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AN ASSESSMENT OF THE ECONOMIC IMPACT OF CLIMATE CHANGE ON THE MACROECONOMY IN THE CARIBBEAN

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EXECUTIVE SUMMARY

Between 2008 and 2011, the United Nations Economic Commission for Latin America and the Caribbean (ECLAC) has worked on a project to assess the economic impact of climate change in the Caribbean. The overall aim is to prepare the Caribbean region to better respond to climate change, while fostering a regional approach to reducing carbon emissions by 2050. This study updates the report on the impact of climate change on the macroeconomy at the regional level and will focus on 9 countries: Aruba, the Bahamas, Barbados, Curacao, the Dominican Republic, Montserrat, Jamaica, Saint Lucia and Trinidad and Tobago.

Studying the macroeconomic impact of climate change on the Caribbean is of critical importance because most states in the Caribbean are particularly dependent on their marine and coastal ecosystems. While climate change is expected to negatively affect the Caribbean, a key question faced by policy makers is "how large are the costs of climate change?" To provide an estimate, the authors put forward a two-step methodology. First, forecasts of real GDP under the aforementioned A2 and B2 climate change scenarios are estimated. Second, we integrate the forecasted values of GDP and the estimated change in global commodity prices provided by Parry and others, into a computable general equilibrium (CGE) so that the potential impact climate change on investment, household consumption, government saving, exports and imports can be evaluated. Specifically, the authors adopt the 1-2-3 CGE model of Devarajan and others (1997) to simulate the expected changes in real output and commodity prices on the macroeconomy.

The coefficients on the world real GDP terms are positive in each specification, indicating that reductions in the global output are associated with in real output in the Caribbean. With respect to the climate change index, this coefficient is positive and significant across each model, excepting the Bahamas. Thus, the expected deteriorating climate conditions should have a direct impact on economic growth for Barbados, Dominican Republic, Guyana, Jamaica, St. Lucia and Trinidad and Tobago. For Bahamas, it appears as though effect on real output only emerges through the indirect impact of climate change on the global economy. This may be reflecting the Bahamas' high dependence on Bahamas on services (particularly tourism and off-shore services), and by extension, its high vulnerability to the global economy. In fact, the coefficient of the global GDP variable is largest for the Bahamas, hinting that global shocks may be the most harmful for this country.

In line with our a-prior expectations, consumption is negatively affected by climate change. Investment is also negatively impacted by climate change. In each country, there is a significant deterioration of the fiscal accounts, with government savings being below the BAU scenario by a minimum of 5 percent of 2009 GDP. With respect to trade, looking first at the A2 scenario, exports are generally lower than that the BAU scenario. The only exception is Barbados. Thus, with the A2 climate outcome, the price impact seems to dominate the income impact. Interestingly, under the B2 scenario, most countries have lower exports relative to the BAU scenario; the only exception is the Dominican Republic. With respect to imports, the 1-2-3 models for all countries suggest that the income effects dominate the price effects, resulting in lower demand for imported goods relative to the BAU scenarios.

Caribbean countries have already taken steps toward developing the institutional, legal and technical aspects of climate change adaptation and risk management. While these actions have shown that policy makers in the Caribbean are sensitive to potential adverse climatic events, there is still a further work that could be done. Specifically, we recommend adaptation policies aimed at strengthening not only vulnerable physical infrastructure but also

diversifying Caribbean economies in order to lessen their dependence on industries that are likely to be severely negatively impacted by climate change.

I. INTRODUCTION AND BACKGROUND

A. INTRODUCTION

As early as the 19th century, both economists and climate experts have been concerned about the impact of climate activity on the welfare of individuals. Within recent years, the research in this area has expanded at a rapid pace as the effects of climate change become more evident. Numerous multilateral and national bodies have been established to not only investigate the phenomenon, but also suggest adaptation and mitigation policies.

Over the last two decades, the CARICOM community has taken several steps aimed at strengthening the institutional, technical and financial capacity to address the issue climate change adaptation. By virtue of size and composition it is projected that these small island states will suffer the greatest from the impacts of climate change, although they account for less the one percent of greenhouse gas emissions. For this reason, adaptation to climate change, rather than mitigation, has been the central issue to policy makers, especially in light of the fact that the Caribbean is already experiencing negative impacts from climatic events. As such, there has been an effort by individual states and CARICOM as a whole to implement measures aimed at reducing the vulnerability of the region to climate change.

Barbados Action Plan

One the earlier initiatives was the Small Island Developing States Programme of Action (SIDS/POA), which came out of the Global Conference on the Sustainable Development of Small Island Developing States held in Bridgetown, Barbados between 25th April and 6th May 1994. At this conference, participants recognized the need to consider small states as special cases. Referred to as the “Barbados Declaration”, the conference adopted the stance that “While Small Island Developing States are among those that contribute least to global climate change and sea level rise, they are among those that would suffer most from the adverse effects of such phenomena and could in some cases become uninhabitable. Therefore, they are among those particularly vulnerable States that need assistance under the United Nations Framework Convention on Climate Change, including adaptation measures and mitigation efforts” (UN, 1994).

The participants agreed that the features of concentrated populations, agricultural land, coastal zones and infrastructure in small island states, makes the potential impact of sea level rise a significant threat to the social and economic structure in small islands. For these reason, conference participants made the vulnerability of SIDS, sea level rise and climate change a major talking point at the conference. Issues such as increased intensity and frequency of storms, damage to coral reefs, fishery production and affectation to subsistence were also addressed at the conference. The issues discussed were of such importance that both the United Nations Millennium Summit (2000) and the General Assembly Twenty Special Session both recognized that the Barbados Plan of Action should be implemented swiftly (UN 2000). Also, there was a call to make sure the characteristics and needs of SIDS are taken into account when developing vulnerability indexes.

Caribbean Planning for Adaptation to Climate Change (CPACC) 1997-2001

Coming out of the Barbados Action Plan, was the CPACC project funded by the Global Environment Facility (GEF) with USD $5.6 million for the period 1997-2001. The aim of the project was to improve the capacity of the Caribbean states to develop adaptation measures to cope with climatic impacts. This was to be done through vulnerability assessments, capacity building and adaptation planning activities. This project was the result of a joint effort between OAS and CARICOM, where a number of national and regional workshops were organized to facilitate stakeholder consultation[1] (see Table 1 for a summary of this project).

Table 1: Main Features of CPACC Project

Regional Projects	Pilot Projects
Design and Implement a sea level/climate monitoring network	Coral reef monitoring for climate change (Barbados, Belize and Jamaica)
Establishment of databases and information systems	Coastal Vulnerability and risk assessment (Barbados, Guyana, and Grenada)
Inventory of coastal resources	Economic Valuation of coastal and marine resources (Dominica, Saint Lucia, and Trinidad & Tobago)
Use and formulation of initial adaptation policies	Formation of economic/regulatory proposals (Antigua & Barbuda and St. Kitts and Nevis)
	National communications (St. Vincent and the Grenadines)
Specific Project Achievements	
Establishment of a sea level and climate monitoring system. A total of 18 monitoring systems were installed in 12 countries.	
Improved access and availability of data – An integrated database for the monitoring of climate change effects was established through the Inventory for Coastal Resources and the institutionalization of coral reef monitoring.	
Increased appreciation of climate change issues at the policy-making level – CPACC enabled more unification among regional parties and better articulation of regional positions for negotiations under the United Nations Framework Convention on Climate Change (UNFCCCC) and the Kyoto Protocol.	
Meeting country needs for expanded vulnerability assessment – Pilot vulnerability studies were carried out in Grenada, Guyana, and Barbados	
Establishment of coral reef monitoring protocols – This resulted in a significant increase in monitoring and early warning capabilities.	
Articulation of national climate change adaptation policies and implementation plans – Such policies and plans were formulated in 11 participating countries.	
Creation of a network for regional harmonization – CPACC developed initial collaborative efforts with a number of existing regional agencies. Partners include PetroTrin of Trinidad and Tobago, as well as key players in the insurance and banking sectors.	

Source: CARICOM Secretariat

Adaptation to Climate Change in the Caribbean (ACCC) 2001-2004.

Following the CPACC project was the ACCC project. Overseen by the World Bank with assistance from the CARICOM countries, the stated aim of this project was to maintain the current policies of the CPACC and to address any issues of climate change adaptation that were not covered by the CPACC. In addition, the project also resulted in the transformation of the Regional Project Implementation Unit (developed under the CPACC) into a regional legal entity[2] (see Table 2).

[1] (CARICOM Secretariat, Caribbean Planning for Adaptation to Climate Change (CPACC) Project, 1997-2001)

[2] (CARICOM Secretariat, Adaptation To Climate Change In the Caribbean (ACCC) Project, 2001-2004).

Table 2: Main Features of ACCC Project

Projects Components
Project design and business plan development for a regional climate change centre;
Public education and outreach;
Integration of climate change into a physical planning process using a risk management approach to adaptation to climate change;
Strengthening of regional technical capacity, in partnership with the Caribbean Institute for Meteorology and Hydrology (CIMH), the University of the West Indies (Scenario Projection and Establishment of Climate Change Master's Programme), and the Caribbean Environmental Health Institute, in order to enhance association between Caribbean and South Pacific small island States;
Integration of adaptation planning in environmental assessments for national and regional development projects;
Implementation strategies for adaptation in the water sector
Formulation of adaptation strategies to protect human health
Adaptation strategies for agriculture and food
Fostering of collaboration/cooperation with non-CARICOM countries
Development and distribution of risk management guidelines for climate change adaptation decision making; Political endorsement (by CARICOM) of the business plan and establishment of the basis of financial self-sustainability for the Caribbean Community Climate Change Centre (CCCCC);
Development of a guide to assist environmental impact assessment (EIA) practitioners in CARICOM countries to integrate climate change in the EIA process;
A draft regional public education and outreach (PEO) strategy;
Development and handover to MACC (see below) of the organization's website;
Successful launch of a Master's Programme in climate change (the first set of graduates, in 2003, included eight students);
Statistically downscaled climate scenarios development for Jamaica, Trinidad and Tobago, and Barbados;
Staff training and development at the Caribbean Institute for Meteorology and Hydrology (CIMH) in climate trend analysis in order to strengthen climate change capacity;
Dialogue established with the South Pacific Regional Environment Programme (SPREP) and the Pacific Islands Climate Change Assistance Programme (PICCAP) for collaboration on issues related to climate change
Implementation of pilot projects on adaptation studies in the water health and agricultural sectors.

Source: CARICOM Secretariat

Mainstreaming of Adaptation to Climate Change (MACC) project 2004-2007

Implemented by the World Bank, and funded with USD $5 million from the GEF, the main goal of the MACC project was to mainstream adaptation strategies into developmental strategies for small, low-lying developing countries. This project was intended to build on the progress on both the CPACC and the ACCC by strengthening institutional capacity, increasing the knowledge base, increasing awareness and encouraging participation (see Table 3). This project was undertaken in 12 Caribbean countries: Antigua and Barbuda, Bahamas, Barbados, Belize, Dominica, Grenada, Guyana, Jamaica, Saint Lucia, St. Kitts and Nevis, St. Vincent, and Trinidad and Tobago[3].

[3] (CARICOM Secretariat, Mainstreaming Adaptation to Climate Change (MACC) Project, 2004-2007)

Table 3: Main Features of MACC Project

Project Components
Building capacity to identify climate change risks – Among other things, this will include strengthening networks to monitor impacts on regional climate, downscaling global climate models, and developing impact scenarios
Building capacity to reduce vulnerability to climate change
Building capacity to effectively access and utilize resources to minimize the costs of climate change
Public education and outreach
Project management
Project Outcomes
The mainstreaming of adaptation to climate change into national and sectoral planning and policies through the use of climate models developed and customized through the project
A strong public education and outreach (PEO) program and a comprehensive communications strategy including all stakeholders in the Caribbean mass media
The creation of an environment conducive to the implementation of measures for adaptation to climate change

Source: CARICOM Secretariat

Between 2008 and 2011, the United Nations Economic Commission for Latin America and the Caribbean (ECLAC) has worked on a project to assess the economic impact of climate change in the Caribbean. The overall aim is to prepare the Caribbean region to better respond to climate change, while fostering a regional approach to reducing carbon emissions by 2050. So far, the following items have been completed:

- a scoping study on 9 Caribbean countries[4] that documented information and data on climate variables as well as identified the sectors that countries considered most vulnerable to climate change;
- a report on econometric models that may be employed in the conduct of an assessment of the economic impacts of climate change
- an assessment of the impact of climate change at the national sectoral level in select Caribbean countries[5]
- three reports under the initiative "Understanding the Potential Economic Impact of Climate Change in Latin America and the Caribbean" with specific focus on the macroeconomy[6] as well as the tourism[7] and water[8] sectors
- a report describing the methodology for climatic modeling in the Caribbean[9]

This study seeks to update the report on the impact of climate change on the macroeconomy at the regional level and will focus on 9 countries: Aruba, the Bahamas, Barbados, Curacao, the Dominican Republic, Montserrat, Jamaica, Saint Lucia and Trinidad and Tobago.

[4] Aruba, Barbados, Dominican Republic, Guyana, Jamaica, Montserrat, Netherland Antilles, Saint Lucia and Trinidad and Tobago

[5] Aruba, Bahamas, Barbados, British Virgin Islands, Curacao, Grenada, Guyana, Jamaica, Montserrat, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, the Turks and Caicos Islands and Trinidad and Tobago

[6] ECLAC, 2010. Climate Change and the Macroeconomy in the Caribbean Basin: Analysis and Projections to 2099. LC/CAR/L.264. 29pp

[7] ECLAC, 2010. The Impact of Climate Change on the Tourism Sector in the Caribbean. LC/CAR/L.263. 26pp

[8] ECLAC, 2010. The Impact of Climate Change on the Water Sector in the Caribbean. LC/CAR/L.260 29pp

[9] ECLAC, 2010. Regional Climate in the Caribbean. LC/CAR/L.265 26pp

B. RELATIONSHIP BETWEEN PHYSICAL ENVIRONMENT AND MACROECONOMIC AND SOCIAL DEVELOPMENTS IN THE CARIBBEAN

Studying the macroeconomic impact of climate change on the Caribbean is of critical importance because most states in the Caribbean are particularly dependent on their marine and coastal ecosystems. The Caribbean's coastal and marine ecosystems provide services that are important for the realization of economic objectives, including: regulation of floods; carbon sequestration; provision of food, medicines, fresh water and other raw materials; habitats for species and genetic diversity; supporting role for nutrient cycling, photosynthesis and soil formation; and, provision of non-material benefits such as recreation, tourism, spiritual endeavors and aesthetic enjoyment (TEEB, 2010). Given these services, climate change is expected to have important physical consequences, which would in turn result in economic and social impacts.

To illustrate the physical vulnerability faced by these ecosystems, consider the coral reef, one of the most threatened bio-diverse ecosystems due to its high sensitivity to sea surface temperature. An increase of just 2°C in sea temperatures – associated with CO_2 concentrations of 500 ppm – would threaten the existence of most coral reefs around the world, but particularly those within the Caribbean (Hoegh-Guldberg O. and others, 2007). Furthermore, the Inter-Governmental Panel on Climate Change (IPCC) predicts a collapse of the coral biome during this century. A study conducted by Burke and others (2008) focused on three areas to estimate the contribution of coral reefs to economic activity in his case study country of St. Lucia: coral reef-associated tourism, fisheries and shoreline protection services. The study estimates a direct economic impact in the form of visitor expenditure of around US$91.6 million in St. Lucia – or about 11 percent of GDP – and that indirect impacts related to tourism support services contribute an additional US$68-US$102 million. Local residents' use of reefs and coralline beaches was estimated at US$52-US$109 million.

Estimating the economic impact of climate change on the region is challenging due to the differences in the physical, economic and social characteristics of Caribbean countries. Physically, the regional grouping consists of island micro-states such as Antigua and Barbuda, The Bahamas, Barbados, Dominica, Grenada, St. Kitts-Nevis, St. Lucia and St. Vincent and the Grenadines – all of which are less than 10,000 sq. km in terms of land area – as well as continental countries like Guyana and Suriname – which occupy land areas of more than 150,000 sq. km, more than 15 times the size of most of Caribbean states. There is also a significant difference in relation to population density. For example, although Haiti, the Dominican Republic, Jamaica and Trinidad and Tobago occupy less than half the land area of Guyana, they dwarf the country in relation to population size and together account for almost 90 per cent of the total population of the Caribbean region. Though most other countries have populations of less than 350,000 persons, they are some of the most densely populated countries in the world. In fact, 14 of the top 50 most densely populated countries in the world are located in the Caribbean[10]

GDP per capita ranges widely by country (see Table 4). Most Caribbean countries would be considered middle-income based on the World Bank's income classification. By 2010, Antigua and Barbuda, The Bahamas, Barbados, St. Kitts-Nevis, and Trinidad and Tobago all had per capita GDP of more than US$12,276 per annum (high-income based on the World Bank's income classification). In the Bahamas, in particular, GDP per capita was as high as US$25,000, or more than twice the level of high-income threshold, and above that of countries such as the Republic of Korea. The per capita income of these relatively high-income states is in stark contrast to much of the rest of the region. In Haiti, per capita income was about US$265 per year in the 1980s and by the end of the review period, per capita income still had not crossed the US$1000 low-income threshold. Only one country fell within

[10] United Nations World Population Prospects, 2010 Revision

the lower middle-income range (Guyana) and most of the other countries fell within the upper middle-income range: US$3,976-US$12,275.

