of regression	2474.111	Akaike info criterion	18.75805
Sum squared resid	61212252	Schwarz criterion	19.10114
Log likelihood	-152.4434	Hannan-Quinn criter.	18.79215
F-statistic	0.021412	Durbin-Watson stat	1.859971
Prob(F-statistic)	0.999931		

5. Test for Homoscedasticity

Heteroskedasticity Test: White

F-statistic	1.822147	Prob. F(8,8)	0.2071
Obs*R-squared	10.97622	Prob. Chi-Square(8)	0.2031
Scaled explained SS	1.976876	Prob. Chi-Square(8)	0.9817

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 05/16/11 Time: 15:12
Sample: 1989 2005
Included observations: 17
Collinear test regressors dropped from specification

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1.31E+11	1.18E+11	-1.109829	0.2993
IMPROVE_WATER_RURAL	4.99E+09	4.40E+09	1.133678	0.2898
IMPROVE_WATER_RURAL^2	-58808982	49758389	-1.181891	0.2712
IMPROVE_WATER_RURAL*(IMPROVE_WATER_RURAL*IMPROVE_WATER_RURAL*IMPROVE_WATER_RURAL)	2874.770	2245.530	1.280219	0.2363
IMPROVE_WATER_RURAL*HUMIDITY_8	3853517.	4047543.	0.952063	0.3689
IMPROVE_WATER_RURAL*(HUMIDITY_8*HUMIDITY_8)	-48339.06	89625.96	-0.539342	0.6043
(IMPROVE_WATER_RURAL*IMPROVE_WATER_RURAL*IMPROVE_WATER_RURAL)^2	-0.088117	0.069450	-1.268778	0.2402
(IMPROVE_WATER_RURAL*IMPROVE_WATER_RURAL*IMPROVE_WATER_RURAL)*HUMIDITY_8	169.7254	492.9230	0.344324	0.7395
HUMIDITY_8*(HUMIDITY_8*HUMIDITY_8)	12198.01	30266.01	0.403027	0.6975

R-squared	0.645660	Mean dependent var	3646980.
Adjusted R-squared	0.291320	S.D. dependent var	3196273.
S.E. of regression	2690724.	Akaike info criterion	32.75357
Sum squared resid	5.79E+13	Schwarz criterion	33.19468
Log likelihood	-269.4053	Hannan-Quinn criter.	32.79742
F-statistic	1.822147	Durbin-Watson stat	1.979474
Prob(F-statistic)	0.207061		

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	1.650054	Prob. F(4,12)	0.2256
Obs*R-squared	6.032386	Prob. Chi-Square(4)	0.1967
Scaled explained SS	1.086465	Prob. Chi-Square(4)	0.8964

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 06/24/11 Time: 10:36
Sample: 1989 2005

Included observations: 17

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-6.82E+09	3.52E+09	-1.939143	0.0764
IMPROVE_WATER_RURAL	1207535.	1639038.	0.736734	0.4754
IMPROVE_WATER_RURAL*IMPROVE_WATER_RURAL*IMPROVE_WATER_RURAL	-51.86321	84.38703	-0.614587	0.5503
HUMIDITY_8	1.62E+08	84122677	1.923089	0.0785
HUMIDITY_8*HUMIDITY_8	-969084.4	505121.4	-1.918518	0.0791

R-squared	0.354846	Mean dependent var	3646980.
Adjusted R-squared	0.139795	S.D. dependent var	3196273.
S.E. of regression	2964455.	Akaike info criterion	32.88221
Sum squared resid	1.05E+14	Schwarz criterion	33.12728
Log likelihood	-274.4988	Hannan-Quinn criter.	32.90657
F-statistic	1.650054	Durbin-Watson stat	1.575494
Prob(F-statistic)	0.225629		

Heteroskedasticity Test: Harvey

F-statistic	1.639228	Prob. F(4,12)	0.2281
Obs*R-squared	6.006792	Prob. Chi-Square(4)	0.1986
Scaled explained SS	3.272279	Prob. Chi-Square(4)	0.5133

