International Risk Sharing & Hurricanes in the Caribbean

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ABSTRACT

This paper applies international risk sharing measurement methodologies developed by Eijffinger & Wagner (2001) and Auffret (2001) to Caribbean data, developing estimates of welfare gains (2.73%) that are higher than those generally associated with developed economies. An index to measure exposure to hurricanes is developed using weather data, and a test of the linkage between risk sharing potential and hurricane exposure conducted. The results are suggestive that international risk sharing potential is increased by hurricane exposure, but inconclusive.

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International Risk Sharing & Hurricanes in the Caribbean

Introduction

Does the creation of an international natural catastrophe risk sharing facility in the Caribbean move the region a step closer towards realising the untapped potential for international risk sharing between developing nations? Since the 1990s, the level of consumption risk that is shared internationally has been debated. An "international risk sharing puzzle" has developed, with researchers reporting both low levels of risk sharing *and* also high benefits available from increasing it.

Much of the research has focussed on economies in the developed world. However, one emergent theme in the literature is that the benefits from increased international risk sharing are higher when the developing world is considered. Developing countries exhibit greater volatility and lower co-movement in many macroeconomic variables than the developed world, and can therefore be expected to show higher marginal gains from increased sharing of risk.

Macroeconomic fluctuations can be particularly acute in small nations. According to the World Bank Task Force on Small States, small states face a number of development challenges including poverty, limited diversification, remoteness, isolation, and susceptibility to natural disasters. Together, these factors adversely influence income volatility and access to external capital (World Bank, 2000). Economic policy in the developing world has typically targeted increased rates of growth. However, without risk sharing, the cost of existing consumption volatility may outweigh the welfare benefits of attainable increases in growth. Worse, in the light of the following analysis, these challenges can be expected to limit the ability for developing nations to share risk internationally, precisely where such risk sharing has its greatest potential.

One area in which a demonstrable need for risk sharing exists is the exposure of developing countries' populations and assets to natural catastrophes. According to the United Nations, 85 percent of the world population that is exposed to disasters, including earthquakes, tropical wind storms, floods and droughts, lives in developing countries (UN, 2004). This exposure carries a significant cost; since 1984 the World Bank has financed over 500 disaster related projects totalling over USD 26Bn (World Bank, 2006b). The estimated annual economic cost of natural disasters in the Caribbean alone may be as high as USD 3.3Bn (Charveriat, 2000). Thus is it of interest to examine how catastrophes relate to international risk sharing, and timely, as the Caribbean Catastrophic Risk Insurance Facility was recently created to formalise the regional and international sharing of natural catastrophe risk.

The Caribbean Catastrophic Risk Insurance Facility (CCRIF)

The CCRIF was created in 2007 to address the need for immediate liquidity following disaster events. Several comparable initiatives exist that address the economic and social problems caused by natural catastrophes (See Table 12 in Appendix 1). However, there

are relatively few such schemes in the developing world, and all but the CCRIF are bilateral schemes between the sponsor nation and international markets. The CCRIF is the only example of an intra-regional & international natural catastrophe risk sharing scheme.

The CCRIF is essentially an insurance company that is capitalised and patronized by the governments of the Caribbean region.[1] The CCRIF offers, in exchange for an annual premium, insurance policies against hurricanes and earthquakes. The payout of these policies is linked directly to attributes of the hazards themselves (e.g. wind speed, location of storm, earthquake intensity and epicentre location) according to a predefined scale, facilitating rapid payout following an event.

In addition to offering insurance, the CCRIF fulfils a second purpose by aggregating regional risk, and harnessing the diversification benefit (it is unlikely that disaster experience will be perfectly correlated amongst participants) to reduce overall transfers to world markets and to reduce the cost of coverage to participants. This creates a pool of less volatile risk, offering a more attractive proposition to the international reinsurers and financial markets that assume the risk of extremely large or highly correlated events, increasing the long term solvency of the scheme (World Bank, 2006)[2].

Catastrophes and Risk Sharing

The CCRIF is important in this context because it is a formal international risk sharing mechanism, operating in a region of developing economies. The scheme is as yet untested by disasters[3,4], and cannot provide direct evidence of the link between catastrophes and the international risk sharing question.

Whereas a subsection of the risk sharing literature addresses risk sharing at the household level by identifying specific shocks, and examining the response of households' consumption to them[5], relatively few attempts have been made to identify specific shocks at the national level with international risk sharing opportunities and measure the associated benefits. The study of the link between the occurrence of catastrophes and the benefits of risk sharing may illuminate the international risk sharing debate by providing an identifiable exogenous shock variable that does not depend upon the actions of the countries engaged in risk sharing.