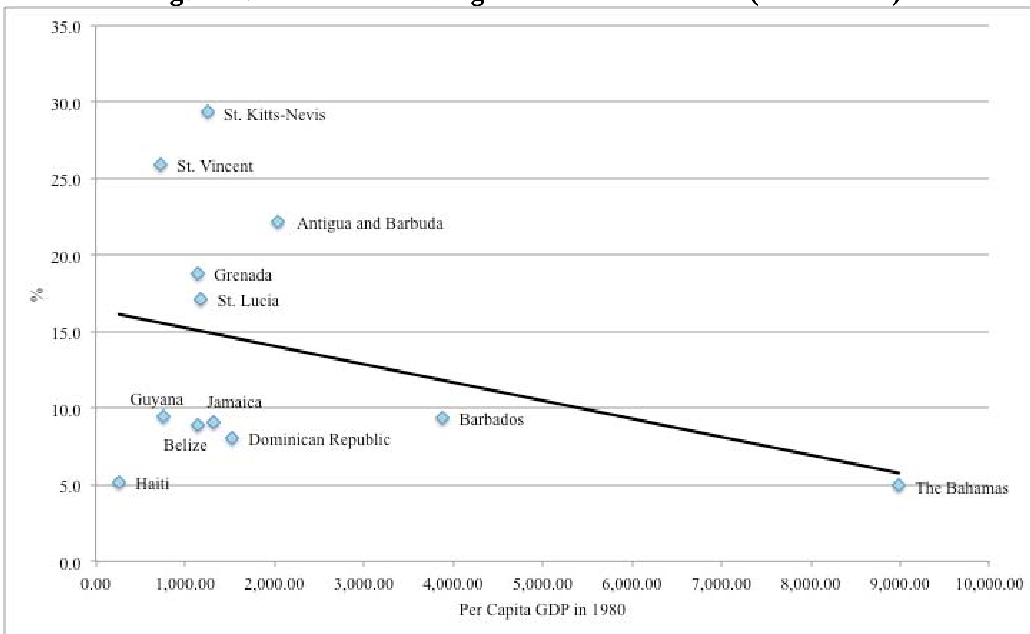
Table 4: GDP Per Capita in Various Caribbean Countries (US$)

	1980s	1990s	2000s	2010
Antigua and Barbuda	3,977.5	9,079.8	13,873.1	15,635.3
The Bahamas	12,030.0	15,701.9	22,842.9	22,350.5
Barbados	5,509.1	8,551.9	12,850.8	14,858.1
Belize	1,386.3	2,705.6	3,825.2	4,226.2
Dominica	n.a.	3,615.5	5,465.4	6,632.0
Dominican Republic	1,446.6	1,936.1	3,658.3	5,226.8
Grenada	1,714.4	3,516.4	6,459.4	7,571.4
Guyana	709.3	1,161.7	1,980.1	2,923.4
Haiti	264.9	272.9	505.5	667.2
Jamaica	1,328.5	2,715.6	4,206.4	4,914.8
St. Kitts-Nevis	2,263.1	6,271.6	10,698.1	12,262.6
St. Lucia	1,856.8	3,915.1	5,651.6	7,233.4
St. Vincent and the Grenadines	1,333.0	2,877.0	5,279.0	6,381.5
Trinidad and Tobago	5441.1	4393.9	12,173.8	15,462.6
Notes				
United States	17,031.6	27,688.5	41,813.5	46,860.2
Caribbean	2,818.3	4,793.9	7,819.3	9,024.7

Source: IMF Economic Outlook (2011)

Table 4 also shows that, using GDP per capita as an indicator, several countries have experienced a significant rise in their standard of living. Furthermore, there has been some evidence of income convergence with the United States (US). In the 1980s, US per capita GDP was almost 7 times that of the region and by 2010 US per capita GDP had declined to 5 times that of the Caribbean. 1 plots per capita income at the beginning of the sample period (1980) on the horizontal axis and the average growth over the sample period (1980 – 2010). If income per capita in the region is converging then low-income countries should grow at a faster rate than high-income countries, i.e. negative relationship between per capita income and growth. The results provided in Figure 1 also suggest that there is some evidence of income convergence within the region as well. Countries such as St. Kitts-Nevis, St. Vincent and the Grenadines as well as Antigua and Barbuda all grew significantly faster than high-income countries like Barbados and The Bahamas.

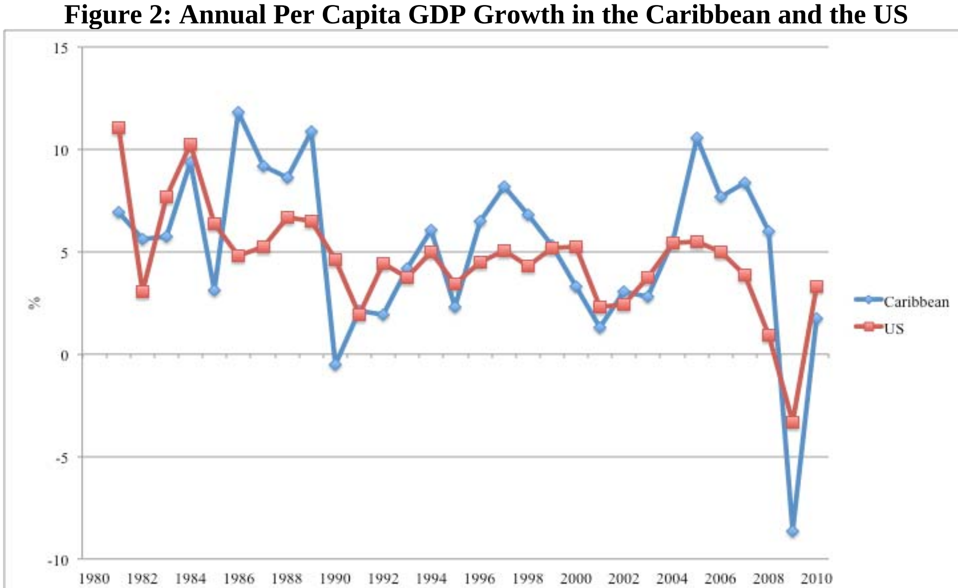
Figure 1: Economic Convergence in the Caribbean (1980 - 2010)



Source: IMF Economic Outlook (2011)

One of the factors behind this convergence is the high degree of correlation between growth in the Caribbean and the outturn in the US. Figure 2 plots the average growth in GDP per capita for the Caribbean and in the US between 1980 and 2010. The figure shows that there is high degree of correlation between the critical turning points for growth in the US and the Caribbean: early 1990s (Gulf War 1), early 2000s (post 9/11 slowdown) and 2007-2009 ('Great Recession'). In addition, the figure also shows that the decline in GDP growth in the region is often more severe than that in the US: while in the US per capita GDP declined by almost 5 per cent, in the Caribbean the contraction in per capita GDP was almost 10 percent. This relationship highlights the vulnerability that regional economies face as open economies.

Figure 2: Annual Per Capita GDP Growth in the Caribbean and the US



Source: IMF Economic Outlook (2011)

In addition to the vulnerability that stems from being small open economies, the structure of regional economies also increases economic vulnerability. Many of the countries in the region are highly tourism-dependent – both in terms of its contribution to GDP as well as share of exports (see table 5) – and the majority of the hotel plant is located along the coast.

Table 5: International Tourism Receipts (% of Exports, 2007)

Country	Percentage
Antigua and Barbuda	58
The Bahamas	65
Barbados	57
Belize	35
Dominica	50
Dominican Republic	34
Grenada	58
Guyana	6
Haiti	26
Jamaica	42
St. Kitts-Nevis	54
St. Lucia	66
St. Vincent and the Grenadines	52
Suriname	5
Trinidad and Tobago	4

Source: World Bank World Development Indicators Online

While the region often performs quite well in terms of economic indicators of development, there are still numerous social disparities within the region. Many countries often rank quite high in terms of Human Development (Table 6); for example, Barbados, The Bahamas, and Trinidad and Tobago are three of the highest-ranking developing countries in the entire world. Despite this laudable performance, poverty and unemployment still remain important issues within the region. Gafar (1998), for example, notes that 43 percent of the population in Guyana was below the poverty line (approximately US$1 per day per person), more than 80 per cent in Haiti, and over 20 per cent in Jamaica, Barbados and Trinidad and Tobago. The paradox of high levels of poverty in conjunction with high levels of human development highlights the issue of income inequality in the region. A common indicator used to assess income inequality is the Gini coefficient. A Gini coefficient of 0 implies complete equality while one of 1 indicates complete inequality. Using household budget survey data, Henry (1989) and Watson (1983) reported that the Gini coefficient was more than 0.4 for most of Trinidad and Tobago's history. In the case of Jamaica, Gafar (1998) notes that the Gini coefficient was more 0.66 while in the Dominican Republic it was 0.49.

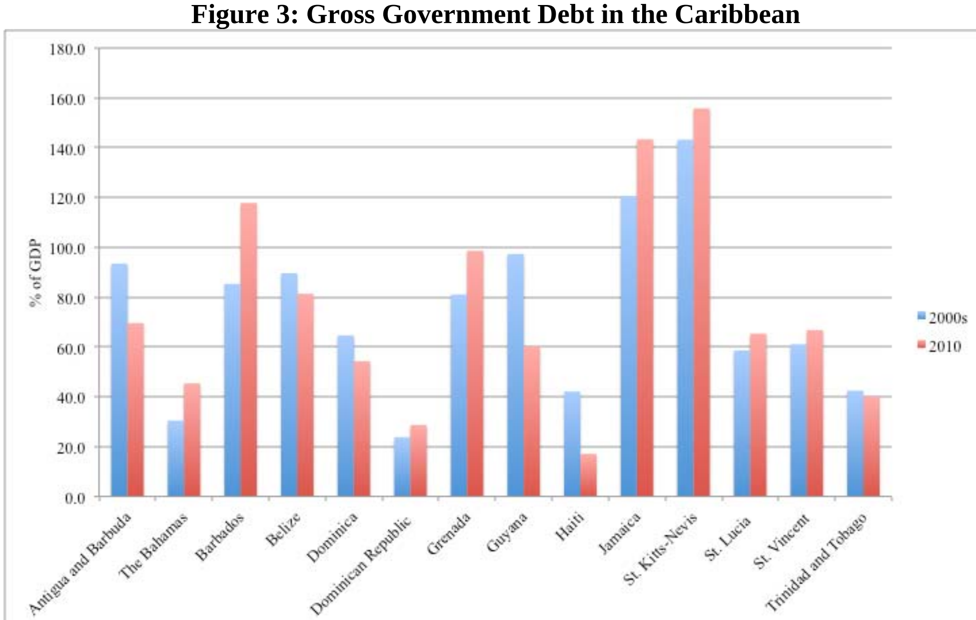
One of the potential reasons behind the poor record of social development has been the fact that high levels of debt in the region have constrained the ability of governments to implement social programmes. In some territories gross government debt is more than 100 per cent of GDP (Figure 3). The three most highly indebted countries were Barbados, Jamaica and St. Kitts-Nevis and, if not for debt restructuring, Haiti and Guyana would have also had very high levels of debt.

Table 6: Human Development Index for the Caribbean

	1980	1990	2000	2010
Antigua and Barbuda	n.a.	n.a.	n.a.	n.a.
Bahamas	n.a.	n.a.	n.a.	0.784
Barbados	n.a.	n.a.	n.a.	0.788
Belize	n.a.	n.a.	n.a.	0.694
Dominica	n.a.	n.a.	n.a.	n.a.
Dominican Republic	n.a.	0.560	0.624	0.663
Grenada	n.a.	n.a.	n.a.	n.a.
Guyana	0.500	0.472	0.552	0.611
Haiti	n.a.	n.a.	n.a.	0.404
Jamaica	0.589	0.620	0.665	0.688
Saint Kitts and Nevis	n.a.	n.a.	n.a.	n.a.
Saint Lucia	n.a.	n.a.	n.a.	n.a.
Saint Vincent and the Grenadines	n.a.	n.a.	n.a.	n.a.
Suriname	n.a.	n.a.	n.a.	0.646
Trinidad and Tobago	0.656	0.660	0.685	0.736

Source: United Nations Development Programme

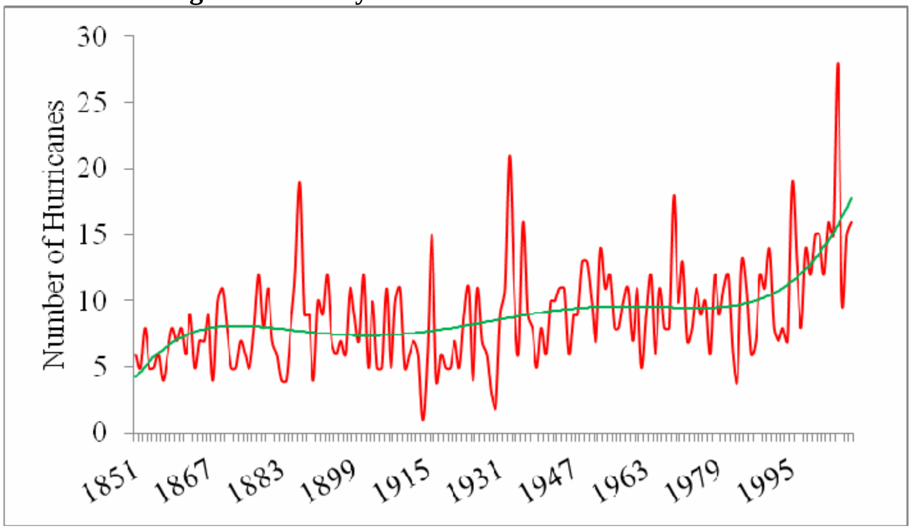
Figure 3: Gross Government Debt in the Caribbean



Source: IMF Economic Outlook (2011)

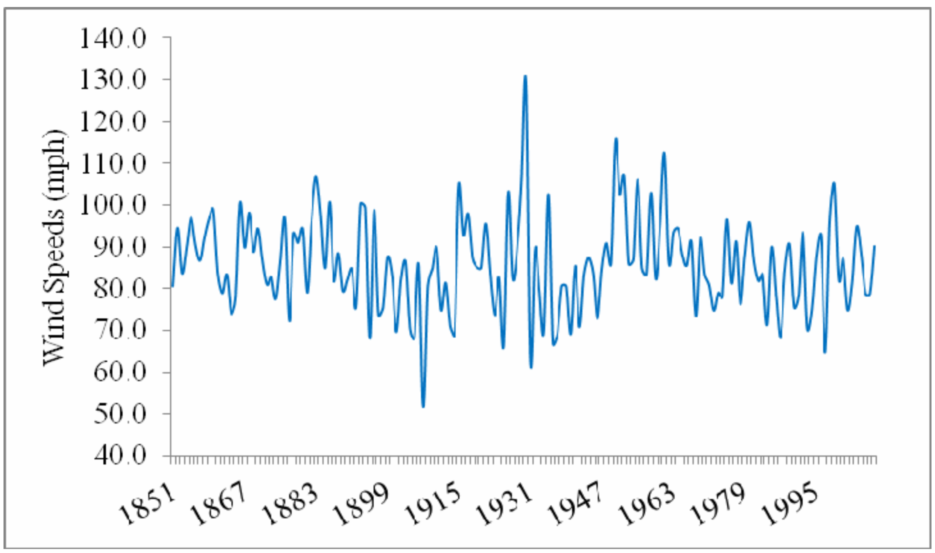
While for some countries the deterioration in debt indicators has been the result of poor fiscal policies, in others high debt levels are related to rebuilding efforts in the wake of adverse weather. Already within the Caribbean, there has been a rise in the number of hurricanes striking the region, though this is not necessarily linked to the issue of climate change. Since the early 20th century, the number of Atlantic hurricanes has risen from about 5-6 per year to more than 25 in some years of the 21st century (see Figure 4), though there is no similar trend in the average intensity of these storms (on average, wind speeds for these storms tend to be 80 and 100 miles per hour) (Figure 5). Climate change studies have suggested that the incidence of extreme weather will increase as global temperatures rise and this could have implications for debt.