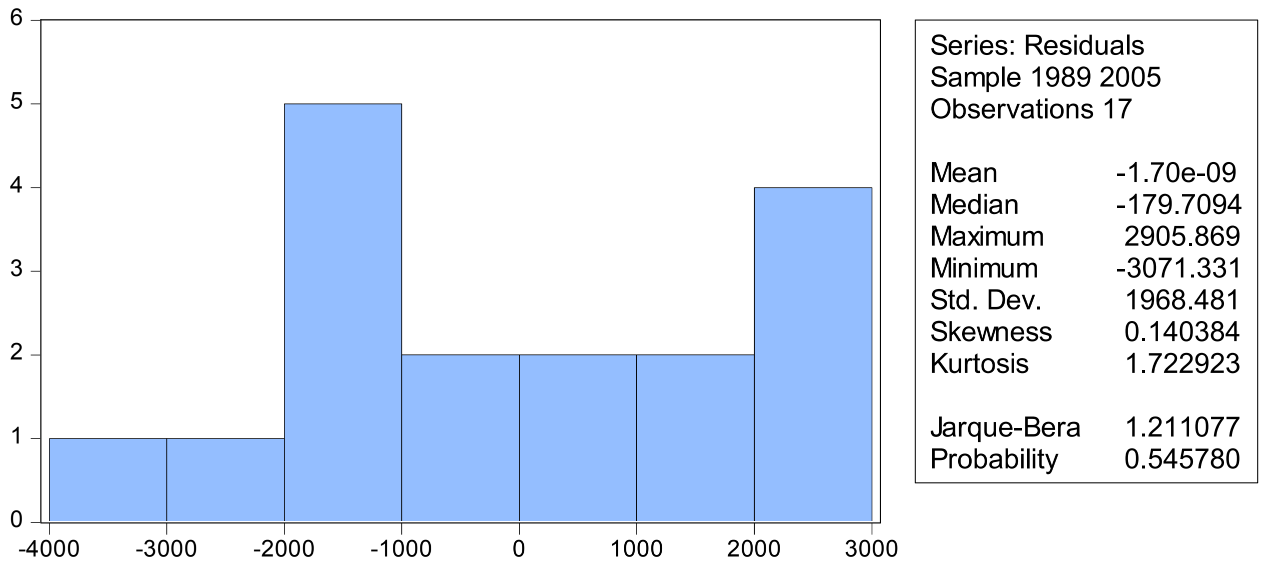
Test Equation:
Dependent Variable: LRESID2
Method: Least Squares
Date: 06/24/11 Time: 10:37
Sample: 1989 2005
Included observations: 17

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1696.436	1861.052	-0.911547	0.3800
IMPROVE_WATER_RURAL	1.467893	0.867670	1.691764	0.1165
IMPROVE_WATER_RURAL*IMPROVE_WATER_RURAL*IMPROVE_WATER_RURAL	-6.95E-05	4.47E-05	-1.554817	0.1460
HUMIDITY_8	38.96350	44.53265	0.874942	0.3988
HUMIDITY_8*HUMIDITY_8	-0.232878	0.267400	-0.870898	0.4009

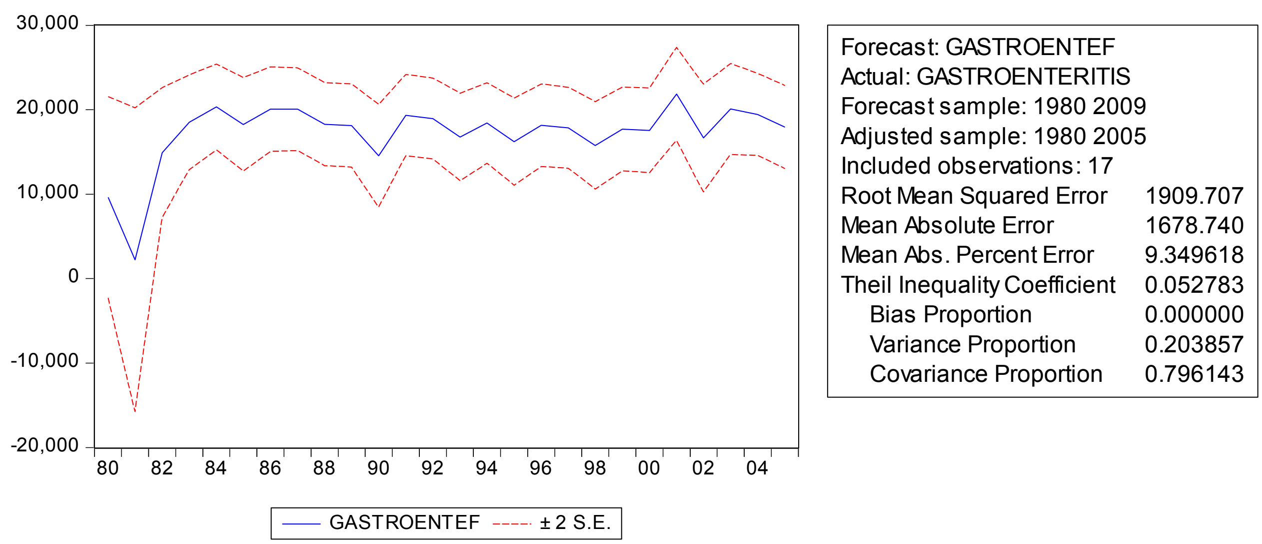
R-squared	0.353341	Mean dependent var	14.36535
Adjusted R-squared	0.137788	S.D. dependent var	1.690064
S.E. of regression	1.569316	Akaike info criterion	3.979085
Sum squared resid	29.55303	Schwarz criterion	4.224148
Log likelihood	-28.82222	Hannan-Quinn criter.	4.003445
F-statistic	1.639228	Durbin-Watson stat	1.767801

Prob(F-statistic) 0.228147

6. Test of Normality



7. Forecasting Abilities



8. *COMMENTS*

Multicollinearity is low among the independent variables. Normality is accepted at 1% and no serial correlation at 5% and 1% significance.