[1] There were 16 participants at 30/1/2007.
[2] This risk has been reinsured and transferred to capital markets using a "catastrophe swap". Hofman & Brukoff (2006) provide a review of catastrophe risk securitization methods. Lane (2004) assesses the viability of "cat bonds" as an ex-ante financing instrument for developing countries.
[3] Hurricane Dean in 2007 did not trigger a payout.
[4] Subsequent to the original preparation of this paper, a magnitude 7.4 earthquake that occurred close to Martinique on November 29th 2007 caused a payout to two CCRIF member countries.
[5] See Cochrane (1991), Mace (1991), Townsend (1994 & 1995) and Ligon, (1998).

METHODOLOGY

Can evidence for the benefits of sharing catastrophe risk be detected in developing country data? The primary research question of this paper is to establish whether a method of measuring the welfare gains from risk sharing developed by Eijffinger & Wagner (2001) is more closely correlated to catastrophe risk in the Caribbean than another more traditional approach, and to compare and contrast the two methods.

The intuition behind this approach is that by comparing a risk sharing measurement based on historical consumption data (rather than stochastic processes that represent future consumption) with an index based on the occurrence of historical hurricane events, a link between catastrophes and risk sharing may be more readily identifiable than by comparing results based on volatility statistics with established, but incomplete databases of economic losses due to catastrophes. Using an index based approach, the paper mirrors the structure of the CCRIF and motivates the use of data from other disciplines where the economic records are incomplete.

The remainder of the paper is structured as follows: Section I presents a review of the key risk sharing literature and empirical results, and the economics of catastrophes in the developing world. Section II describes the theoretical framework and methodology used in the present research, and develops a Caribbean hurricane exposure index. Section III discusses the data. Section IV presents the results of applying the methods to a sample of Caribbean island nations and relates them to the hurricane exposure index. Finally, Section V concludes, draws policy implications and presents avenues for further research.

I. Literature Review

The international risk sharing literature grew out of the theory of real business cycles (Plosser, 1989; Kydland & Prescott, 1982; Zarnowitz, 1985). In a closed economy, agents are able to share their idiosyncratic risk (resulting from circumstances such as unemployment, illness, etc.) through financial, credit, insurance, social redistribution schemes and other means[6] but they cannot effectively diversify their business cycle risk.

The proposition examined by the international risk sharing literature is that risk averse agents inhabiting an internationally linked set of economies will act in such a manner as to obtain future consumption paths that smooth domestic shocks through the international markets, trading country specific risk for a lower, shared, risk across the cycle. The literature can be broadly characterized into two categories: theoretical work and applications of a model devised by Lucas (1987), and its descendants, measuring the welfare gains attainable by increasing risk sharing; and empirical work related to the work of Backus *et al.* (1992), measuring correlations between consumption and output[7], or using a method related to the approach of Asdrubali, Sørensen, & Yosha (1996) (ASY hereafter) to identify the channels through which existing risk sharing is achieved.

ASY Methodology

Whilst the present paper focuses on the welfare impact of further risk sharing, it is instructive to briefly review the literature that measures existing risk sharing, which typically addresses a federation or group of states or regions within a nation. ASY identify the channels through which existing risk sharing smoothes consumption.

The identity describing the co-movements of per-capita gross state product *(gsp)*, state income *(si)*, disposable state income *(dsi)* and state consumption (*c*) for state *i* can be written:

$$gsp^i \equiv \frac{gsp^i}{si^i}\frac{si^i}{dsi^i}\frac{dsi^i}{c^i}c^i \qquad [1]$$

Which can be manipulated to produce the following:

$$\begin{aligned}\mathrm{var}\{\Delta \log gsp\} = {} & \mathrm{cov}\{\Delta \log gsp, \Delta \log gsp - \Delta \log si\} \\ & + \mathrm{cov}\{\Delta \log gsp, \Delta \log si - \Delta \log dsi\} \\ & + \mathrm{cov}\{\Delta \log gsp, \Delta \log dsi - \Delta \log c\} \\ & + \mathrm{cov}\{\Delta \log gsp, \Delta \log c\}\end{aligned} \qquad [2]$$

[6] Cochrane (1991) describes a test for "consumption insurance" within the US by identifying the impact of specific factors using household data, concluding that full insurance is not rejected for the majority. Mace (1991) reports similar results.