Figure 4: History of Hurricanes in the Caribbean



Source: Tropical Prediction Centre

Figure 5: Intensity of Caribbean Hurricanes



Source: Tropical Prediction Centre

C. CARIBBEAN CLIMATE

1. History

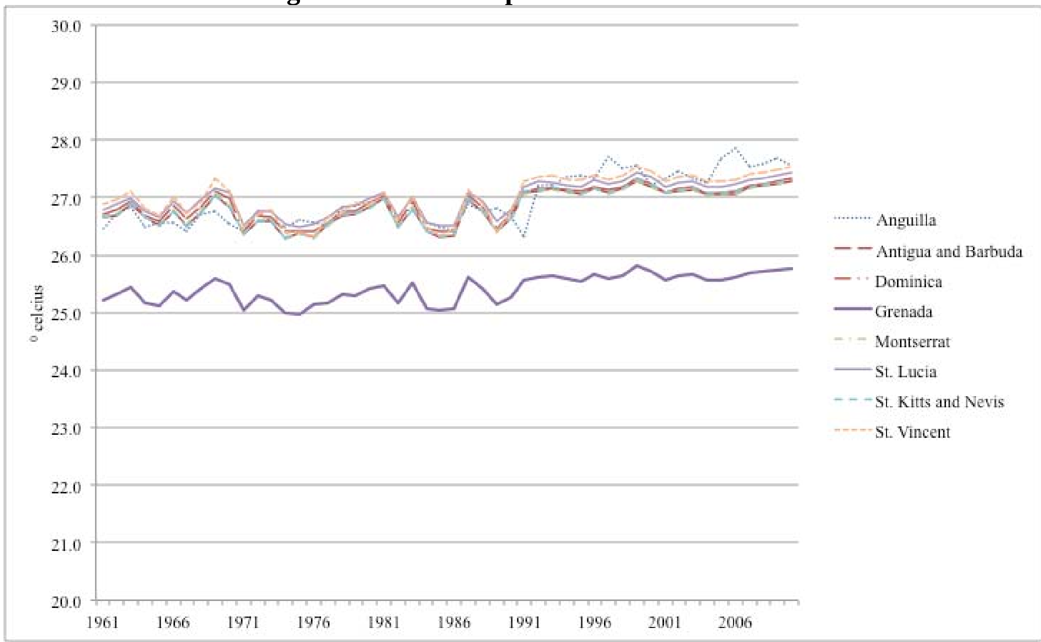
The climatic features of most Caribbean countries do not converge to some regional norm. Climatic features tend to vary both between countries as well as within particular states. The observations used in this study are taken from the PRECIS output text files that provide observations for most countries within the region at the 50x50km resolution. It should therefore be noted that these observations might differ from the point estimates obtained from station observation, as the estimates represent the mean model results for the 50x50km grid box.

For ease of analysis, these climate variables are presented for three country groups:

1. Group 1: Anguilla, Antigua and Barbuda, Dominica, Grenada, Montserrat, St. Kitts and Nevis, St. Lucia and St. Vincent and the Grenadines.
2. Group 2: the Bahamas, the British Virgin Islands (BVI), Cayman Islands, Dominican Republic, Haiti, Jamaica and Turks and Caicos.
3. Group 3: Barbados, Belize, Guyana and Trinidad and Tobago.

For every country considered, mean temperatures rose between 1960 and 2010. Figure 6 provides the mean temperatures for Group 1 countries (OECS) over the period 1960 to 2010. Over the period, the mean temperatures for most countries within the group rose by around 1^0C: from 26.5^0C to 27.5^0C. Over the period, the mean temperatures in Grenada were about 1^0C lower than for the other Group 1 countries. Nevertheless, the rise in temperature was similar to that for the other countries within the regional grouping.

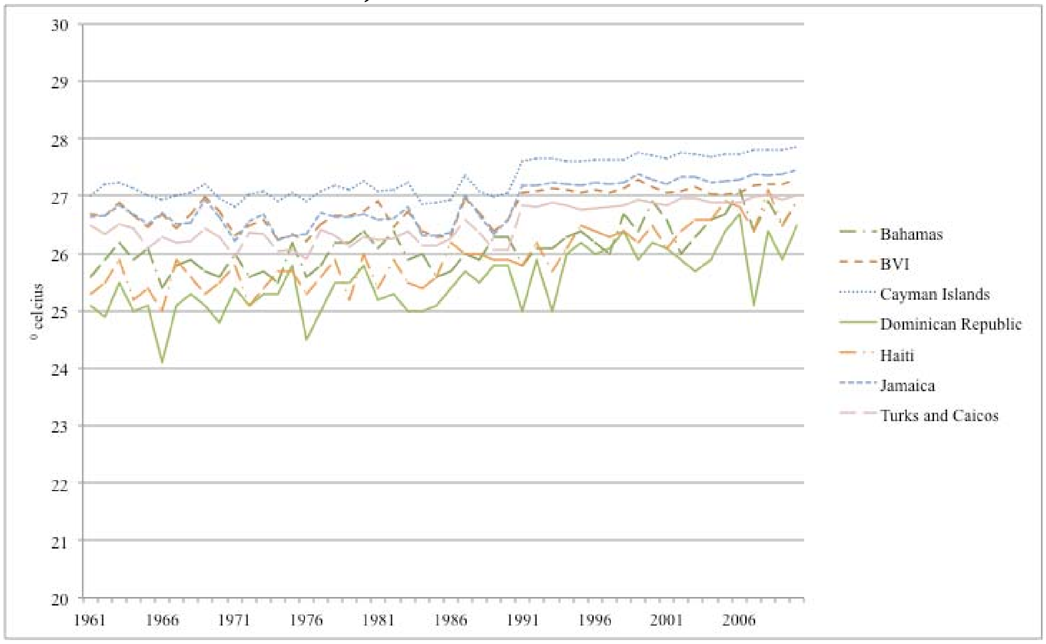
Figure 6: Mean Temperatures for the OECS



Source: PRECIS

The mean temperature trends for Group 2 countries, relative to those states in Group 1, were significantly more heterogeneous. Figure 7 shows that over the period mean temperatures varied between 24^0C and 28^0C. Over the review period, the Cayman Islands had the highest average mean temperatures of above 27^0C, reaching as high as 28^0C by the end of the sample period. The BVI, Jamaica and the Turks and Caicos were the only other countries to end the period with a mean temperature above 27^0C.

Figure 7: Mean Temperatures for Bahamas, BVI, Cayman Islands, Dominican Republic, Haiti, Jamaica and Turks and Caicos

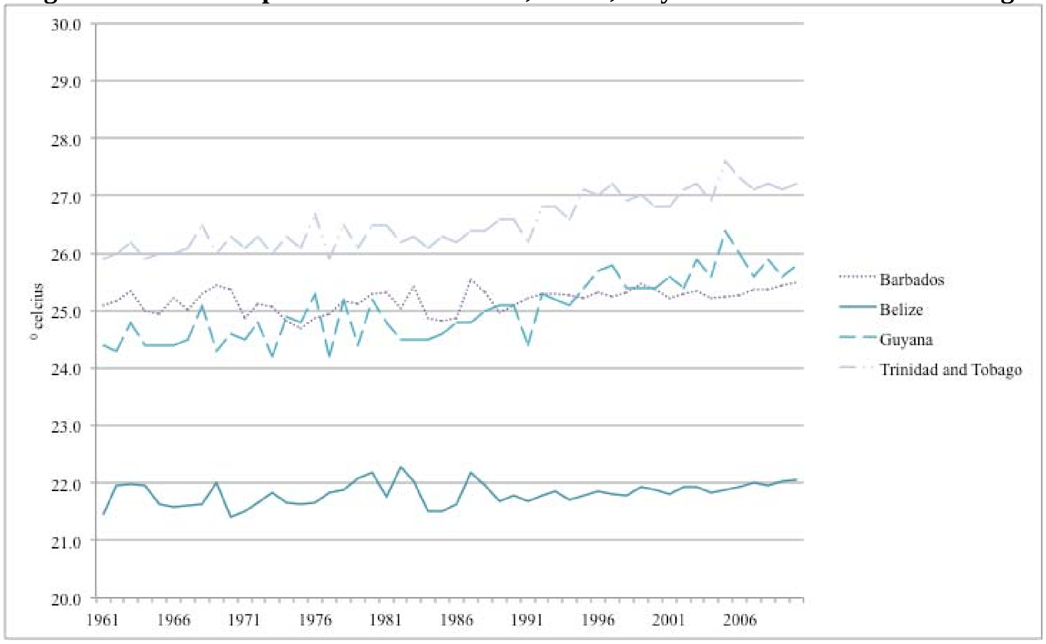


Source: PRECIS

The temperature increases for most Group 2 countries were, generally, on par with those provided earlier for Group 1 states. For the Cayman Islands, the BVI, Jamaica and the Turks and Caicos mean temperatures rose by just under 1^0C over the 49-year period under investigation. For the Dominican Republic, Haiti and the Bahamas the increase in mean temperatures was significantly greater: temperatures rose by about 1.5^0C. In Haiti, mean temperatures rose from just over 25^0C to almost 27^0C.

The final group, Group 3, provides a fairly diverse picture. In Belize, mean temperatures were the lowest of all the countries considered in the study: on average less than 22^0C. In addition, there was little or no evidence of an upward trend in mean temperatures, with mean temperatures fluctuating around the mean for most of the sample period. In the case of Barbados and Guyana, mean temperatures were generally between 24^0C and 26^0C. In the case of Barbados, mean temperatures rose by about 0.5^0C between 1960 and 2010. In contrast, Guyana saw mean temperatures rise from 24.5^0C to above 26^0C, an increase of 1.5^0C. Trinidad and Tobago also experienced a similar rise in mean temperatures, with the mean for the twin-island republic ending the review period at above 27^0C.

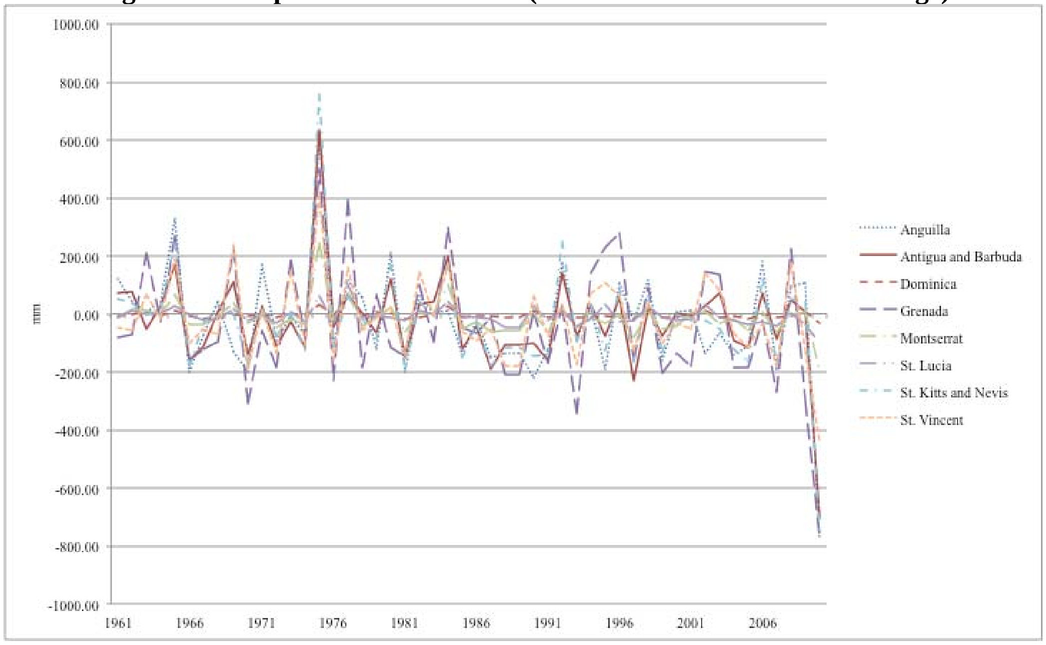
Figure 8: Mean Temperatures in Barbados, Belize, Guyana and Trinidad and Tobago



Source: PRECIS

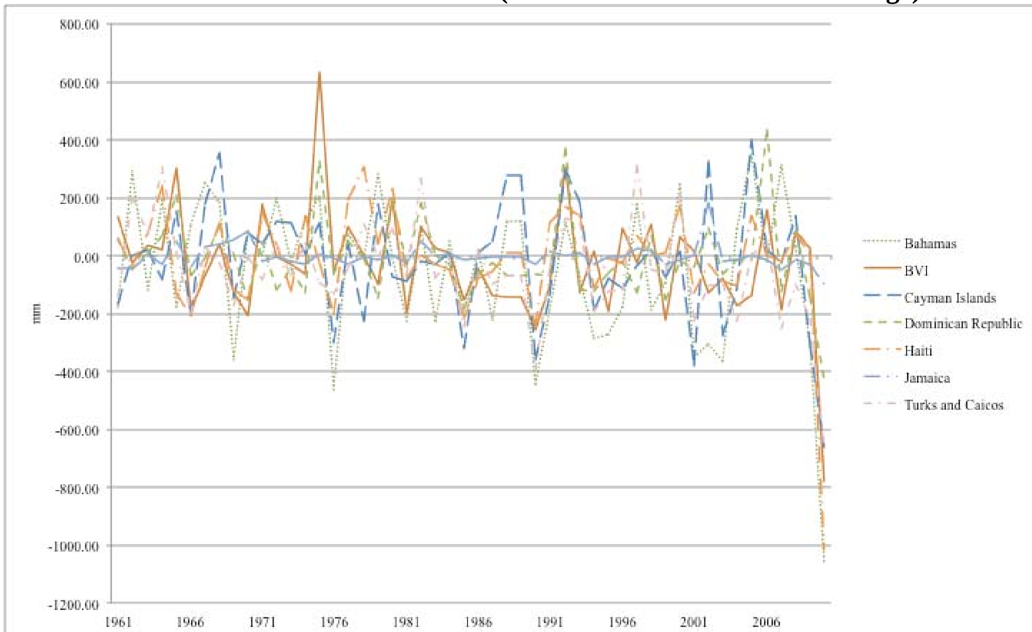
The PRECIS database also provides observation on precipitation anomalies (deviation from the 1960-1990 mean) for precipitation. Figure 9, Figure 10, and figure 11 provide the precipitation anomalies for Group 1, 2 and 3 countries, respectively. Unlike the observations for rainfall, there was not apparent trend in precipitation over the review period.

Figure 9: Precipitation in the OECS (Deviation from 1960-1990 average)



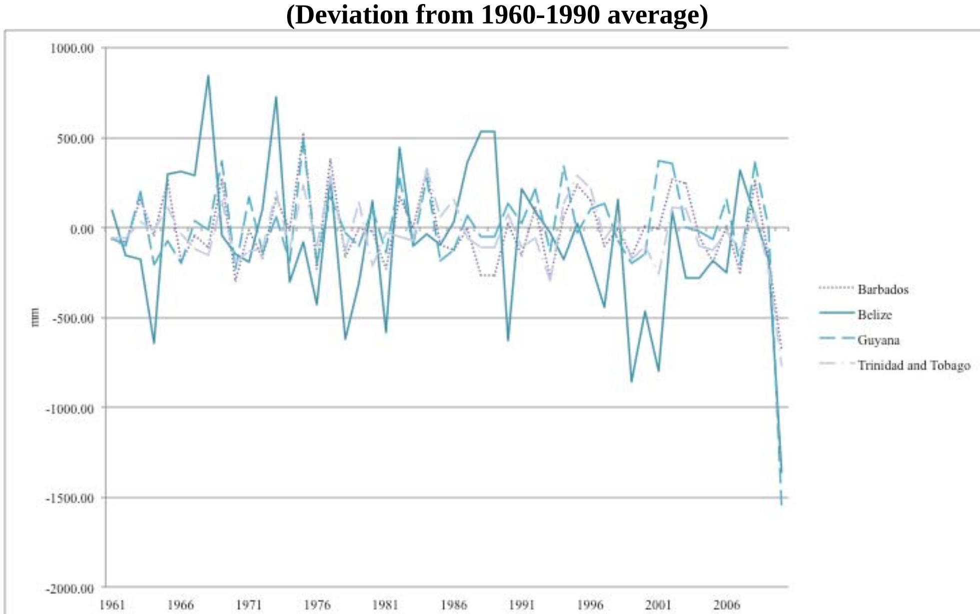
Source: PRECIS

Figure 10: Precipitation in Bahamas, BVI, Cayman Islands, Dominican Republic, Haiti, Jamaica and Turks and Caicos (Deviation from 1960-1990 average)



Source: PRECIS

Figure 11: Precipitation in Barbados, Belize, Guyana and Trinidad and Tobago (Deviation from 1960-1990 average)

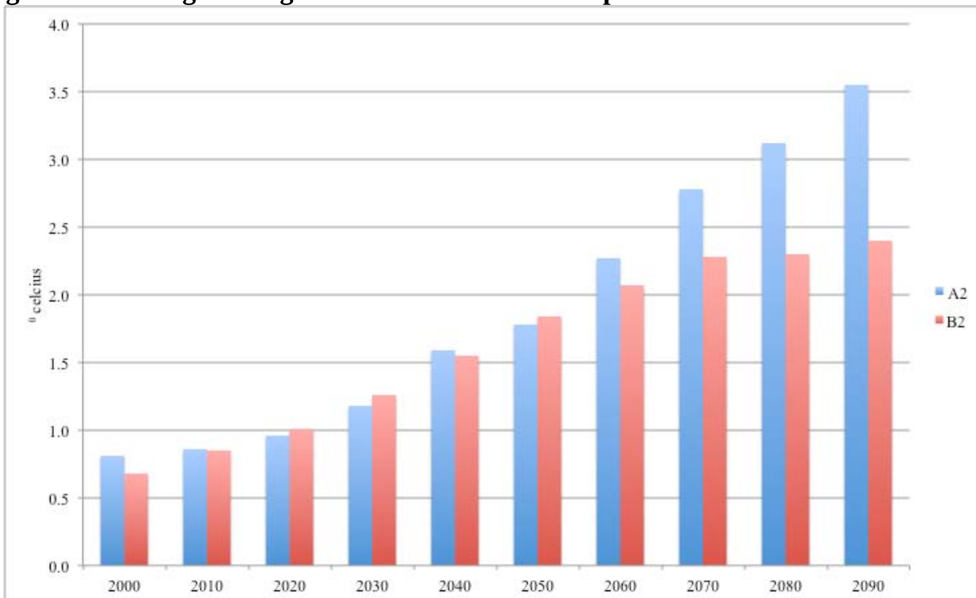


Source: PRECIS

2. Likely Future

The PRECIS outputs also provide future climate anomalies (climate change) from the HadAM3p and ECHAM4 Global Models. Two SRES Scenarios are considered: A2 and B2. Figure 12 provides estimates of the mean temperature change for the Caribbean for both SRES Scenarios over the period 2000 to 2100. In the B2 scenario, temperatures are expected to rise by 2^0C up to 2070, but after this period some moderation in mean temperature changes is expected. In contrast, the A2 scenario envisions a slower acceleration in mean temperatures up to 2050, but unlike the B2 scenario there is no moderation in temperatures. Between 2050 and 2100 temperatures are likely to rise by a further 3^0C.