B. *TESTING RESIDUALS FOR COINTEGRATION*

1. ACF Test

Date: 05/16/11 Time: 15:13
Sample: 1980 2009
Included observations: 17

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
. | . |	. | . |	1	-0.039	-0.039	0.0310	0.860
. | . |	. | . |	2	-0.061	-0.063	0.1124	0.945
. |* . |	. |* . |	3	0.108	0.104	0.3837	0.944
. *| . |	. *| . |	4	-0.176	-0.175	1.1531	0.886
. | . |	. | . |	5	-0.011	-0.008	1.1566	0.949
. |* . |	. | . |	6	0.078	0.047	1.3363	0.970
. | . |	. | . |	7	0.008	0.047	1.3384	0.987
. **| . |	. **| . |	8	-0.241	-0.275	3.4313	0.904
. |* . |	. | . |	9	0.078	0.067	3.6755	0.931
. **| . |	. **| . |	10	-0.259	-0.309	6.7773	0.746
. *| . |	. *| . |	11	-0.136	-0.072	7.7773	0.733
. |** . |	. |* . |	12	0.247	0.105	11.733	0.467

2. Augmented dickey Fuller Test for Unit roots

Null Hypothesis: GASTRO_POLY_ERROR has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=3)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.659126	0.0165
Test critical values:	1% level	-3.920350	
	5% level	-3.065585	
	10% level	-2.673459	

*MacKinnon (1996) one-sided p-values.
Warning: Probabilities and critical values calculated for 20 observations and may not be accurate for a sample size of 16

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(GASTRO_POLY_ERROR)
Method: Least Squares
Date: 05/16/11 Time: 15:14
Sample (adjusted): 1990 2005

Included observations: 16 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GASTRO_POLY_ERROR				
(-1)	-1.041895	0.284739	-3.659126	0.0026
C	60.45258	522.7980	0.115633	0.9096
R-squared	0.488850	Mean dependent var	245.3330	
Adjusted R-squared	0.452339	S.D. dependent var	2812.550	
S.E. of regression	2081.403	Akaike info criterion	18.23594	
Sum squared resid	60651334	Schwarz criterion	18.33251	
Log likelihood	-143.8875	Hannan-Quinn criter.	18.24089	
F-statistic	13.38921	Durbin-Watson stat	1.813402	
Prob(F-statistic)	0.002578			

3. Residual Equation

Dependent Variable: D(GASTRO_POLY_ERROR)
Method: Least Squares
Date: 05/16/11 Time: 15:14
Sample (adjusted): 1990 2005
Included observations: 16 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GASTRO_POLY_ERROR				
(-1)	-1.045077	0.273927	-3.815169	0.0017
R-squared	0.488362	Mean dependent var	245.3330	
Adjusted R-squared	0.488362	S.D. dependent var	2812.550	
S.E. of regression	2011.786	Akaike info criterion	18.11190	
Sum squared resid	60709260	Schwarz criterion	18.16018	
Log likelihood	-143.8952	Hannan-Quinn criter.	18.11437	
Durbin-Watson stat	1.805868			

C. *THE ERROR CORECTION MODEL*

1. The Model

Dependent Variable: D(GASTROENTERITIS)
Method: Least Squares
Date: 05/16/11 Time: 15:16
Sample (adjusted): 1990 2005
Included observations: 16 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.

C	59.79607	582.9212	0.102580	0.9203
D(IMPROVE_WATER_RURAL)	2016.150	764.8485	2.636012	0.0249
D(IMPROVE_WATER_RURAL*IMPROVE_WATER_RURAL*IMPROVE_WATER_RURAL)	-0.104054	0.040406	-2.575234	0.0276
D(HUMIDITY_8)	111327.7	43710.75	2.546919	0.0290
D(HUMIDITY_8*HUMIDITY_8)	-667.3731	262.1089	-2.546167	0.0291
GASTRO_POLY_ERROR(-1)	-1.008591	0.328554	-3.069785	0.0118

R-squared	0.688290	Mean dependent var	233.5625
Adjusted R-squared	0.532435	S.D. dependent var	3380.271
S.E. of regression	2311.386	Akaike info criterion	18.60908
Sum squared resid	53425042	Schwarz criterion	18.89880
Log likelihood	-142.8726	Hannan-Quinn criter.	18.62391
F-statistic	4.416224	Durbin-Watson stat	1.737709
Prob(F-statistic)	0.022014		