[7] Risk sharing is generally rejected in tests of correlations (e.g. Backus *et al*., 1992), although other models suggest that these results can be explained even with complete risk sharing, if agents are heterogeneous (Pakko, 1994), or foreign exchange movements are taken into account (Corsetti *et al.*, 2003; Cavaliere, 2006).

Dividing by *var{Δlog gsp}*, and defining constants gives:

$$1 = \beta_K + \beta_F + \beta_C + \beta_U \quad [3]$$

The β co-efficients form the slopes of separate regressions of *Δlog gsp* on the second argument in each of the four covariance terms, representing the percentage of smoothing achieved through each channel: β_K relates to capital markets, β_F to federal transfers, β_C to credit markets and β_U to the un-smoothed portion of the risk. Performing these regressions, risk sharing can be decomposed into three channels, and the proportion of risk left un-smoothed identified.

Table 1 summarizes a selection of empirical investigations in the literature. There appears to be broad agreement that risk is shared between states in a federation or regions in a country. ASY measure risk sharing across the US and find that 75% of all risk is shared between states. Using related methods, Athanasoulis & van Wincoop (AVW hereafter) (1998), Crucini (1999), Crucini & Hess (1999) and Kalemli-Ozcan, *et al.* (2003) find similar levels of intranational risk sharing in various developed countries.

ASY present a robust argument for their results, concluding that 39% of total risk sharing is achieved through capital markets, 23% through credit markets and 13% through federal government transfers, with the residual 25% of risk unsmoothed. They conduct sensitivity tests, showing that credit market smoothing decreases as the time horizon increases, and that the channels of smoothing vary according to the nature of the principal business activity conducted in each state.

These measurements are important, as if substantially all risk is shared domestically, the marginal benefits of sharing risk internationally may be insufficient to outweigh the costs (e.g. creating, monitoring and administering international markets or risk sharing contracts). However, the results of ASY and others suggest that although domestic risk sharing is typically high in a developed economy, for a small developing country, where capital and credit markets are less complete and fewer opportunities exist to share risk between geographically distinct sections of the economy, the unsmoothed portion may be larger.

The Lucas Model

A formal model of international risk sharing was introduced by Lucas (1987). The expected utility, V, for a representative consumer can be written as follows, where $u(c_t)$ is the utility acquired from consumption path c_t, and δ is the discount factor.

$$V = E\left[\int \delta^t u(c_t)\,dt\right] \quad [4]$$

Risk averse agents generally prefer smooth consumption paths to those that fluctuate. The welfare gains from international risk sharing (equivalently, the welfare costs of economic instability) can be defined as the increase in consumption across all dates required to

leave a consumer indifferent between a perfectly smooth consumption path, c^*, with constant growth μ, and a volatile path c^σ:

$$\begin{aligned} \ln\left(c_t^*\right) &= \ln\left(c_0\right) + \left(1+\mu\right)t \\ \ln\left(c_t^\sigma\right) &= \ln\left(\left(1+g\right)c_0\right) + \left(1+\mu\right)t + \varepsilon_t \\ \varepsilon_t &\rightarrow N\left(0,\sigma^2\right) \end{aligned} \qquad [5]$$

The fractional increase in initial consumption, g, is such that $V\left(c^*\right) = V\left(c^\sigma\right)$. A constant relative risk aversion (CRRA) function with risk aversion level γ is used to specify preferences:

$$\begin{aligned} u\left(c\right) &= \frac{c^{1-\gamma}-1}{1-\gamma} \qquad \gamma > 0, \gamma \neq 1 \\ u\left(c\right) &= \ln\left(c\right) \qquad \gamma = 1 \end{aligned} \qquad [6]$$

In a multi-country model, each of which is inhabited by representative agents, an approximate solution for the welfare gains from complete risk sharing can be written:

$$g \approx \frac{1}{2}\gamma\sigma^2 \qquad [7]$$

Thus, the welfare gains depend only upon the risk-aversion factor and the volatility of consumption, with increases in either parameter increasing welfare gains.

Empirical Results and Discussion

The results of measurements on international risk sharing vary widely. The estimates of the extent of existing risk sharing range from 0% to 80% in Table 1. The estimates of welfare gains that would arise from complete international risk sharing range from 0.48% to over 100%. This lack of consensus is suggestive of various possibilities including: theoretical problems, incompleteness of markets, moral hazards associated with risk sharing and the impact of globalization.

Theoretical Issues

The Lucas model can be criticised for the choice of a trend stationary process for consumption. There are many possible choices, including random walks, mean reverting and others, and it is difficult to determine empirically the true generating process. The model implicitly assumes that risk sharing policies will affect only the variance of consumption, and not the growth of consumption. If growth can be expected to increase as a result of risk sharing, then welfare gains may be significantly higher.