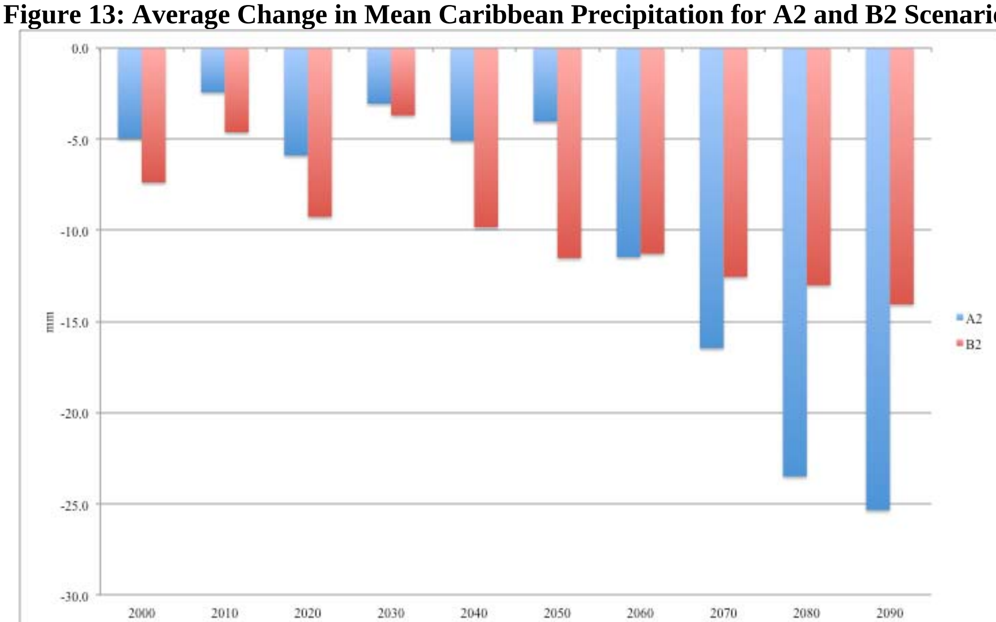
Figure 12: Average Change in Mean Caribbean Temperatures for A2 and B2 Scenarios



Source: PRECIS

In relation to precipitation, a significant decline is expected under both SRES Scenarios. In the B2 scenario, annual precipitation is projected to decline by between 5 and 15 mm, while under the A2 scenario the decline is expected to be as high as 25 mm.

Figure 13: Average Change in Mean Caribbean Precipitation for A2 and B2 Scenarios



Source: PRECIS

II. LITERATURE REVIEW

A. METHODOLOGICAL APPROACHES

One of the earliest studies on the impact of climate activity on the welfare of individuals was conducted in the 19th century by the British Government in collaboration with Indian scientists. They developed techniques in an attempt to predict the quality of monsoon rains, with the aim of mitigating the damages from potential droughts (Brown, Meeks, Ghile, & Hunu, 2010). Since then, much of climate change literature has focused on projecting the future paths of climate variables and the likely physical impacts; however, it is only since the beginning of the 1990s that researchers have focused on its economic impacts (Tol R. S., 2009).

Studies in this area follow a general approach. Usually assumptions are made regarding the future patterns of climate variables, including: changes in temperature, sea level rise, warming patterns, precipitation and the changing intensity of storminess. These estimates are then combined with other macroeconomic to obtain estimates of the total economic loss expressed in monetary terms (Tol R. S., 2009). Given the uncertainty of future climate patterns, the long term nature of the problem and the various channels through which climatic impacts are transmitted the options for analysis are numerous. Nevertheless, the various methodologies applied in the literature can be classified in three categories: enumerative approach, general equilibrium, and marginal costing.

The earlier studies on the aggregate economic impact of climate change employ the enumerative approach. This approach first estimates the physical impact of climate change by incorporating studies in the natural sciences where estimates of each individual climate scenarios are obtained from laboratory experiments, climate and/or impact models (Tol R. S., 2009). Having established the likelihood and magnitude of potential impacts, a cost is then attached to each damage category and then aggregated to arrive at a total cost (Frankhauser, 1994), (Frankhauser, 1995), (Nordhaus, 1994), (Tol R. S., 1995), (Tol R. S., 2002a) and (Tol R. S., 2002b). By relying on natural experiments the estimates of physical impacts are closer to being realistic and also lend itself to easy interpretation. However, there are concerns about this approach as studies extrapolated estimates from other issues for climate change purposes, also values from recent events are applied to the future. Also for those goods that are not traded in markets, such as health, this method proves to be inappropriate when applied to test benefit models as the errors can be significantly large (Brouwer & Spaninks, 1999).

Perhaps, one of the main criticism of the preceding studies is the assumption the there is no higher order feedback effects between the various sectors. Indeed, given the long term nature of climate change, and the numerous of channels through which impacts are transmitted, interactions between different sectors must accounted for the capture the direct effects of the sector under study and any knock-on effects in other. As such, a subset of the literature has employed a general equilibrium approach to the issue of climate change impacts. The "Mink Study" by (Crosson and Rosenberg, 1993) is one of the more comprehensive studies of the earlier attempts in applied general equilibrium analysis of climate change. The study evaluates the impact of climate change on agriculture, energy, water and forestry for four US States: Iowa, Missouri, Nebraska and Kansas. To account for feedback impacts, the first round effects are estimated first then feed in the model using input-output models. Unlike most studies, the weather pattern of the 1930s is used as a climate proxy rather than 2 X CO_2 data.

Following this approach, Scheraga and others (1993) estimates the macroeconomic impact of climate change on the US economy. In contrast to the forgoing study, the authors used the 2 x CO_2 data with a worst case scenario of $5.1^{\underline{0}}$ C warming assumed to occur until 2060. The study reveals several important considerations: the increase in sea level rise cause public expenditure to move from consumption to expenditure in response to sea level rise protection, the fall reduction of agricultural yield results in higher prices which reduced demand these goods. The moving from consumption related spending the more investment and capital related activities, provides an example of the changing structure of the economy in response to climate change impacts. For more applications of the general equilibrium approach see (Bosello and Zhang, 2005) and (Zhai, Lin and Byambadorj, 2009).

Both the enumerative and general equilibrium approach allows researchers to estimate the total cost of climatic impact over some extended period. However, as global warming is a dynamic problem and mitigation strategies can see significant amount of resources diverted to this end, the marginal cost associated with every unit of green house gases would be relevant for appraising mitigation/adaptation strategies (Frankhauser, 1994). This is particularly important given that both the economic structure of economies and climatic patterns change over time, hence, the marginal/social cost of climate variation will change over time. Social costs is defined as the "net present value of incremental damage due to a small increase in carbon dioxide emissions (Tol R. S., 2009)

Frankhauser (1994) outlines two main approaches for evaluating the marginal cost for greenhouse gas mitigation strategies. The first approach is a cost benefit framework, where it is recommended that the marginal cost of CO_2 mitigation be equal to the marginal benefits of mitigating greenhouse damage at each time period. Theoretically, this approach suggests that the cost of CO_2 emissions can be derived from cost-benefit models as the carbon tax which is require to maintain emission at social optimal levels. The major drawback of this approach, however, is that data requirements are well beyond the 2 X CO_2 studies which often result in several assumptions. Secondly, another approach utilized in the literature is the direct computation of the marginal cost. As with the cost-benefit approach, a thorough understanding of climatic processes and the interrelationships of temperature and climate is required. The marginal cost of climate change is estimated by evaluating the present value of project damages in each period under a given scenario, with that of an alternative scenario in the base period. Unlike the cost-benefit models, where optimal paths are determined by the model, it provides researchers with the advantage of calculating marginal cost for various scenarios (Tol R. S., 2008).

B. ESTIMATES OF THE EFFECTS OF CLIMATE CHANGE

1. Global

Given that climate change is a worldwide phenomenon, both in its causes and effects, several studies have attempted to estimate its global welfare effects. Earlier studies by Nordhaus (1994), Frankhauser (1995), Tol (1995) and Tol (2002) estimate the likely impact of climate change on global GDP by first projecting the physical impacts then estimating their economic cost, while assuming some increase of temperature overtime. It should be noted that these studies are essentially static analyses, since they assume future climatic events will impact on the current GDP levels. Nordhaus (1994) reports that the cost of an increase in temperature of 3.0^0 C would translate into approximately a 1.3% decline GDP, while Frankhauser (1995), Tol (1995) project the damage of a 2.5^0 C increase in temperature to be approximately 1.4% and 1.9% of global GDP respectively.

The studies also provide some perspective on the regions which would be the least and most likely affected. Both Tol and Frankhauser's studies suggest that Eastern Europe and the former Soviet Union would experience the least impact from a rise in temperatures, with reported economic losses for this region of 0.3% and 0.7% of GDP respectively. On the other hand, Frankhauser predicts China would suffer the greatest impact with an estimated loss of 4.7% of GDP, while estimates in Tol's study suggests that Africa will bear the highest cost, 8.7% of GDP.

Similarly, the work of Mendelsohn and others (2000), Maddison (2003) and Nordhaus (2006) estimates the total global economic impact of climate change. However, rather than model the physical impacts, the authors utilized a statistical approach where estimates are derived from the patterns of macroeconomic variables and climate scenarios. Mendelsohn estimates are done on a country by country basis then aggregated; Maddison utilizes patterns in of aggregate household income with climate information; while Nordhaus focuses of the total climate impact on global income. Mendelsohn report that a 2.5^0 C increase in temperature is associated with a 0.1% increase in the global GDP. However, when analyzed by region, the study indicates that Africa would incur damages of around 3.6% of GDP. Maddison's results also indicate an unequal distribution of climate effects. In terms of the global impact this is estimated at 0.1%, while the economic impact for the South America region is expected to be 14.6% of GDP. This is in stark contrast to the 2.5% increase in GDP reported for Western Europe. Nordhaus reports a global impact of 0.9% of GDP, however, no estimate was provided for the regions least/most likely impacted.

The results above shed light one important fact, although climate change is a global problem, there is an unequal distribution of its effects. As such, there is a clear need to for a thorough investigation of the regional impacts if policy makers are to craft suitable adaptation strategies. According to the Ciscar and others (2011), this rational is the prime motivation for their study on both the physical and economic impacts of climate change in Europe. This study models the physical impacts of climate change and the economic impacts, which are then entered in a multi-sector general equilibrium model. The key sectors in this study are tourism, agriculture, river floods, coastal areas and human health. For the 2.5^0 C and 5.4^0C climate scenarios, the overall monetary loss, in terms of GDP, is estimated to EU$20 and EU$65 billion.

Similar studies have been done for other regions in the world. For example, Clements and Practical Action Consulting (2009) briefly review studies of climate change impacts in Africa. In their report, the authors note that the costs of climatic impacts are significant for African countries. Take a for instance the estimates in Egypt which suggest that a 0.5m in Egypt's Port is estimated at US$2.250 billion, or the estimated cost of US$563.28 billion resulting from damaged ports in Alexandria due to sea level rise. In Ethiopia, the marginal increase in temperature would have the effect of reducing agriculture revenue by approximately US$997.7 per hectare in winter and US$177.6 per hectare in summer. In Latin America and Caribbean, the available evidence points to significant economic impacts. As a whole, it is estimated that by 2100 climate disasters would cost the region around US$11 billion, US$64 billion and US250 billion under assumed discount rates of 4%, 2% and 0.5%. However, given the diversity of each country climate impacts are heterogeneous both is space in time, nonlinear, varying magnitudes and can be irreversible (ECLAC, 2009).

2. Regional

Haites and others (2002) provide one of earliest attempts to estimate the potential aggregate economic effects of climate change for countries of the CARICOM region. Given the tight timeline and budgetary constraints of this study no original research on the economic effects was undertaken. Rather, the estimates are derived from a combination of the cost of land loss due to sea level rise and past hurricanes damage reported in existing studies for individual countries. According to the study, the potential economic impact of climate change is estimated to be in the range of 1999 US$1.4 to $9.0 billion for the CARICOM countries. The total impact of the low climate scenario is estimated to be about 5.6% of GDP (from 3.5% to as high as 16% in Guyana). More pronounced is the high scenario as the total impact is an estimated 34% of GDP, starting from as low as 22% in Trinidad and reaching as high as 103% for Guyana. As highlighted by the study, Trinidad's limited dependence on tourism and relatively low susceptibility to hurricanes in the past, as well as Guyana's lower per capita

GDP explains why Trinidad's economic loss is significantly less than Guyana's. The study also indicates that the largest economic loss occurs from the loss of land, tourism infrastructure, housing, other buildings and infrastructure resulting from sea level rise. These categories make up approximately 65% to 75% of the total economic impacts. The remaining economic impacts follows from the fall out of tourism demand in light of rising temperatures, loss of beaches, coral reefs and other eco-systems (15%-20%), and property damage due to increased intensity of storms and hurricane.

The wide range of estimates reported in the preceding study highlights a few of its shortcomings. First, the authors note that the estimates in the study should be considered "rough estimates" since it was hindered by a lack of data, and as a result, numerous assumptions had to made about future climatic events and their economic impact. Also, the lack of data made it impossible to calculate the economic loss for some categories like agriculture and fisheries output. Secondly, the report based the estimates on the GDP reported in 2000 despite the climate change is expected to manifest over the very long run. Thirdly, as highlighted earlier the economic effects does not take into account the adaptation/mitigation cost, hence, the estimate may be overstated since adaption measure may significantly reduce climate change impacts. Nevertheless, the report provides a useful first step toward analyzing the potential impact of climate change in the Caribbean.

A more recent study conducted by Bueno and others (2008) estimates the likely impact of climate change if emissions were allowed to continue on the current path. The study attempts to calculate the "cost of inaction" by comparing optimistic and pessimistic scenarios based on the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007). Under the pessimistic scenario greenhouse gas emissions continue to increase unabated, on the other hand, the optimistic scenario assumes that the world takes a unified approach in reducing greenhouse gas emissions and a reduction is achieved by mid-century. The cost of inaction is then calculated by taking the difference of economic loss between the two scenarios, where this represents the economic savings if appropriate action is taken to mitigate the potential fallout from future climate scenarios.

Results of the study estimate the cost of global inaction to climate change to be approximately US$22 billion annually by 2050 and US$46 billion by 2100 for the Caribbean; in relative terms this represents 10% and 22% of the aggregate GDP of Caribbean States, respectively. This is primarily driven by the loss of infrastructure, accounting for approximately 70% of total cost, while the impacts on tourism and loss due to storms account for the 15 percent of total cost each. With respect to country specific losses, the study indicates that climatic impacts will potentially impact some countries more than others. For instance, when measured in terms of 2004 GDP, the economic fallout from climate change can reach as high as 75% by 2100 in Dominica, Grenada, Haiti, St. Kitts and Nevis and Turks and Caicos. According to the authors, however, these estimates are not to be taken as precise predictions, given that the estimates were calculated assuming 2004 GDP levels it is likely that higher future GDP may result in lower ratios of damage.