2. Test for Autocorrelation

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.789783	Prob. F(2,8)	0.4864
Obs*R-squared	2.638225	Prob. Chi-Square(2)	0.2674

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Date: 05/16/11 Time: 15:18
Sample: 1990 2005
Included observations: 16
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-74.72335	605.3575	-0.123437	0.9048
D(IMPROVE_WATER_RURAL)	1025.270	1155.378	0.887390	0.4008
D(IMPROVE_WATER_RURAL*IMPROVE_WATER_RURAL*IMPROVE_WATER_RURAL)	-0.051148	0.059727	-0.856370	0.4167
D(HUMIDITY_8)	48240.77	60025.20	0.803675	0.4448
D(HUMIDITY_8*HUMIDITY_8)	-290.0100	360.4520	-0.804573	0.4443
GASTRO_POLY_ERROR(-1)	-1.636211	1.396629	-1.171543	0.2751
RESID(-1)	1.850768	1.527971	1.211259	0.2604
RESID(-2)	-0.228685	0.437731	-0.522432	0.6155

R-squared	0.164889	Mean dependent var	-1.02E-12
Adjusted R-squared	-0.565833	S.D. dependent var	1887.239
S.E. of regression	2361.563	Akaike info criterion	18.67889

Sum squared resid	44615836	Schwarz criterion	19.06518
Log likelihood	-141.4311	Hannan-Quinn criter.	18.69867
F-statistic	0.225652	Durbin-Watson stat	1.973026
Prob(F-statistic)	0.967554		

3. Misspecification Test

Ramsey RESET Test
Equation: UNTITLED
Specification: D(GASTROENTERITIS) CD(IMPROVE_WATER_RUR AL)D(IMPROVE_WATER_RURAL*IMPROVE_WATER_RURAL *IMPROVE_WATER_RURAL) D(HUMIDITY_8) D(HUMIDITY_8 *HUMIDITY_8) GASTRO_POLY_ERROR(-1)
Omitted Variables: Squares of fitted values

	Value	df	Probability
t-statistic	1.526375	9	0.1613
F-statistic	2.329820	(1, 9)	0.1613
Likelihood ratio	3.683417	1	0.0550

F-test summary:

	Sum of Sq.	df	Mean Squares
Test SSR	10986116	1	10986116
Restricted SSR	53425042	10	5342504.
Unrestricted SSR	42438925	9	4715436.
Unrestricted SSR	42438925	9	4715436.

LR test summary:

	Value	df
Restricted LogL	-142.8726	10
Unrestricted LogL	-141.0309	9

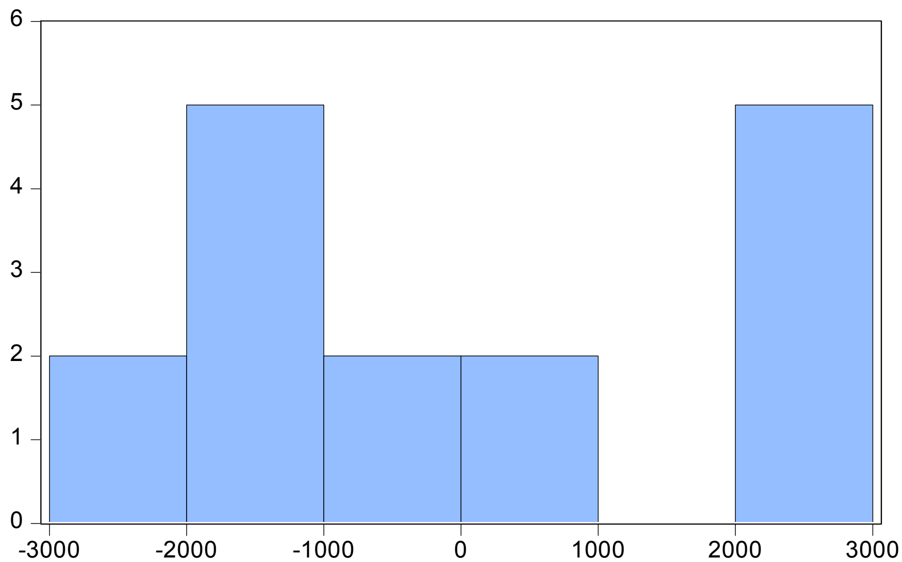
Unrestricted Test Equation:
Dependent Variable: D(GASTROENTERITIS)
Method: Least Squares
Date: 05/16/11 Time: 15:17
Sample: 1990 2005
Included observations: 16

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1258.992	1022.942	-1.230756	0.2496
D(IMPROVE_WATER_RURAL)	2446.969	772.0075	3.169618	0.0114
D(IMPROVE_WATER_RURAL*IMPROVE_WATER_RURAL*IMPROVE_WATER_RURAL)	-0.122484	0.039835	-3.074831	0.0133
D(HUMIDITY_8)	126145.7	42197.36	2.989422	0.0152
D(HUMIDITY_8*HUMIDITY_8)	-756.0712	253.0103	-2.988302	0.0152