Simpson and others (2010) uses both a top-down and bottom-up approached to evaluate the impact of sea level rise on the economies of the countries in the Caribbean. The method used is captured in a macro and micro-approach where estimates are obtained for each individual country. One advantage of this approach is that it allows the combination of macro data on economic activity (GDP) with micro information of geospatial impacts of sea level rise. Unlike previous studies, the authors include GDP growth scenarios for each country based on estimates for the IPCC SRES AS and B1 scenarios. In these scenarios, sea level rise is projected to increase over the 21st century by 1m and 2m, where the impacts are calculated for the years 2050 and 2080. Impacts in this instance are calculated for two categories: annual ongoing cost to the economy resulting from climatic impacts, and capital cost which are the cost associated with the rebuilding/relocation due to land loss.

Results suggest that the cost associated with sea level rise will increase significantly approaching the end of the century, under both medium and high impact scenarios. Capital cost in 2050 is estimated to be in the range of US$26 to US$60.7 billion, while the yearly economics loss is estimated to between $US3.9 and US$6.1 billion. In 2080, capital cost is projected to be around US$68.2 to US$187 billion representing 8.3% to19.2% respectively. The annual cost in 2080 stood at US$13.5 to US$19.4 (1.6% to 2% of GDP in 2080). Further analysis reveals that those countries highly dependent on the tourism industry tend to have greater annual cost. To illustrate this point, the tourism sector in the Bahamas suffer losses between US$869 and US$946 million in 2050, and moving to between US$2.2 and US$2.6 billion in 2080. In addition, the countries of Bahamas, Jamaica and Haiti will incur most of the capital cost in the region. Capital cost is mainly driven by losses to dry land, as high as US$21 billion in 2050 and US$60.6 in 2080. Conversely, loss to agriculture and industry we estimated to be negligible; however, the authors indicated that this may be a result of the limitations of the analysis given that they did not account for secondary or tertiary feedback effects.

More recently, studies by Moore (Moore W. R., 2011; Moore, Harewood and Grosvenor, 2010; Moore W. R., 2010) provide a significant insight into the inter-relationships between climate change and the potential impact on the tourism industry in the Caribbean. This is particularly important since tourism is a main source of foreign exchange and employment, and most small island states are vulnerable to land loss and infrastructural damage from sea level rise. To this end, Moore (2011) constructs a climatic index that captures historical observations as well as sea level rise climate scenarios A2 and B2. This index is then incorporated into a tourism demand model for St. Lucia, where the results suggest that the negative impacts when expressed in terms of GDP could be 5 times greater than 2009 GDP. Moreover, when supply-side impacts are considered the study reports that total cost of climate change for the sector is projected to be US$12.1 billion (12 times 2009 GDP) and US$7.9 billion (8 times 2009 GDP) over a 40-year horizon under the A2 scenario and for the B2 scenario, respectively.

A similar story emerges for Barbados. Moore and others (2010) estimated the supply-side impact of sea level rise and intense weather events in Barbados. The study suggest extreme weather events pose a significant threat to Barbados' infrastructure, as revenue loss under the best case scenario estimated at US$355.7 million and US$2 billion for the worst case. The impact of sea level rise tends to be lower, with the cost under the worst-case scenario projected to be US$150 million under the worst-case. From a demand side perspective, Moore (2010) estimates the cost of climatic change to the tourism industry in the Caribbean could be in the range of US$118 million to US$146 million annually

III. EMPIRICAL APPROACH

The previous section highlighted the drastic changes expected in temperature and precipitation over the next few decades. These changes are likely to have serious macroeconomic consequences. Particularly, Haites and others (2002) note that reductions in precipitation, coupled with rising temperatures, are likely to result in loss of agricultural output and assets; loss of timber and fuel; and reduced fishery output in the Caribbean.

There are also some indirect impacts. Specifically, as noted in the literature review, quite a few studies have shown that future climatic events could translate into significant global GDP losses. Moreover, Parry and others (2004) note that further increases in temperature may significantly reduce cereal production and by extension, lead to a rise in global cereal prices. Parry and others estimate that under the A2 scenario without CO_2 effects, cereal prices could be nearly 100 percent higher by 2050, relative to the scenario with no climate change. Meanwhile, the increase in prices under the B2 scenario is about 50 percent. Given that (1) the economic fortunes of several Caribbean are largely dependent on the performance of the world economy, and (2) Caribbean states generally have a high propensity to import and are generally price takers [Witter and others (2002)], Caribbean economies may also suffer from the knock-on effects of climate change on the world economy.

While climate change is expected to negatively affect the Caribbean, a key question faced by policy makers is "how large are the costs of climate change?" To provide an estimate, the authors put forward a two-step methodology. First, forecasts of real GDP under the aforementioned A2 and B2 climate change scenarios are estimated. Second, we integrate the forecasted values of GDP and the estimated change in global commodity prices provided by Parry and others into a computable general equilibrium (CGE) so that the potential impact climate change on investment, household consumption, government saving, exports and imports can be evaluated. Specifically, the authors adopt the 1-2-3 CGE model of Devarajan, and others (1997) to simulate the expected changes in real output and commodity prices on the macroeconomy.

A. QUANTIFYING THE IMPACT OF CLIMATE CHANGE ON REAL GDP

To assess the impact of climate change on real GDP, the following growth model is estimated for all countries under investigation:

$$y_t = \alpha_0 + \beta Y_t^{world} + \gamma CCI_t + \delta I_t + \varepsilon_t \qquad (22)$$

where y is real GDP, Y^{world} represents World real GDP, CCI is a climate change index, *I* represents intervention (dummy) variables [11] and ε_t is an error term. The essential characteristic of most Caribbean economies is that economic activity tends to be driven by foreign demand for the good and services of the region (e.g. travel and leisure, bauxite, gold, among others). World growth[12] is therefore included in the specification to capture the effects of foreign demand. It is expected that world growth should therefore have a positive impact on domestic output in each regional economy under consideration. The climate change index is the weighted average of annual average temperature and total precipitation. A priori, the average temperature should be negatively related to real GDP, while a positive relationship between real GDP and precipitation is expected. Given the differences in the expected impact of the climate variables, the index is calculated as:

$$CCI_t = w_t \cdot \frac{1}{\textit{average temperature}} + w_p \cdot \text{Precipitation} \qquad (23)$$

Thus, increases in the index imply better climate conditions (higher precipitation and lower temperatures) and so, should be positively related to real GDP. In equation (23) w_t represents the weight given to temperature in the CCI while w_p is the weight assigned to precipitation. For ease of calculation, both temperature and precipitation is given a weight of 50%.[13] The analysis above is done on an individual country basis to account for potential heterogeneity in the potential impact of climate change on particular Caribbean islands. For

[11] Caribbean economies, like most small states are highly vulnerable to exogenous economic shocks (both positive and negative). These shocks can include the effects of a tropical storm or simply he proceeds of a large inflow of capital. To capture these outlier events intervention dummies are included in the model. These dummies vary from country to country.

[12] It is also possible to include US GDP growth as a potential explanatory variable rather than world GDP; however, this would ignore the potential dependence that some regional economies have in relation to both the UK and Canada. Nevertheless, the model was also estimated using US GDP growth and the results were quite similar.

[13] Simulations were conducted where the weights were changed, but the results did not change appreciably.

example, it is likely that the impact of climate change on a primarily serviced-based economy is likely to differ from that of a commodities-based economy. The approach is therefore not a regional modelling framework, as all countries are modelled individually. Nevertheless, aggregate regional results can be obtained as all findings are provided as a proportion of based year GDP (2009).

Before equation (22) is estimated, the order of integration of the variables must be determined. To test the stationarity properties of the variables, the authors employ the familiar ADF, PP and KPSS unit root test. But, plots of the real GDP variables suggest that these series undergo at least one structural break. Because classical unit root tests have reduced power in the presence of structural breaks, the unit root test by Saikkonen and Lutkepohl (2002) and Lanne and others (2002) is adopted for the real GDP variables. The test considers models with general nonlinear deterministic shift functions. In the first step of the test, the deterministic component is estimated and subtracted from the series. In the second step, the standard ADF unit root test is applied to the transformed series. Critical values can be found in Lanne and others (2002, p.678). The results are presented in Table 7 which suggests that the real GDP and US real GDP variables are I(1) and the CCI is I(0).

Table 7: Unit root tests

Unit root test:	***Lanne and others***			
Variable	Level	Break date	Shift function	1st difference (ADF)
Bahamas Real GDP	-2.574	1973	Shift Dummy	-4.110***
Barbados Real GDP	-2.561	1992	Exponential Shift	-3.716***
Dominican Republic Real GDP	-1.813	2001	Impulse dummy	-4.351**
Guyana Real GDP	-2.658	1982	Rational shift	-3.519**
Jamaica Real GDP	-2.633	1992	Shift Dummy	-4.210***
Saint Lucia Real GDP	-2.146	1975	Shift Dummy	-4.358***
Trinidad and Tobago Real GDP	-2.397	1983	Rational Shift	-2.684*
World – Real GDP	-2.310	1983	Rational Shift	-3.171**
Unit Root Test	ADF	PP	KPSS	
Bahamas CCI	-6.580***	-6.588***	0.124	
Barbados CCI	-8.083***	-7.897***	0.103	
Dominican Republic CCI	-8.562***	-8.480***	0.117	
Guyana CCI	-10.458***	-13.461***	0.369*	
Jamaica CCI	-6.070***	-6.764***	0.112	
Saint Lucia CCI	-7.858***	-7.953***	0.375*	
Trinidad and Tobago CCI	-7.037***	-8.136***	0.270	

Note: ***, ** and * indicate significance at the 1%, 5% and 10% levels respectively. First differences of Guyana CCI and Saint Lucia CCI are stationary.

The authors also investigate the existence of a cointegrating relationship. As the order of integration is mixed, a residual based method of cointegration (the Engle-Granger test) is employed.[14] The results are presented in Table 8 and suggest that the null hypothesis of no cointegration can only be rejected for the Barbados and Guyana specifications. As such, the models for the Dominican Republic, Jamaica, St. Lucia and Trinidad and Tobago are estimated with the I(1) variables in first differences. Meanwhile, the models for Barbados and Guyana models are estimated using dynamic OLS (Saikkonen, 1991; Stock and Watson, 1993). A key benefit of this approach is that it allows for a mixture of I(1) and I(0) variables. Thus, equation (22) can be re-written as:

$$y_t = \alpha_0 + \beta Y_t^{us} + \gamma CCI_t + + \delta I_t + \sum_{j=-m}^{m} \delta \Delta N_{jt+m} + \varepsilon_{1t} \qquad (23)$$

where N_{jt+m} are the lead and lagged differences of the explanatory variables which account for possible serial correlation and endogeneity of the errors, respectively The optimal *m* is chosen based on Schwarz information criterion.

Table 8: Cointegration Tests

Country	***Engle-Granger τ statistic***	***Engle Granger Z statistic***
Bahamas	-2.084	-7.853
Barbados	-3.985**	-58.605***
Dominican Republic	-2.022	-8.762
Guyana	-3.448**	-18.953**
Jamaica	-1.915	-6.838
Saint Lucia	-0.802	-2.152
Trinidad and Tobago	-1.942	-13.834

Note: ***, ** and * indicate significance at the 1%, 5% and 10% levels respectively.

The models are then used to forecast real GDP up to 2050, using estimates of CCI and world real GDP under A2 and B2 climate change scenarios. Under the A2 scenario, it is assumed that climate change accrues output losses equivalent to about 0.9 percent over the period, as in Nordhaus (2006). Under the B2 scenario, the loss in world GDP is moderated to 0.5 percent.

The dataset utilised in this study consists of annual data for seven countries (the Bahamas, Barbados, Dominican Republic, Guyana, Jamaica, Saint Lucia and Trinidad and Tobago) over the period 1970 to 2009. These countries on average account for approximately 30 percent of the Caribbean's GDP. All data was attained from the United Nations National Accounts Main Aggregates Online Database and various Central Banks in the region. All variables are expressed in natural logarithms.

B. THE 1-2-3 MODEL

Once the impact of climate change on real GDP is estimated, the 1-2-3 model described below is used to simulate the impact of climate change on real GDP (X) and changes in

[14] Given the small sample properties and that there are only two I(1) variables in the model, the Engle-Granger test was chosen over other data-intensive approaches.

world prices (taken from Parry and others 2004) under the A2 and B2 climate change scenarios.

The 1-2-3 model is one of the simplest CGE models. The basic model refers to one country with two producing sectors and three goods and the model can be calibrated using little more than national accounts data The country produces an export good (which is sold to foreigners only) and a domestic good (D), which is only sold domestically. The third good is an import good (M) which is produced abroad. The country is small in world markets, facing fixed world prices for imports and exports. This model can be extended to include government revenue, government expenditure, savings and investment. The system of equations defining the 1-2-3 model with government and investment is presented in Table 9.

Table 9: The 1-2-3 Model with Government and Investment

Equations	Variable Description
Real Flows	Endogenous Variables
(1) $\bar{X} = G(E, D^s; \Omega)$	E: Export good
(2) $Q^s = F(M, D^d; \sigma)$	M: Import good
(3) $Q^d = C + Z + \bar{G}$	D^s : Supply of domestic good
(4) $\frac{E^s}{D} = g_2(P^e, P^d)$	D^d : Demand for domestic good
(5) $\frac{M^d}{D} = f_2(P^m, P^t)$	Q^s : Supply of composite good
Nominal Flows	Q^d : Demand for composite good
(5) $T = t^m \cdot R \cdot pw^m \cdot M + t^s \cdot P^q \cdot Q^d + t^y \cdot Y - t^e \cdot R \cdot pw^e \cdot E$	P^e : Price of domestic export good
(6) $Y = P^x \cdot \bar{X} + tr \cdot P^q + re \cdot R$	P^m : Price of domestic import good
(7) $S = \bar{s} \cdot Y + R \cdot \bar{B} + S^g$	P^t : Sales of composite good
(8) $C \cdot P^t = (1 - \bar{s} - t^y) \cdot Y$	P^x : Price of aggregate output
(9) $P^m = (1 + t^m) \cdot R \cdot pw^m$	P^q : Price of composite good
(10) $P^e = (1 + t^e) \cdot R \cdot pw^e$	R: Exchange rate
(11) $P^t = (1 + t^s) \cdot P^q$	T: Tax Revenue
(12) $P^x = g_1(P^e, P^d)$	S^g : Government savings
(13) $P^q = f_1(P^m, P^t)$	Y: Nominal GDP
(14) $R = 1$	C: Aggregate Household Consumption
Equilibrium Conditions	Z: Aggregate real investment
(15) $D^D - D^s = 0$	Exogenous Variables
(16) $Q^D - Q^s = 0$	pw^m : World price of import good
(17) $pw^m \cdot M - pw^e \cdot E - ft - re = \bar{B}$	pw^s : World price of export good
(18) $P^t \cdot Z \cdot S = 0$	t^m : Tariff rate
(19) $T \cdot P^q \cdot \bar{G} - tr \cdot P^q - ft \cdot R - S^g = 0$	t^e : Export subsidy rate
Accounting Conditions	t^s : Sales/Excise/Value-Added Tax rate
(20) $P^x \cdot \bar{X} = E \cdot P^e + P^d \cdot D^s$	t^y : Direct tax rate
(21) $P^q \cdot Q^s = P^m \cdot M + P^t \cdot D^D$	tr: Government transfers
	ft: Foreign transfers to government

	re: Foreign remittances to private sector
	$\bar{s}$: Average savings rate
	$\bar{X}$: Real GDP
	$\bar{G}$: Real Government Demand
	$\bar{B}$: Balance of Trade
	Ω : Export transformation elasticity
	σ : Import substitution elasticity

Source: Devarajan and others 1997

The 1-2-3 model can also be seen as a simple programming model (presented below) that maximises consumer utility, which is equivalent to social welfare.

Maximize $Q = F(M, D^D, \sigma)$
with respect to: M, E, D^D, D^S
subject to

Shadow Prices

$G(E, D^S; \Omega) \leq \bar{X}$ (technology) $\quad \lambda^x = \frac{P^x}{P^q}$

$pw^m \cdot M \leq pw^e \cdot E - ft - re = \bar{B}$ (balance of trade) $\quad \lambda^b = \frac{R}{P^q}$

$D^D \leq D^S$ (domestic supply and demand) $\quad \lambda^c = \frac{P^d}{P^q}$

Individual CGE models are solved for each country and the estimates of real GDP and increases in global food prices from Parry and others (2004) are integrated into the 1-2-3 model in order to evaluate the impact of climate change on the macroeconomy. A-priori, the higher prices and lower incomes expected under the A2 and B2 climate change scenarios should have negative impacts on most variables under consideration. For instance, conventional economic wisdom suggests that lower income should result in lower consumption and investment. Moreover, higher international food prices would translate to higher inflation, thus reducing the purchasing power by individuals and the real return on investment. Thus, under the B2 and A2 scenarios, consumption and investment should be lower than that of the BAU case. All simulations are calculated for 2050 using the forecasted climatic features and economic projections from Parry and others (2004).