GASTRO_POLY_ERROR(-1)	-1.335275	0.375613	-3.554925	0.0062
FITTED^2	0.000168	0.000110	1.526375	0.1613

R-squared	0.752389	Mean dependent var	233.5625
Adjusted R-squared	0.587315	S.D. dependent var	3380.271
S.E. of regression	2171.506	Akaike info criterion	18.50386
Sum squared resid	42438925	Schwarz criterion	18.84187
Log likelihood	-141.0309	Hannan-Quinn criter.	18.52117
F-statistic	4.557888	Durbin-Watson stat	1.648986
Prob(F-statistic)	0.021307		

4. Test for Normality



Series: Residuals
Sample 1990 2005
Observations 16

Mean	-1.02e-12
Median	-489.9541
Maximum	2724.278
Minimum	-2716.669
Std. Dev.	1887.239
Skewness	0.237637
Kurtosis	1.580394
Jarque-Bera	1.494111
Probability	0.473760

5. Test for Autocorrelation

Date: 05/16/11 Time: 15:18
Sample: 1990 2005
Included observations: 16

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
. |* . |	. |* . |	1	0.079	0.079	0.1201	0.729
. *| . |	. *| . |	2	-0.081	-0.088	0.2550	0.880
. | . |	. | . |	3	0.011	0.025	0.2577	0.968
. | . |	. | . |	4	-0.036	-0.047	0.2892	0.990
. *| . |	. *| . |	5	-0.121	-0.112	0.6699	0.985
. | . |	. | . |	6	0.010	0.023	0.6725	0.995
. *| . |	. *| . |	7	-0.075	-0.099	0.8517	0.997
. *| . |	. *| . |	8	-0.137	-0.122	1.5298	0.992
. | . |	. | . |	9	0.045	0.044	1.6138	0.996
. **| . |	. **| . |	10	-0.275	-0.336	5.2390	0.875
. *| . |	. | . |	11	-0.115	-0.065	5.9945	0.874
. |* . |	. |* . |	12	0.179	0.119	8.3130	0.760

6. Test for Homescedasticity

Heteroskedasticity Test: White

F-statistic	0.767336	Prob. F(5,10)	0.5939
Obs*R-squared	4.436532	Prob. Chi-Square(5)	0.4884
Scaled explained SS	0.502917	Prob. Chi-Square(5)	0.9920

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 05/16/11 Time: 15:18
Sample: 1990 2005
Included observations: 16

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2876469.	1965278.	1.463644	0.1740
(D(IMPROVE_WATER_RURAL))^2	-61523.48	40332.12	-1.525421	0.1581
(D(IMPROVE_WATER_RURAL*IMPROVE_WATER_RURAL*IMPROVE_WATER_RURAL))^2	0.000167	0.000107	1.563187	0.1491
(D(HUMIDITY_8))^2	-17845208	16070513	-1.110432	0.2928
(D(HUMIDITY_8*HUMIDITY_8))^2	652.8940	580.2217	1.125249	0.2868
GASTRO_POLY_ERROR(-1)^2	-0.003200	0.294877	-0.010853	0.9916

R-squared	0.277283	Mean dependent var	3339065.
Adjusted R-squared	-0.084075	S.D. dependent var	2627246.
S.E. of regression	2735460.	Akaike info criterion	32.76149
Sum squared resid	7.48E+13	Schwarz criterion	33.05121
Log likelihood	-256.0920	Hannan-Quinn criter.	32.77633
F-statistic	0.767336	Durbin-Watson stat	2.507076
Prob(F-statistic)	0.593882		

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	0.557920	Prob. F(5,10)	0.7303
Obs*R-squared	3.489837	Prob. Chi-Square(5)	0.6249
Scaled explained SS	0.395602	Prob. Chi-Square(5)	0.9954

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 06/24/11 Time: 10:39
Sample: 1990 2005

Included observations: 16

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3217966.	717555.1	4.484625	0.0012
D(IMPROVE_WATER_RURAL)	5521.825	941501.1	0.005865	0.9954
D(IMPROVE_WATER_RURAL*IMPROVE_WATER_RURAL*IMPROVE_WATER_RURAL)	0.575390	49.73795	0.011568	0.9910
D(HUMIDITY_8)	71998527	53806360	1.338104	0.2105
D(HUMIDITY_8*HUMIDITY_8)	-432933.8	322646.7	-1.341820	0.2093
GASTRO_POLY_ERROR(-1)	-464.6815	404.4384	-1.148955	0.2773