IV. RESULTING MACROECONMIC IMPLICATIONS FOR THE CARIBBEAN

A. IMPACT OF CLIMATE CHANGE ON REAL GDP

The econometric results linking climate change and real GDP are provided in Table 10. The coefficients on the world real GDP terms are positive in each specification, indicating that Caribbean and world business cycles tend to be closely correlated. With respect to the climate change index, for most countries this coefficient is positive and significant across each model indicating that an improvement in climatic conditions (relatively higher precipitation and relatively lower temperatures) are positively correlated with improved economic outcomes. Thus, the expected deteriorating climate conditions, as a result of global warming, should have a direct impact on economic growth for Barbados, Dominican

Republic, Guyana, Jamaica, St. Lucia and Trinidad and Tobago. The only country where the climate index was statistically insignificant was Bahamas, probably due to the relative importance of world GDP on this economy, eliminating any domestically driven sources of economic fluctuations. For Bahamas, it appears as though effect on real output only emerges through the indirect impact of climate change on the global economy. This may be reflecting the Bahamas' high dependence on Bahamas on services (particularly tourism and off-shore services), and by extension, its high vulnerability to the global economy. In fact, the coefficient of the global GDP variable is largest for the Bahamas, hinting that global shocks may be the most harmful for this country.

Table 10: Regression Estimates

	Bahamas	Barbados	Dominican Republic	Guyana	Jamaica	St. Lucia	Trinidad and Tobago
ln(World Real GDP)	1.667*** [0.387]	0.406** [0.103]	0.589* [0.345	1.043** [0.276]	0.348** [0.160]	0.589** [0.286]	0.537** [0.317]
ln(CCI)	------	0.445** [0.026]	0.007*** [0.002]	1.043** [0.054]	0.018** [0.008]	0.005* [0.003]	0.006** [0.002]
Adjusted R^2	0.765	0.973	0.255	0.956	0.848	0.703	0.683
Q-Statistic (2)	1.336	3.573	3.241	3.134	0.290	0.018	4.292
Jarque-Bera Statistic	1.588	0.253	0.953	0.952	2.160	1.065	0.237

Notes (1) Standard errors are in squared parentheses
(2) ***,** and * represent significance at the 1%, 5% and 10% levels of significance

Using the estimates presented in Table 10, forecasts of the likely losses in real GDP due to climate change are provided. The authors consider three scenarios: the A2, B2 and 'baseline' or 'business as usual' (BAU) scenarios. In this study, BAU is interpreted to mean the likely future for key economic and environmental variables in the absence of changes in climatic pattern. As such, the BAU scenario values of real GDP are forecasted using the univariate structural time series model of Harvey, 1989. The cumulative losses due to climate change factors are then calculated as the difference between the BAU scenarios and the respective A2 and B2 climate change scenarios.

Given the long-run nature of the climate change impact assessments, the authors opt to also calculate the present value of the impacts over the forecast horizon. Unfortunately, there is no commonly accepted notion of what discount rate should be used. As such, this study opts for an eclectic approach by using a number of discount rates: 1, 2 and 4 percent. All calculations begin from 2009 and are presented in Table 11.

The estimates suggest that each country under investigation will experience significant losses in real GDP if no action is undertaken to mitigate the damage caused by climate change. Based on a discount value of 1%, losses due to climate change range from a low of US $4.6 billion to as high as US $696 billion.

In nominal terms, the future impact of climate change appears to be greatest for the Dominican Republic, with this country reporting nominal losses of between US $512 (B2) and US $696 billion (A2) up to 2050, which translates to about US $12 -17 billion in real GDP losses per annum. Of course, the discounted values are much less dramatic. Based on a discount rate of 1 percent, the projected losses in real output under the A2 scenario and B2 scenarios are within the range of US $341- 463 billion. Considering the cumulative losses as a percent of 2009 GDP, the impact of climate is largest for Guyana. In Guyana, the cumulative losses in real GDP are the equivalent of about 30 times nominal GDP in 2009. Initially, the findings for Guyana may seem quite large relative to its Caribbean neighbors, but as noted by Haites and others (2002), a key channel through which climate change affects Caribbean economies is through their agricultural, forestry and fishing sectors. Data from the UN National Accounts databases suggests that between 1970-2009, the average contribution of the agriculture, hunting, forestry and fishing sectors to GDP for Bahamas, Barbados, Dominican Republic, Guyana, Jamaica, St. Lucia and Trinidad and Tobago was 2.2, 6.8, 11.1, 23.3, 6.9, 10.4 and 2.4 percent respectively. Given that Guyana has the largest dependence on the agriculture, hunting, forestry and fishing sectors, the high costs of climate change in terms of GDP relative to the other countries in the sample are quite plausible.

Table 11: Estimated Cumulative Losses in Real GDP under Various Climate Change Scenarios (US $ Millions)

	Bahamas	Barbados	Dominican Republic	Guyana	Jamaica	St. Lucia	Trinidad and Tobago
A2 Scenario							
Cumulative Losses	205295	13410	695906	60495	194746	6681	8980
Cumulative Losses - Present Value (1 % discount rate)	136522	8918	462780	40229	129507	4443	5971
Cumulative Losses - Present Value (2 % discount rate)	91153	5954	308990	26860	86469	2966	3987
Cumulative Losses - Present Value (4 % discount rate)	41116	2686	139375	12116	39003	1338	1798
Cumulative Losses as a ratio of 2009 GDP	29.0	3.7	14.9	29.6	15.7	7.0	0.4
Cumulative Losses (Present Value 1 % discount rate) as a ratio of 2009 GDP	19.3	2.5	9.9	19.7	10.4	4.7	0.3
Cumulative Losses (Present Value 2 % discount rate) as a ratio of 2009 GDP	12.9	1.7	6.6	13.1	7.0	3.1	0.2
Cumulative Losses (Present Value 4 % discount rate) as a ratio of 2009 GDP	5.8	0.7	3.0	5.9	3.1	1.4	0.1
B2 Scenario							
Cumulative Losses	204920	14091	512056	61517	233058	7348	7930
Cumulative Losses - Present Value (1 % discount rate)	136273	9371	340519	40909	154985	4887	5273
Cumulative Losses - Present Value (2 % discount rate)	90987	6257	227358	27314	103480	3263	3521
Cumulative Losses - Present Value (4 % discount rate)	41041	2822	102554	12320	46676	1472	1588
Cumulative Loss as a ratio of 2009 GDP	29.0	3.9	11.0	30.1	18.8	7.8	0.4
Cumulative Losses (Present Value 1 % discount rate) as a ratio of 2009 GDP	19.3	2.6	7.3	20.0	12.5	5.2	0.2
Cumulative Losses (Present Value 2 % discount rate) as a ratio of 2009 GDP	12.9	1.7	4.9	13.4	8.3	3.4	0.2
Cumulative Losses (Present Value 4 % discount rate) as a ratio of 2009 GDP	5.8	0.8	2.2	6.0	3.8	1.6	0.1

An interesting observation is that for most countries, the losses in real GDP are greatest under the B2 scenarios. This result is somewhat expected. As depicted in Figure 12 and Figure 13 up to year 2050, the decline in Caribbean precipitation is much greater under the B2 scenario than in the A2 scenario. Moreover, the differences in temperature are modest. The only deviation from this trend is the Bahamas Dominican Republic. Looking first at the case of Bahamas, this finding largely reflects that the losses in global GDP under the A2 scenario are greater than that of the B2 scenario. For the Dominican Republic, a close look at the data reveals that in contrast to the other countries under consideration, the decline in precipitation under the A2 scenario are much more dramatic than that of the B2, while the difference in temperatures under the two scenarios are quite small. Thus, the losses in GDP are smaller under the B2 scenarios for this country.

B. POTENTIAL MACROECONOMIC IMPACTS – RESULTS FROM THE 1-2-3 MODEL

The estimates of real GDP outlined earlier and increases in global food prices from Parry and others (2004) are integrated into the 1-2-3 model to evaluate the impact of climate change on the macroeconomy. These higher prices and lower incomes under the A2 and B2 climate change scenarios are anticipated to have negative impacts on key economic variables. For instance, conventional economic wisdom suggests that lower income should result in lower consumption and investment. Moreover, higher international food prices would translate to higher inflation, thus reducing the purchasing power by individuals and the real return on investment. Thus, under the B2 and A2 scenarios, consumption and investment should be lower than that of the BAU case.

The case of the fiscal balance is a bit more complex. On the revenue side, the lower income due to climate change may reduce tax receipts. But, the overall decline may be somewhat mitigated by the increased revenues from import duties (due to the higher price of imported food). Government's expenditure may also be inflated from higher prices, but may be offset by lower domestic demand. Thus, the overall effect on savings is ambiguous.

The impact of climate change on international trade is also complicated, as the price and income effects move in opposite directions. Generally, the price increases identified by Parry and others (2004), should result in inflated import and export values. However, the reduction in real GDP may lower demand for imports and also reduce the production of the export good. As such, the net effect on the trade variables is ambiguous and largely depends on which impact dominates.

Table 12 presents the impact of climate change on the macroeconomy. Specifically, the difference between the forecasts for the year 2050 under the climate change scenarios and the BAU case are shown for each variable and expressed as a ratio of 2009 nominal GDP. In line with our a-prior expectations, consumption is negatively affected by climate change. Consumption losses are largest for Guyana, with this country reporting losses in consumption equivalent to about 81 percent of 2009 GDP under the A2 scenario and 81 percent of 2009 GDP in the B2 scenario. Investment is also negatively impacted by climate change. Under the A2 scenario, the reduction in investment relative to the BAU scenario lies with the range of US $255 million (Guyana) and US $14.9 billion (Trinidad), and US $225 million and US $10.6 billion for the B2 outcome.

Turning to the case of fiscal balances, it appears as though climate change is negatively related to government savings. In each country, there is a significant deterioration of the fiscal accounts, with government savings being below the BAU scenario by a minimum of 5 percent of 2009 GDP. The impact on the fiscal accounts of Jamaica is particularly severe, with the fiscal deficit being below the BAU estimates by 33 percent of 2009 GDP under the A2 forecasts, and as high as 41 percent of 2009 GDP in the B2 case.

Finally, the impact on trade is examined. Looking first at the A2 scenario, exports are generally lower than that the BAU scenario. The only exception is Barbados. Thus, with the A2 climate outcome, the price impact seems to dominate the income impact. Interestingly, under the B2 scenario, most countries have lower exports relative to the BAU scenario; the only exception is the Dominican Republic. With respect to imports, the 1-2-3 models for all countries suggest that the income effects dominate the price effects, resulting in lower demand for imported goods relative to the BAU scenarios.

Table 12: Estimated Impact of Climate Change on the Macroeconomy, expressed as a ratio of 2009 nominal GDP

	Bahamas	Barbados	Dominican Republic	Guyana	Jamaica	St. Lucia	Trinidad and Tobago
A2 Scenario							
Consumption	-0.76	-0.17	-0.22	-0.81	-0.45	-0.57	-0.56
Investment	-0.62	-0.26	-0.32	-0.12	-0.16	-0.34	-0.67
Fiscal Balance	-0.32	-0.13	-0.13	-0.20	-0.33	-0.19	-0.27
Exports	-0.57	0.21	-0.08	-0.40	-0.23	-0.19	-0.11
Imports	-0.81	-0.40	-0.68	-0.65	-0.42	-0.63	-1.05
B2 Scenario							
Consumption	-0.74	-0.34	-0.09	-0.88	-0.45	-0.51	-0.41
Investment	-0.59	-0.55	-0.15	-0.11	-0.14	-0.28	-0.50
Fiscal Balance	-0.27	-0.35	-0.05	-0.22	-0.41	-0.16	-0.22
Exports	-0.57	-0.48	0.03	-0.52	-0.24	-0.24	-0.18
Imports	-0.75	-0.68	-0.40	-0.65	-0.38	-0.53	-0.79

As in the case of real GDP, the present value of the impact of climate change is also calculated using discount rates of 1 percent, 2 percent and 4 percent. These are presented in Table 13.

Table 13: Present Value Estimates of the Impact of Climate Change on the Macroeconomy (US $ Million)

	Bahamas	Barbados	Dominican Republic	Guyana	Jamaica	St. Lucia	Trinidad and Tobago
A2 Scenario							
Discount rate – 1%							
Consumption	-3597	-402	-6773	-1106	-3717	-359	-7905
Investment	-2920	-616	-10063	-166	-1322	-211	-9349
Fiscal Balance	-1486	-321	-4169	-277	-2737	-122	-3822
Exports	-2685	510	-2589	-540	-1871	-121	-1593
Imports	-3812	-951	-21135	-882	-3446	-397	-14816
Discount rate – 2%							
Consumption	-2402	-268	-4522	-738	-2482	-240	-5278
Investment	-1950	-411	-6719	-111	-883	-141	-6242
Fiscal Balance	-992	-214	-2783	-185	-1828	-81	-2552
Exports	-1793	340	-1728	-361	-1249	-81	-1064
Imports	-2545	-635	-14111	-589	-2301	-265	-9892
Discount rate – 4%							
Consumption	-1083	-121	-2040	-333	-1119	-108	-2381
Investment	-879	-185	-3031	-50	-398	-64	-2816
Fiscal Balance	-448	-97	-1256	-84	-824	-37	-1151
Exports	-809	153	-780	-163	-563	-36	-480
Imports	-1148	-286	-6365	-266	-1038	-120	-4462
B2 Scenario							
Discount rate – 1%							
Consumption	-3474	-821	-2651	-1198	-3710	-323	-5798
Investment	-2770	-1316	-4699	-156	-1184	-179	-6990
x	-1293	-840	-1613	-305	-3415	-100	-3079
Exports	-2704	-1156	1013	-714	-2020	-151	-2500
Imports	-3551	-1618	-12482	-890	-3096	-337	-11061
Discount rate – 2%							
Consumption	-2320	-548	-1770	-800	-2477	-216	-3871
Investment	-1849	-879	-3138	-104	-791	-119	-4667
Fiscal Balance	-863	-561	-1077	-204	-2280	-67	-2056
Exports	-1805	-772	677	-477	-1349	-101	-1669
Imports	-2371	-1080	-8334	-594	-2067	-225	-7385
Discount rate – 4%							
Consumption	-1046	-247	-798	-361	-1117	-97	-1746
Investment	-834	-396	-1415	-47	-357	-54	-2105
Fiscal Balance	-389	-253	-486	-92	-1029	-30	-927
Exports	-814	-348	305	-215	-608	-46	-753
Imports	-1070	-487	-3759	-268	-932	-101	-3331

V. ADAPTATION OPTIONS

A. RECOMMENDATIONS

As noted above, Caribbean countries have already taken steps toward developing the institutional, legal and technical aspects of climate change adaptation and risk management. While these actions have shown that policy makers in the Caribbean are sensitive to potential adverse climatic events, there is still a further work that could be done. According to Trotz (2008), there is still a lack of understanding and seriousness about climate change and its impacts among Caribbean governments. Consequently, most governments are not committed to invest in adaptation measures on the basis of climate change. Moreover, those policies that can be considered adaptation responses were not informed by knowledge of climate change potential impacts, but rather driven by other stressors (Trotz, 2008).

There is also a further concern that adaptation measures adopted by small states are limited, based directly on climate change concerns, ad hoc or implemented in isolation (UNEP, 2008). Consequently, Caribbean states are at different stages of their development goals with respect to climate change adaptation and risk management. In light of this, this section seeks to provide broad adaptation measures that will strengthen and improve climate change adaptation readiness in the Caribbean. Trotz (2008) highlights some of the main gaps in the Caribbean's adaptation response to climate change impacts.

- The database covering sea-level and climate monitoring is limited. It was suggested that there be an upgrading of the infrastructure that was developed under the CPACC. This is meant to improve the collection, analysis and mapping of climate and sea-level information.
- There needs to be an improvement in the knowledge base if climate impact and vulnerability assessments are to be effective, since most of the information of eco-systems in the Caribbean is sub-standard.
- There needs to be the development of models and capacity to understand the impact of climate change on coastal ecosystems and water-cycle specific to the Caribbean.
- Caribbean countries need to develop a comprehensive inventory of vulnerable key infrastructure and economic sectors to adverse climate change.
- There is a lack of emphasis on the social vulnerabilities in most assessments studies, and they fail to account for community level information.
- There is a need to review climate impact models and risk assessment methodologies in order to develop a reliable knowledge base applicable to Caribbean economies.
- Impact studies on ecosystems, human settlement, and coastal infrastructure.
- Continued push toward public education and outreach.
- There needs to be a clear definition of what constitutes climate change risk in so as to develop suitable insurance instruments.

Key to succesfully minimising the negative impact of climate change on the regional macroeconomy will be the ability of countries to diversify their economies away from vulnerable industries such as fisheries, agriculture and tourism. As noted, the region is particularly dependent on these industries which, when coupled with inherent vulnerability as small island states, heightens the urgency of considering the development of industries that are less directly impacted by rising temperatures, rising sea levels and increased incidence of severe weather. Examples of attractive industries would include financial services, cultural industries, health services, education services as well as other service industries. While there will still be indirect impacts, reducing dependency on industries that depend on coastal ecosystems should be part of the adaptation to climate change.

With respect to adaptation options geared toward specific adverse climatic impacts, there are several individual options available to Caribbean states. Many of these options may also be considered a part of or incorporated into the development strategies of countries in the region. As noted earlier in the study the effects of climate change on Caribbean economies is likely to be quite heterogeneous. As a result, a fairly comprehensive list of adaptation options is outlined so as to capture varied effect of climate change in the region. In table 19, we summarise specific adaptation options according to the risk to the region. For each risk, we identify its source as well as suggest options for mitigation. The benefits of each option are identified based on 10 criteria:

- cost
- effectiveness
- acceptability to local stakeholders
- acceptability to financing agencies
- endorsement by experts
- an attractive time frame
- institutional capacity
- size of beneficiaries group
- potential environmental or social impact
- potential to sustain over time

It is hoped that classifying the risks this way will assist decision-makers in understanding how each risk can be minimised.

Table 19: Risks Associated with Climate Change and Potential Adaptation Options

Risks	Source	Risk mitigation or transfer options	Possible Benefits									
			Cost	Effectiveness	Acceptability to Local Stakeholders	Acceptability to Financing Agencies	Endorsement by Experts	Time Frame	Institutional Capacity	Size of Beneficiaries Group	Potential Environmental or Social Impacts	Potential to Sustain over time
Higher peak demand and transmission inefficiencies in electricity supply	Rising temperatures	Building energy rating programme		X		X	X			X	X	
		Require LEED or equivalent standards for new buildings		X		X	X			X	X	
		Retrofitting programme		X		X	X			X	X	
		Time-of-use or peak demand energy pricing				X	X		X			X
		Incentives for the installation of renewable energy systems on new buildings		X		X				X		
Rising energy costs	Rising global demand for energy	Incentives for the transition to the green economy		X	X	X	X			X	X	
		Establish a green roof/wall grant or incentive programme		X		X	X					X
		Outreach programme to inform firms and individuals about the benefits of cool roof technologies	X	X	X	x	X			X	X	X
		Cool paving techniques for streets		X	X	X	X		X	X	X	

Risks	Source	Risk mitigation or transfer options	Possible Benefits									
			Cost	Effectiveness	Acceptability to Local Stakeholders	Acceptability to Financing Agencies	Endorsement by Experts	Time Frame	Institutional Capacity	Size of Beneficiaries Group	Potential Environmental or Social Impacts	Potential to Sustain over time
		Shade trees and permeable reflective pavements		X	X	X	X		X	X	X	
		Incentives for urban forests and private properties		X	X	X						
Reduction in agro-biodiversity	Higher temperature s and lower rainfall	Selection of crops and cultivars with tolerance to abiotic stresses	X	X		X	X			X		
	Variability in rainfall patterns	Soil organic matter		X		X	X			X		
		Hedges and other landscaping practices		X	X	X	X			X	X	
		Water storage			X	X						
Reduction in forest area	Altered time of seeding and increased pest and disease outbreaks	Development of monitoring and assessment	X	X	X	X	X			X	X	
Reduced crop yields	Variability in climatic patterns	Early warning and risk management systems		X	X	X	X			X	X	
		Agricultural subsidies and support programmes			X			X	X			
Reduction in livestock productivity	Reduction in availability of fodder and pastures	Development of monitoring and evaluation systems	X	X	X	X	X			X	X	

Risks	Source	Risk mitigation or transfer options	Possible Benefits									
			Cost	**Effectiveness**	**Acceptability to Local Stakeholders**	**Acceptability to Financing Agencies**	**Endorsement by Experts**	**Time Frame**	**Institutional Capacity**	**Size of Beneficiaries Group**	**Potential Environmental or Social Impacts**	**Potential to Sustain over time**
Increased variability of fish catches	Rising sea tem-peratures	Monitoring and feedback systems		X		X	X					
		Aquaculture		X		X	X					
		Wild fish management		X		X						
Increased rural poverty	Reduction in incomes from agriculture	National and sub-national early warning systems	X	X	X	X	X			X	X	X
		Strengthen the capacity of communities to manage their resources	X	X	X	X	X			X		X
		Technological options to manage climate variability		X		X	X				X	
		Raise awareness among farmers	X	X	X	X	X	X	X	X	X	
		Crop insurance		X		X	X	X				
		Crop share and futures				X	X					
		Income stabilization programs		X	X							
Increased wind speed	Greater number of category 4 and 5 hurricanes	Increase recommended design wind speeds for new structures	X	X			X	X			X	X
		Offer incentives to retrofit facilities to limit the impact of increased wind speeds									X	
		Retrofit ports to accommodate the expected rise in wind		X			X					

Risks	**Source**	**Risk mitigation or transfer options**	**Possible Benefits**									
			Cost	**Effectiveness**	**Acceptability to Local Stakeholders**	**Acceptability to Financing Agencies**	**Endorsement by Experts**	**Time Frame**	**Institutional Capacity**	**Size of Beneficiaries Group**	**Potential Environmental or Social Impacts**	**Potential to Sustain over time**
		speeds										
		Catastrophe insurance for government buildings		X	X	X						
		Insurance for adaptive rebuilding		X	X	X						
Decreased availability of fresh water	Increased frequency of droughts	Construction of water storage tanks			X	X	X	X				
		Irrigation network that allows for the recycling of waste water			X	X	X			X	X	
		Retrofit buildings to conserve water		X	X	X	X					
		Build desalination plants		X	X					X		
		Drought insurance		X	X			X				
Land loss	Sea level rise	Build sea wall defences and breakwaters			X					X	X	
		Replant mangrove swamps			X		X			X	X	
		Raise the land level of low lying areas			X							
		Build infrastructures further back from coast	X	X		X	X				X	
		Beach nourishment			X							
		Limit sand mining for building materials	X	X		X	X				X	
		Introduce new legislation to change planning policies, zoning and land use priorities as needed	X	X			X				X	

Risks	Source	Risk mitigation or transfer options	Possible Benefits									
			Cost	**Effectiveness**	**Acceptability to Local Stakeholders**	**Acceptability to Financing Agencies**	**Endorsement by Experts**	**Time Frame**	**Institutional Capacity**	**Size of Beneficiaries Group**	**Potential Environmental or Social Impacts**	**Potential to Sustain over time**
Loss of coral reefs	Inhibition of aragonite formation as carbonate-ion concentrations fall	Coral nurseries to help restore areas of the reef that have been damaged due to the effects of climate change		X			X			X	X	
		Enhanced reef monitoring systems to provide early warning alerts of bleaching events	X	X	X	X	X			X	X	X
		Strengthen the scientific rigor and ecological relevance of existing water quality programs	X	X	X	X	X			X	X	X
		Develop innovative partnerships with, and provide technical guidance to landowners and users to reduce land based sources of pollution		X			X				X	
		Control discharges from known point sources such as vessel operations and offshore sewage		X			X				X	
		Artificial reefs or fish-aggregating devices		X	X		X			X	X	
		Enhancing coral larval recruitment		X	X		X			X	X	
		Enhancing recovery by culture and		X	X		X			X	X	

Risks	Source	Risk mitigation or transfer options	Possible Benefits									
			Cost	Effectiveness	Acceptability to Local Stakeholders	Acceptability to Financing Agencies	Endorsement by Experts	Time Frame	Institutional Capacity	Size of Beneficiaries Group	Potential Environmental or Social Impacts	Potential to Sustain over time
		transportation of corals										
		Establish special marine zones		X			X			X	X	
		Implement pro-active plans to respond to non-native invasive species		X							X	
Extreme weather events	Climate Change	Provide greater information about current weather events	X	X	X	X	X	X	X	X		X
		Develop national guidelines	X	X	X	X	X	X	X	X	X	X
		Develop national evacuation and rescue plans	X	X	X	X	X	X	X	X	X	X
		More stringent insurance conditions coastal properites	X	X			X					
		Flood drainage protection for coastal properties	X	X			X					
		Accelerated depreciation of properties in vulnerable coastal zones		X	X		X					
		Supporting infrastructure investment for new tourism properties		X	X							
Reduction in travel demand	Climate Change	Increase advertising in key source markets		X	X		X	X				
		Fund discount programmes run by airlines		X	X		X	X				
		Fund discount		X	X		X	X				

Risks	Source	Risk mitigation or transfer options	Possible Benefits									
			Cost	Effectiveness	Acceptability to Local Stakeholders	Acceptability to Financing Agencies	Endorsement by Experts	Time Frame	Institutional Capacity	Size of Beneficiaries Group	Potential Environmental or Social Impacts	Potential to Sustain over time
		programmes run by hotels										
		Introduce "green certification" programmes for hotels		X	X		X					
		Conducting energy audits and training to enhance energy efficiency in the industry		X			X					
		Introduce built attractions to replace natural attractions		X			X			X		
		Recognition of the vulnerability of some eco-systems and adopt measures to protect them		X			X				X	
		Introduction of alternative attractions		X	X		X			X	X	
		Provide re-training for displaced tourism workers		X	X		X	X		X		
		Revise policies related to financing national tourism offices to accommodate the new climatic realities	X	X	X		X	X				
Reduction in available water supplies	Reduced rainfall	Meter all water users		X		X	X			X	X	X
		Support inclining block rate or volumetric water pricing	X	X		X	X	X	X	X	X	X

Risks	Source	Risk mitigation or transfer options	Possible Benefits									
			Cost	Effectiveness	Acceptability to Local Stakeholders	Acceptability to Financing Agencies	Endorsement by Experts	Time Frame	Institutional Capacity	Size of Beneficiaries Group	Potential Environmental or Social Impacts	Potential to Sustain over time
		Educational tours of water resources for students	X	X	X	X	X	X	X	X	X	X
		Provide incentives for water efficiency retrofits		X	X	X	X			X	X	
		Change building codes to require low flow plumbing	X	X		X	X	X		X	X	
		Use of reclaimed/recycled water		X			X			X	X	
		Desalination					X			X	X	
		Water offsets for new developments		X			X			X	X	
		Reduce leakages in water supply networks		X	X	X	X			X	X	

VI. REFERENCES

A, C. M. (2005). The Evolution of El Nino, Past and Future. *Earth and Planetary Science Letters , 230* (3-4), 227-240.

Amelung, B., Nicholls, S., & Viner, D. (2007). Implications of Global Climate Change for Tourism Flows and Seasonality. *Journal of Travel Research , 45* (3), 285-296.

Aronson, R. B., Precht, W. F., Macintyre, I. G., & Murdoch, T. J. (2000). Ecosystems: Coral Bleach-Out in Belize. *Nature , 405* (6782), 36.

Beniston, M. (2003). Climate Change in Mountain Regions: A Review of Possible Impacts. *Climatic Change , 59* (1-2), 5-31.

Beukering, P., Brander, L., Immerzeel, D., Leotaud, N., Mendes, S., Soesbergen, A., and others (2008). *Value After the Volcano: Economic Valuation of Montserrat's Centre Hills.* Bedfordshire: Royal Society for the Protection of Birds.

Bishop, M. L. (2010). Tourism as a Small-State Development Strategy: Pier Pressure in the Eastern Caribbean. *Progress in Development Studies , 10* (2), 99-114.

Black, B. A., Schroeder, I. D., Sydeman, W. J., Bograd, S. J., & Lawson, P. W. (2010). Wintertime Ocean Conditions Synchronize Rockfish Growth and Seabird Reproduction in the central California Current Ecosystem. *Canadian Journal of Fisheries and Aquatic Sciences , 67* (7), 1149.

Bosello, F., & Zhang, J. (2005). Assessing Climate Change Impacts: Agriculture. *FEEM Working Paper No. 94. 05; CMCC Research Paper No. 02* .

Brouwer, R., & Spaninks, F. A. (1999). The Validity of Environmental Benefits Transfer: Futher Empirical Testing. *Environmental and Resource Economics , 14* (1), 95-117.

Brown, C., Meeks, R., Ghile, Y., & Hunu, K. (2010). *An Empirical Analysis of the Effects of Climate Variables on National Level Growth.* World Bank.

Bueno, R., Stanton, E. A., Ackerman, F., & Herzfeld, C. (2008). *The Caribbean and Climate Change: The Cost of Inaction.* Tufts University.

Burke, L., Greenhalgh, S., Prager, D., & Cooper, E. (2008). *Coastal Capital: Economic Valuation of Coral Reefs in Tobago and St. Lucia.* Washington, DC: World Resources Institute.

CARICOM Secretariat, .. (2001-2004). *Adaptation To Climate Change In the Caribbean (ACCC) Project.* Retrieved September 21, 2011, from Caribbean Community (CARICOM) Secretariat: http://caricom.org/jsp/projects/macc%20project/accc.jsp

CARICOM Secretariat, .. (1997-2001). *Caribbean Planning for Adaptation to Climate Change (CPACC) Project*. Retrieved September 21, 2011, from Caribbean Community (CARICOM) Secretariat: http://caricom.org/jsp/projects/macc%20project/cpacc.jsp

CARICOM Secretariat, .. (2004-2007). *Mainstreaming Adaptation to Climate Change (MACC) Project*. Retrieved September 21, 2011, from http://caricom.org/jsp/projects/macc%20project/macc.jsp

CCCCC. (2010, March 1). CCCCC News Letter. *Special Program on Adaptation to Climate Change* , p. 7.

Chand, S. S., E, W. K., & Chan, J. C. (2010). A Bayesian Regression Approach to Seasonal Prediction of Tropical Cyclones Affectiing the Fiji Region. *Journal of Climate , 23* (13), 3425-3446.

Ciscar, J.-C., Iglesias, A., Feyen, L., Szabo, L., Regemorter, D. V., Amelung, B., and others (2011). Physical and Economic Consequences of Climate Change in Europe. *10.1073/pnas.1011612108* , *108* (7), 2678-2683.

Clayton, A. (2009). Climate Change and Tourism: The Implications for the Caribbean. *Worlwide Hospitality and Tourism Themes* , *1* (3), 212-230.

Clements, R., & Practical Action, C. (2009). *The Economic Cost of Climate Change in Africa.* Pan African Climate Justice Alliance.

Coathrup, D. C. (2002). Situational Analysis and Overview: The Tourism Sector in St. Lucia. *Discussion Paper* . Castries.

Collins, M. (2000). The El Nino - Souther Oscillation in the Second Hadley Centre Coupled Model and its Response to Greenhouse Warming. *Journal of Climate* , *13* (7), 1299-1312.

Crick, A. P. (2003). Internal Marketing of Attitudes in Caribbean Tourism. *International Journal of Contemporary Hospitality Management* , *15* (3), 161-166.

Crosson, P. R., & Rosenberg, N. J. (1993). An Overview of the Mink Study. *Climate Change* , *24* (1-2), 159-173.

CTO. (Various Issues). *Caribbean Statistical Report.* Bridgetown: Caribbean Tourism Organisation.

Davies, R. B. (1987). Hyothesis Testing When a Nuisance Parameter is Present Only Under the Alternative. *Biometrika* , *74*, 33-43.

de Albuquerque, K., & McElroy, J. (1995). Planning for Effective Management and Sustainable Development of Coastal Resources in Caribbean Small Island States. *Caribbean Dialogue* , *2* (1), 11-16.

de Freitas, C. R. (2003). Tourism Climatology: Evaluating Environmental Information for Decision Making and Business Planning in the Recreation and Tourism Sector. *International Journal of Biometeorology* , *48* (1), 45-54.

Deslandes, D. (2006). Assessing the Image of St. Lucia: Does the Type of Visitor Matter? *Journal of Eastern Caribbean Studies* , *31* (4), 53-84.

Devarajan, S., Go, D., Lewis, J., Robinson, S., & Sinko, P. (1997). Simple General Equillibrium Modeling. In J. Francois, & K. Reinert (Eds.), *Applied Methods for Trade Policy Analysis: A Handbook* (pp. 156-185). New York: Cambridge Univesity Press.

ECCB. (2009). *Annual Economic and Financial Review.* Basseterre, St. Kitts and Nevis: Eastern Caribbean Central Bank.

ECLAC. (2009). *Economimcs of Climate Change in Latin America and the Caribbean. Summary.* Santiago, Chile.

Emmanuel, K., & Spence, B. (2009). Climate Change Implications for Water Resource Management in the Caribbean. *Worldwide Hospitality and Tourism Themes* , *1* (3), 252-268.

Frankhauser, S. (1994). The Social Cost of Greenhouse Gas Emission: An Expected Value Approach. *The Energy Journal* , *15* (2), 157-184.