R-squared	0.218115	Mean dependent var	3339065.
Adjusted R-squared	-0.172828	S.D. dependent var	2627246.
S.E. of regression	2845233.	Akaike info criterion	32.84018
Sum squared resid	8.10E+13	Schwarz criterion	33.12991
Log likelihood	-256.7215	Hannan-Quinn criter.	32.85502
F-statistic	0.557920	Durbin-Watson stat	1.980332
Prob(F-statistic)	0.730298		

Heteroskedasticity Test: Harvey

F-statistic	0.870047	Prob. F(5,10)	0.5337
Obs*R-squared	4.850357	Prob. Chi-Square(5)	0.4344
Scaled explained SS	3.008991	Prob. Chi-Square(5)	0.6986

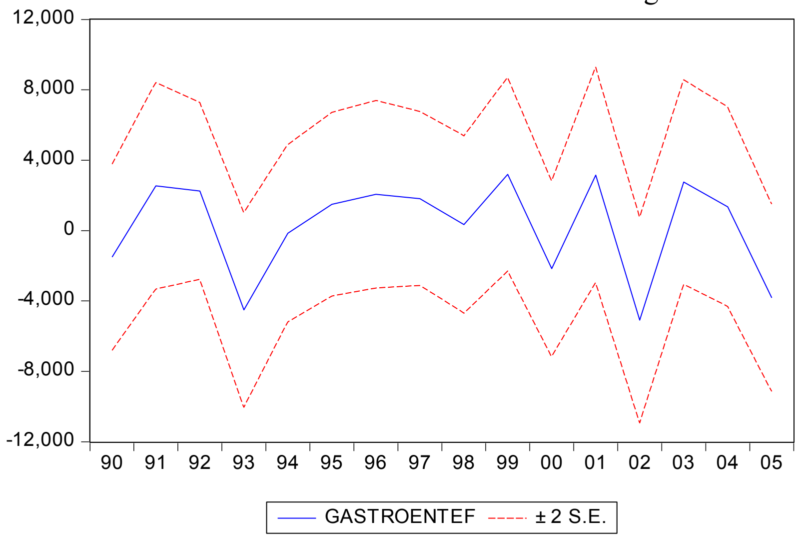
Test Equation:
Dependent Variable: LRESID2
Method: Least Squares
Date: 06/24/11 Time: 10:39
Sample: 1990 2005
Included observations: 16

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	14.20114	0.465936	30.47873	0.0000
D(IMPROVE_WATER_RURAL)	0.326375	0.611353	0.533857	0.6051
D(IMPROVE_WATER_RURAL*IMPROVE_WATER_RURAL*IMPROVE_WATER_RURAL)	-1.66E-05	3.23E-05	-0.514371	0.6182
D(HUMIDITY_8)	66.18708	34.93854	1.894386	0.0874
D(HUMIDITY_8*HUMIDITY_8)	-0.396097	0.209507	-1.890618	0.0880
GASTRO_POLY_ERROR(-1)	-0.000250	0.000263	-0.952038	0.3635

R-squared	0.303147	Mean dependent var	14.28532
Adjusted R-squared	-0.045279	S.D. dependent var	1.807061
S.E. of regression	1.847519	Akaike info criterion	4.345561
Sum squared resid	34.13328	Schwarz criterion	4.635282
Log likelihood	-28.76449	Hannan-Quinn criter.	4.360397

F-statistic	0.870047	Durbin-Watson stat	1.164878
Prob(F-statistic)	0.533729		

7. Forecasting Abilities



Forecast: GASTROENTEF	
Actual: D(GASTROENTERITIS)	
Forecast sample: 1980 2009	
Adjusted sample: 1990 2005	
Included observations: 16	
Root Mean Squared Error	1827.311
Mean Absolute Error	1626.162
Mean Abs. Percent Error	168.0886
Theil Inequality Coefficient	0.304216
Bias Proportion	0.000000
Variance Proportion	0.093116
Covariance Proportion	0.906884

ANNEX V- BAU PROCESS

BAU Process

Following the models that were specified for each disease, a new EVIEWS database was made for each disease except, in these cases, the time period inputted into the databases was 1980 to 2050. Though the data used for the actual diseases were kept constant and only fit the years for which data was available, the independent variables were extended to 2050. The following is an outline of each variable and the process by which they were extrapolated to 2050.

Variable	Extra Notes	Process
Population	A High Variant Category was chosen to be comparable to the assumed rising population in the A2 and B2 scenarios.	The High Variant Category of the World Population Prospects :The 2008 Revision
Temperature (Mean of Maxima)	The range of change as projected of .7 to 2.6˚C by 2060 (GOVTT 2008,2) with a change by .55˚C by 2050.	The variables were trended against time and forecasted to the future using the equation found.
Rainfall	Note that it was assumed a downward trend as expected in GOVTT(2009).	
Humidity at 8 a.m		
Improved water source, rural (% of rural population with access)		
Improved sanitation facilities, urban (% of urban population with access)		
Forest area(% of land area in Trinidad and Tobago)		
Improved sanitation facilities, urban (% of urban population with access)		

After these steps, such data is entered into EVIEWS 6; the models were run as specified for this project highlighting an extension to the year 2050. The forecasted values were then generated and the BAU scenarios for all diseases were discovered using the derived forecast series.