Frankhauser, S. (1995). *Valuing Climate Change: The Economics of the Greenhouse.* Routledge.

Gafar, J. (1998). Growth, Inequality and Poverty in Selected Caribbean and Latin American Countries, with Emphasis on Guyana. *Journal of Latin American Studies* , *30*, 591-617.

GCSI. (2002). *Assessment of the Economic Impact of Climate Change on CARICOM Countries.* World Bank, Environment and Socially Sustainable Development -

Latin America and the Caribbean. Toronto: Global Change Strategies International.

Gill, J. A., Watkinson, A. R., McWilliams, J. P., & Cote, I. M. (2006). Opposing Forces of Aerosol Cooling and the El Nino Drive Coral Bleaching on Caribbean Reefs. *Proceedings of the National Academy of Sciences of the United States of America , 103* (49), 18870.

Government_of_Saint_Lucia. (2005, January 19). *St. Lucia National Climate Change Policy and Adaptation Plan.* Retrieved October 13, 2010 from Climate Change Website of St. Lucia: http://www.climatechange.gov.lc/NCC_Policy-Adaptation_7April2003.pdf

Gray, G. A. (2010). *National Climate Change Issues Paper: Towards the Formulation of a National Climate Change (Adaptation) Policy and Action Plan.* Department of Environment. Brades: Ministry of Agriculture, Land, Housing and the Environment.

Griffith, A. (2001). *The Characteristics of Water Use in Three Residential Areas in Barbados Implications for a Conservation Strategy*. unpublished MSc dissertation, University of the West Indies, Kingston.

Haites, E., Pantin, D., & Bruce, J. (2002, July). Assessment of the Economic Impact of Climate Change on CARICOM Countries. Toronto, Canada.

Hamilton, J. M., & Lau, M. A. (2005). The Role of Climate Information in Tourist Destination Choice Making. In S. Gossling, & M. C. Hall, *Tourism and Global Environmental Change* (Vol. 1, pp. 229-250). Routledge.

Harrison, S. J., Winterbottom, S. J., & Sheppard, C. (1999). The Potential Effects of Climate Change on the Scottish Tourist Industry. *Tourism Management , 20* (2), 203-211.

Harvey, A. C. (1989). *Forecasting Structural Time Series and Kalman Filter.* Cambridge: Cambridge University Press.

Hein, L. (2007). *The Impact of Climate Change on Tourism in Spain.* Blindern: Centre for International Climate and Environmental Research.

Hendry, D. F., & Krolzig, H.-M. (2005). The Properties of Automatic Gets Modelling. *Economic Journal , 115*, C32-C61.

Henry, R. (1989). Inequality in Plural Societies: An Exploration. *Social and Economic Studies , 38*, 69-110.

Hoegh-Guldberg, O. e. (2007). Coral Reefs Under Rapid Climate Change And Ocean Acidification. *Science , 318*, 1737-1742.

Hoegh-Guldberg, O., Mumby, P. J., Hooten, A. J., Steneck, R. S., Greenfield, P., Gomez, E., and others (2007). Coral Reefs Under Rapid Climate Change And Ocean Acidification. *Science , 318*, 1737-1742.

Hoegh-Guldberg, O., Mumby, P., Hooten, A., Steneck, R., Greenfield, P., Gomez, E., and others (2007). Coral Reefs Under Rapid Climate Change and Ocean Acidification. *Science , 318* (5857), 1737-1742.

IMF. (2011). *World Economic Outlook - Slow Growth, Rising Risks.* Washington, DC: International Monetary Fund.

IPCC, I. P. (2007). *Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge: Cambridge University Press.

Kaars, S., Tapper, N., & Cook, E. J. (2010). Observed Relationships between El Nino-Southern Oscillation, Rainfall Variability and Vegetation and Fire History on Halmahera, Maluku, Indonesia. *Global Change Biology , 16* (6), 1705.

Kim, Y., & Uysal, M. (1997). The Endogenous Nature of Price Variables in Tourism Demand Studies. *Tourism Analysis , 2* (1), 9-16.

Koenig, U., & Abegg, B. (1997). Impacts of Climate Change on Winter Tourism in the Swiss Alps. *Journal of Sustainable Tourism , 5* (1), 46-58.

Koopman, S. J., Harvey, A. C., Doornik, J. A., & Shephard, N. (2009). *Structural Time Series Analyser, Modeller and Predictor.* London: Timberlake Consultants Ltd.

Kossin, J. P., Camargo, S. J., & Sitkowski, M. (2010). Climate Modulation of North Atlantic Hurricane Tracks. *Journal of Climate , 23* (11), 3057-3077.

Landsea, C. W., Pielke, R. A., Mestas-Nunez, A. M., & Knaff, J. A. (1999). Atlantic Basin Hurricanes: Indices of Climatic Change. *Climate Change , 42*, 89-129.

Lanne, M., Lutkepohl, H., & Saikkonen, P. (2002). Comparison of Unit Root Tests for Time Series with Level Shifts. *Journal of TIme Series Analysis , 23*, 667-685.

Latimer, H. (1985). Developing-Island Economies – Tourism v. Agriculture. *Tourism Management , 6* (1), 32-42.

Lee, C. K., Var, T., & Blaine, T. W. (1996). Determinants of Inbound Tourist Expenditures. *Annals of Tourism Research , 23* (3), 527-542.

Lim, C. (1997). Review of International Tourism Demand Models. *Annals of Tourism Research , 24* (4), 835-849.

Lise, W., & Tol, R. S. (2002). Impact of Climate on Tourist Demand. *Climatic Change , 55* (4), 429-449.

Maddison, D. J. (2003). The Amenity Value of the Climate: The Household Production Function Approach. *Resource and Energy Economics , 25* (2), 155-75.

Magnusson, W. E., Layme, V. M., & Lima, A. P. (2010). Complex Effects of Climate Change: Population Fluctuations in a Tropical Rodent are Associated with the Southern Oscillation Index and Regional Fire Extent, but not Directly with Local Rainfall. *Global Change Biology , 19* (9), 2401.

Malmgren, B. A., Winter, A., & Chen, D. (1998). El Nino-Southern Oscillation and North Atlantic Oscillation control of climate in Puerto Rico. *Journal of Climate , 11* (10), 2713-2718.

Mendelsohn, R. O., Morrison, W. N., Schlesinger, M. E., & Andronova, N. G. (2000). Country-specific Market Impacts of Climate Change. *Climate Change , 45* (3-4), 553-69.

Mieczkowski, Z. (1985). The Tourism Climatic Index: A Method of Evaluating World Climates for Tourism. *Canadian Geographer , 29* (3), 220-233.

Mihalic, T. (2002). Tourism and Economic Development Issues. In R. Sharply, & D. J. Telfer, *Tourism and Development: Concepts and Issues* (pp. 81-111). Clevedon: Channel View Publications.

Mitchell, T. D., Carter, T. R., Jones, P. D., Hulme, M., & New, M. G. (2004). *A Comprehensive Set of High-Resolution Grids of Monthly Climate for Europe and the Globe: The Observed Record (1901-2000) and 16 Scenarios (2001-2100).* Norwich, UK: Tyndall Centre.

Modeste, N. C. (1995). The Impact of Growth in the Tourism Sector on Economic Development: The Experience of Selected Caribbean Countries. *International Economics , 48* (3), 375-385.

Moore, W. R. (2011). *Review of Climate Change Project National Tourism Sector Assessment: St. Lucia.* ECLAC (Economic Commission for Latin America and the Caribbean), Santiago, Chile.

Moore, W. R. (2010). The Impact of Climate Change on Caribbean Tourism Demand. *Current Issues in Tourism , 13* (5), 495-505.

Moore, W. R., Harewood, L., & Grosvenor, T. (2010). *The Supply Side Effects of Climate Change on Tourism.* Germany: University Library of Munich.

Moore, W., & Whitehall, P. (2005). The Tourism Area Lifecycle and Regime Switching Models. *Annals of Tourism Research , 32* (1), 112-126.

Nnicholls, R. J., & Tol, R. S. (2006). Impacts and Responses to Sea-Level Rise: A Global Analysis of the SRES Scenarios over the Twenty-first Century. *Philosophical Transactions of the Royal Society A , 364* (1841), 1073-1095.

Nordhaus, W. D. (2006). Geography and Macroeconomic: New Data and New Findings. *Proceedings of the National Academy of Science , 103* (10), 3510-17.

Nordhaus, W. D. (1994). *Managing the Commons: The Economics of Climate Change.* Cambridge: MIT Press.

Pachauri, R. K., & Reisinger, A. (2007). *Climate Change 2007: Synthesis Report.* Geneva: Intergovernmental Panel on Climate Change.

Parry, M., Rosenzweig, C., Inglesias, A., Livermore, M., & Fischer, G. (2004). Effects of Climate Change on Global Food Production Under SRES Emissions and Socio-Economic Scenarios. *Global Environmental Change , 14*, 53-67.

Pearce, D., Cline, W., Achanta, A., Fankhauser, S., Pachauri, R., Tol, R., and others (1996). The Social Cost of Climate Change: Greenhouse Damage and the Benefits of Control.". In *Climate Change 1995: Economic and Social Dimensions of Climate Change.* Cambridge: Cambridge University Press.

Pesaran, H. M., & Shin, Y. (1998). An Autoregressive Distributed Lag Modeling Approach to Cointegration Analysis. In S. Storm, *Econometrics and Economic Theory in the 20th Century: The Ragnar Frisch Centennial Symposium.* London: Cambridge University Press.

Pesaran, M. H., Shin, Y., & Smith, R. (2001). Bounds Testing Approaches to the Analysis of Level Relationships. *Journal of Applied Econometrics , 16*, 289-326.

Rohr, J. R., & Raffel, T. R. (2010). Linking Global Climate and Temperature Variability to Widespread Amphibian declines Putatively caused by Disease. *Proceedings of the National Academy of Sciences of the United States of America , 107* (18), 8269.

Saikkonen, P. (1991). Asymptotically Efficient Estimation of Cointegration Regressions. *Economic Theory , 7*, 1-21.

Saikkonen, P., & H, L. (2002). Testing for a Unit Root in a Time Series with a Level Shift at Unknown Time. *Econometric Theory , 18*, 313–348.

Sanders, R. (2010, August 2). *Trinidad Express*. Retrieved August 25, 2010 from http://www.trinidadexpress.com/commentaries/99738789.html

Scheraga, J., Leary, N., Goettle, R., Jorgenson, D., & Wilcoxen, P. (1993). Macroeconomic Modelling and the Assessment of Climate Impacts. In Y. Kaya, N. Nakicenovic, W. Nordhaus, & F. Toth (Eds.), *Cost, Impacts and Benefits of CO2 Mitigation* (pp. 107-132). Laxenburg, Austria: International Institute for Applied System Analysis, Collective Paper Series.

Scott, D., & McBoyle, G. (2001). Using a Tourism Climate Index to Examine the Implications of Climate Change for Climate as a Tourism Resource. In A. Matzarakis, & C. R. de Freitas, *Proceedings of the First International Workshop on Climate, Tourism and Recreation* (pp. 69-88). Freiburg: International Society of Biometeorology.

Scott, D., Gossling, S., & de Freitas, C. R. (2007). Climate Preferences for Tourism: An Exploratory Tri-Nation Comparison. In A. Matzarakis, C. R. de Freitas, & D. Scott, *Developments in Tourism Climatology* (pp. 18-23). Freiburg: International Society of Biometeorology.

Simpson, M. C., Scott, D., Harrison, M., Silver, N., O'Keeffe, E., Sim, R., and others (2010). *Quantification and Magnitude of Losses and Damages Resulting from the Impacts of Climate Change: Modelling the Transformational Impacts and Costs of Sea Level Rise in the Caribbean (Summary Document).* Bridgetown: United Nations Development Programme.

Smith Warner International. (2003). *Integrated Vulnerability Assessment of Montserrat.* Brades: Government of Montserrat.

Stern, N. (2007). *The Economics of Climate Change: The Stern Review.* London: Cambridge University Press.

Stock, J., & Watson, M. (1993). A Simple Estimator of Cointegrating Vectors in Higher Order Integrated Systems. *Econometrica , 61*, 783-820.

Tartaglione, C. A., Smith, S. R., & O'Brien, J. J. (2003). ENSO Impact on Hurricane Landfall Probabilities for the Caribbean. *Journal of Climate , 16* (17), 2925.

TEEB. (2010). *A Quick Guide to the Economics of Ecosystems and Biodiveristy for Local and Regional Policy Makers and.*

Timmermann, A., Oberhuber, J., Bacher, A., Esch, M., Latif, M., & Roeckner, E. (1999). Increased El Nino Frequency in a Climate Model Forced by Future Greenhouse Warming. *Nature , 398*, 694-697.

Tol, R. S. (2002a). Estimates of the Damage Cost of Climate Change. Part 1: Benchmark Estimates. *Environmental and Resource Economics , 21* (1), 47-73.

Tol, R. S. (2002b). Estimates of the Damage Cost of Climate Change. Part 2: Dynamic Estimates. *Environmental and Resource Economics , 21* (2), 135-60.

Tol, R. S. (2002). Estimates of the Damage Costs of Climate Change. *Environmental and Resource Economics , 21* (1), 47-73.

Tol, R. S. (1995). The Damage Cost of Climate Change Toward More Comprehensive Calculations. *Environmental and Resource Economics , 5* (4), 353-374.

Tol, R. S. (2009). The Economic Effects of Climate Change. *Journal of Economic Perspectives , 23* (2), 29-51.

Tol, R. S. (2008). The Social Cost of Carbon: Trends, Outliers and Catastrophes. *The Open-Access, Open-Assessment E-Journal , 2* (2008-25).

Trotz, U. O. (2008, January 14). *Climate Change and Development in the Sub-Region.* Retrieved 09 19, 2011, from Caribbean Youth Environment Network: http://www.cyen.org/innovaeditor/assets/Trotz%20overview.pdf

UN, (. N. (1994, October). *General Assembly.* Retrieved 09 22, 2011, from United Nations: http://www.un.org/documents/ga/conf167/aconf167-9.htm

UNEP, (. N. (2008). *Climate Change in the Caribbean and the Challenge of Adaptation.* Panama City, Panama: UNEP Reginal Office for Latin America and the Caribbean.

USAID. (2007). *Adapting to Climate Variability and Change: A Guidance Manual for Development Planning.* Retrieved October 13, 2010 from US Agency for International Development: http://www.usaid.gov/our_work/environment/climate/docs/reports/cc_vamanual.pdf

Uyarra, M. C., Cote, I. M., Gill, J. A., Tinch, R. R., Viner, D., & Watkinson, A. R. (2005). Island-Specific Preferences of Tourists for Environmental Features:

Implications of Climate Change for Tourism-Dependent States. *Environmental Conservation , 32* (1), 11-19.

Vickery, P. J. (2008, October 1). *The Impact of Climate Change on Design Wind Speeds in St. Lucia.* Retrieved October 13, 2010 from Caribbean Community Climate Change Centre: http://www.caribbeanclimate.bz/spacc/spacc.html

Wallace, D. J., & Anderson, J. B. (2010). Evidence of Similar Probability of Intense Hurricane Strikes for the Gulf of Mexio over the Late Holocene. *Geology , 38* (6), 511.

Watson, P. K. (1983). *Income Inequality Comparisons in Trinidad and Tobago: Some Methodological Issues.* Port of Spain: Central Statistical Office.

Westra, S., & Sharma, A. (2010). An Upper Limit to Seasonal Rainfall Predictability? *Journal of Climate , 23* (12), 3332-3352.

Witter, M., Briguglio, L., & Bhuglah, A. (2002, May 9-10). Measuring and Managing the Economic Vulnerability of Small Island Developing States. Montego Bay, Jamaica.

Xie, S.-P., Du, Y., Huang, G., & Zheng, X.-T. (2010). Decadal Shift in El Nino Influences on Indo-Western Pacific and East Asian Climate in the 1970s. *Journal of Climate , Vol. 23* (12), 3352-3369.

Yocom, L. L., Fule, P. Z., Brown, P. M., Cerano, J., Villaneueva-Diaz, J., Falk, D. A., and others (2010). El Niño-Southern Oscillation effect on a fire regime in northeastern Mexico has changed over time. *Ecology , 91* (6), 1660.

Zhai, F., Lin, T., & Byambadorj, E. (2009). *A general equilibrium analysis of the impact of climate change on agriculture in the People's Republic of China.* From MPRA: http://mpra.ub.uni-muenchen.de/21127/

Zhan, W.-Y., Guo, W.-D., Fang, L.-Q., & Li, C.-P. (2010). Climate Variability and Hemorrhagic Fever with Renal Syndrome Transmission in Northeastern China. *Environmental Health Perspectives , 118* (7), 915-921.

Zhuang, J., Liang, Z., Lin, T., & De Guzman, F. (2007). *Theory and Practice in the Choice of Social Discount Rate for Cost-Benefit Analysis: A Survey.* Mandaluyong City: Asian Development Bank.