ANNEX VI – A LIST OF DESCRIPTIVE STATISTICS

DENGUE

Descriptive Statistics	Dengue	Improved water source, rural (% of rural population with access)	Improved sanitation facilities, total (% of urban population with access)	Population Size	Temperature-Mean of Maxima	Relative Humidity	Rain_Dummy
Mean	1128.103	87.33210	93.60836	1240843.	31.64138	83.82471	0.827586
Median	504.0000	88.00000	92.80000	1256204.	31.70000	84.00000	1.000000
Maximum	6246.000	93.58823	100.0000	1333388.	32.50000	88.00000	1.000000
Minimum	0.000000	67.00000	92.00000	1081764.	30.60000	81.00000	0.000000
Std. Dev.	1478.813	5.299533	2.397154	71806.54	0.519283	1.516368	0.384426
Skewness	1.722405	-2.215442	2.051211	-0.635698	-0.215788	0.796623	-1.734455
Kurtosis	5.980726	8.897769	5.731892	2.389939	2.131236	3.776259	4.008333
Jarque-Bera	25.07465	65.75316	29.35416	2.402917	1.137052	3.795390	15.76883
Probability	0.000004	0.000000	0.000000	0.300755	0.566360	0.149914	0.000377
Sum	32715.00	2532.631	2714.642	35984453	917.6000	2430.917	24.00000
Sum Sq. Dev.	61232841	786.3814	160.8977	1.44E+11	7.550345	64.38239	4.137931
Observations	29	29	29	29	29	29	29

LEPTOSPIROSIS

Descriptive Statistics	Leptospirosis	Rainfall	Forest Area	Improved sanitation facilities, total (% of urban population with access)	Temperature-Mean of Maxima
Mean	92.37931	2017.214	45.27726	93.60836	31.64138
Median	95.00000	2018.500	45.26316	92.80000	31.70000
Maximum	193.0000	2358.500	46.87017	100.0000	32.50000
Minimum	11.00000	1478.800	43.79252	92.00000	30.60000
Std. Dev.	55.76316	236.7597	0.985868	2.397154	0.519283
Skewness	0.251565	-0.448015	0.063147	2.051211	-0.215788
Kurtosis	1.885230	2.420246	1.634884	5.731892	2.131236
Jarque-Bera	1.807489	1.376275	2.271053	29.35416	1.137052
Probability	0.405050	0.502511	0.321253	0.000000	0.566360
Sum	2679.000	58499.20	1313.040	2714.642	917.6000
Sum Sq. Dev.	87066.83	1569544.	27.21419	160.8977	7.550345
Observations	29	29	29	29	29

FOODBORNE DISEASES

Descriptive Statistics	Food Borne Diseases	Relative Humidity	Rainfall
Mean	671.9583	83.82471	2017.214
Median	639.0000	84.00000	2018.500
Maximum	1308.000	88.00000	2358.500
Minimum	333.0000	81.00000	1478.800
Std. Dev.	217.5359	1.516368	236.7597
Skewness	0.998181	0.796623	-0.448015
Kurtosis	4.292925	3.776259	2.420246
Jarque-Bera	5.657121	3.795390	1.376275
Probability	0.059098	0.149914	0.502511
Sum	16127.00	2430.917	58499.20
Sum Sq. Dev.	1088403.	64.38239	1569544.
Observations	24	29	29

GASTROENTERITIS

Descriptive Statistics	**Gastroenteritis**	**Relative Humidity**	**Improved water source, rural (% of rural population with access)**
Mean	20894.80	83.82471	87.33210
Median	17793.50	84.00000	88.00000
Maximum	57942.00	88.00000	93.58823
Minimum	14109.00	81.00000	67.00000
Std. Dev.	9637.626	1.516368	5.299533
Skewness	3.086170	0.796623	-2.215442
Kurtosis	12.25482	3.776259	8.897769
Jarque-Bera	103.1246	3.795390	65.75316
Probability	0.000000	0.149914	0.000000
Sum	417896.0	2430.917	2532.631
Sum Sq. Dev.	1.76E+09	64.38239	786.3814
Observations	20	29	29

ANNEX VII – THE COEFFICIENT DESCRIPTIONS – FOR POLYNOMIAL TERMS

The coefficient descriptions, -FOR POLYNOMIAL TERMS
Using differentiation the change in disease incidence was calculated.
The change in y variables, given the particular variable-TEMPERATURE

Year	Variable-Temperature	Change in Dengue Cases
1980	31.2	
1981	31.2	56420.53
1982	30.9	56526.02
1983	31.3	56377.69
1984	30.8	56553.18
1985	30.6	56596.51
1986	30.8	56553.88
1987	32	55961.52
1988	31.9	56032.21
1989	31.3	56376.69
1990	31.7	56164.16
1991	31.3	56376.89
1992	31.3	56377.29
1993	31.9	56032.91
1994	31.5	56278.29
1995	32.3	55719.83
1996	31.7	56163.16
1997	31.4	56329.72
1998	32.3	55719.93
1999	32.4	55630.17
2000	31.8	56099.51
2001	32	55960.52
2002	31.8	56099.91
2003	32.3	55719.53
2004	32.1	55883.93
2005	32.5	55537.21
2006	31.8	56099.41
2007	31.4	56329.62
2008	32.1	55884.83

DENGUE –HUMIDITY

Year	Humidity	Change in Dengue Cases
1980	87	
1981	88	299.6928
1982	86	-572.45
1983	85	-279.608
1984	84	-273.067
1985	85	279.6075
1986	84	-273.067
1987	83	-266.604
1988	82	-260.219
1989	82	0
1990	81	-253.911
1991	83	533.2086
1992	84	273.0672
1993	85	279.6075
1994	84	-273.067
1995	85	279.6075
1996	83	-533.209
1997	84	273.0672
1998	85	279.6075
1999	83	-533.209
2000	83	0
2001	83	0
2002	84	273.0672
2003	82	-520.438
2004	84	546.1344
2005	83	-266.604

FOOD-BORNE DISEASES
HUMIDITY

Year	Humidity	Change in Food-Borne Illnesses Cases
1980	87	
1981	88	69.696
1982	86	-133.128
1983	85	-65.025
1984	84	-63.504
1985	85	65.025
1986	84	-63.504
1987	83	-62.001

1988	82	-60.516
1989	82	0
1990	81	-59.049
1991	83	124.002
1992	84	63.504
1993	85	65.025
1994	84	-63.504
1995	85	65.025
1996	83	-124.002
1997	84	63.504
1998	85	65.025
1999	83	-124.002
2000	83	0
2001	83	0
2002	84	63.504
2003	82	-121.032
2004	84	127.008
2005	83	-62.001

RAINFALL

Year	Rainfall	Change in Food-Borne Illnesses Cases
1980	2024.7	
1981	2181	8.25264
1982	2126	-6.534
1983	2241.4	-2.27107
1984	2254.1	-0.44348
1985	2358.5	-16.7249
1986	1999.2	-97.3559
1987	1659.6	-230.412
1988	2302.2	-59.5305
1989	1743.2	-323.191
1990	2024.5	67.68078
1991	1985.9	-11.0751
1992	1812.4	-85.9033
1993	2018.5	51.07158
1994	1886.6	-53.562
1995	1478.8	-365.16
1996	2119.3	81.24102
1997	1927.8	-68.2966
1998	2303.1	-35.1731
1999	2202.3	-2.74579
2000	2335.9	-17.7795

2001	1574.4	-594.518
2002	1967.1	121.5328
2003	1850.9	-52.1645
2004	2235	-4.6092
2005	2281.7	-3.17747
2006	1894.6	-153.477
2007	1970.2	23.11546
2008	1740.3	-133.719

GASTROENTERITIS-Humidity

Year	Humidity	Change in Gastroenteritis Cases
1980	87	
1981	88	-142179
1982	86	321869.3
1983	85	166591.7
1984	84	164806.9
1985	85	-136824
1986	84	164806.9
1987	83	163022.1
1988	82	161237.3
1989	82	14883.7
1990	81	159452.5
1991	83	-281393
1992	84	-135040
1993	85	-136824
1994	84	164806.9
1995	85	-136824
1996	83	311160.5
1997	84	-135040
1998	85	-136824
1999	83	311160.5
2000	83	14883.7
2001	83	14883.7
2002	84	-135040
2003	82	307590.9
2004	84	-284963
2005	83	163022.1

Gastroenteritis
Water Rural

Year	Improved Access to Water-Rural	Change in Gastroenteritis Cases
1980	85.05	
1981	85.34441	2612.114
1982	85.63882	2612.069
1983	85.93323	2612.024
1984	86.22764	2611.979
1985	86.52205	2611.934
1986	86.81646	2611.889
1987	87.11087	2611.844
1988	87.40528	2611.799
1989	87.69969	2611.754
1990	88	2611.438
1991	88.4	2606.793
1992	88.8	2606.71
1993	89.2	2606.626
1994	89.6	2606.543
1995	90	2606.46
1996	90.2	2615.799
1997	90.4	2615.778
1998	90.6	2615.758
1999	90.8	2615.737
2000	91	2615.716
2001	79	3118.14
2002	67	3043.26
2003	77.5	2202.03
2004	88	2144.7
2005	90.5	2507.53
2006	93	2504.28
2007	93.29412	2610.912
2008	93.58823	2610.867

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