Van Wincoop (1994) extended the Lucas Model, assuming that consumption follows a random walk with drift (a more theoretically appealing assumption motivated by the

permanent income hypothesis), and other researchers adapted the model for other processes. The calculated welfare gains show a similar dependence on the risk aversion parameter and consumption variance, but more complex processes introduce additional dependencies. The measured gains vary widely depending on the choice of generating process. Van Wincoop (1998) provides an analysis of this sensitivity, showing that the choice of process and parameters are significant determinants of the reported gains. In reality, the processes that actually drive consumption are likely to be much more complex (involving linkages between economies, world business cycles, financial and real components, etc.) than the analytically tractable processes examined in the literature.

Several researchers have attempted to address this dependence, and two of these methods form the theoretical basis for the present paper. AVW (1997) develop a measure of risk sharing that, by estimating future consumption from data available to an agent at a given time (the "information set"), has the advantage of making no explicit assumptions about the consumption process. However, calibration requires a substantial dataset (AVW test 21 variables as possible members of the information set, ultimately selecting 3), and the choice of regression variables must be undertaken with care to avoid "data mining" and the inclusion of spurious dependencies. Auffret (2001) and Eijffinger & Wagner (2001) (EW hereafter), also develop methods that reduce or eliminate the dependency of results on the form of endowment process. These methods are described in greater detail in Section II.

Incomplete Markets

Imperfections in international trade and asset markets present an obstacle to risk sharing. If the costs of sharing risk through these channels are high then the benefits must be significant for risk sharing to occur.

Lewis (1996) examines nonseparabilities between tradable and non-tradable goods, together with capital market restrictions & imperfections, suggesting that once the impact of both is taken into account, the lack of risk sharing can be explained[8]. As trade in real goods constitutes only a small part of international financial flows, it may be expected that more evidence for risk sharing can be obtained from the international assets markets; however, this is not the case. Economic agents have an empirically observed preference for domestic assets; itself another macroeconomic anomaly[9] (Lewis, 1999; Castren *et al.*, 2003). With such preferences, the scope for welfare gains through international risk sharing, which Van Wincoop (1996) suggests is otherwise substantial, is reduced. If these preferences are a reaction to market imperfections (e.g. fear of appropriation of assets), then risk sharing may have high welfare gains if these imperfections can be removed.

Much of the literature makes the tacit assumption that is possible to own claims on foreign output. Whilst international financial diversification is possible (through ownership of foreign stocks, debt or direct investment, for example) it is not

[8] Guibaud, (2004) develops a method of measuring trade costs from macroeconomic data, but does not apply it to risk sharing.

[9] Obsfelt & Rogoff (2000) list six major remaining 'puzzles', including those described here and point to the costs of international trade as a possible explanation for all of them.

straightforward to create a portfolio that exactly mimics the aggregate output of an economy. Shiller & Athanasoulis (2001) motivate facilitating risk sharing by devising new asset markets based upon contracts that derive their values from the relative changes in national aggregate statistics. However, such statistics are subject to measurement error and are often revised many years after initial production. The proposed markets have yet to be actively traded.

Moral Hazard & Incentives

If risk is shared then a moral hazard exists; it may benefit a country to "buy insurance" from another, and then fail to produce its share of international output. This counteracts the positive welfare effects of risk sharing. The lack of an effective means to enforce contracts between nations leaves participants in a risk sharing scheme with few options to prevent defaults. Canova & Ravn (1996) test international risk sharing in the developed world at short, medium and long time periods, finding that risk is almost completely shared in the short term, but not in the medium and long term; this result is consistent with the existence of adequate short term financial means to share risk and the lack of enforceable long term contracts. (See also Von Hagen, 1998 & Atkeson, 1991).

Countries in the developing world, which arguably stand to benefit most from greater risk sharing, are also those which have the worst track record of defaulting on international obligations. Imbs & Mauro (2007) study different groupings of countries, focusing on the developing world, and find that groups of as few as seven countries can achieve the majority of available risk sharing gains, but that moral hazard issues may prevent many such groups from being viable in practice.

Globalization

The impact on risk sharing of recent globalisation trends, in both developed and developing economies is not clear. Obstfeld (1994) finds that increasing globalisation may drive a shift from safer to riskier capital, thus increasing production and ultimately welfare. Conversely, Devereux & Smith (1994) contend that a less risky world results in lower savings rates, and thus lower capital accumulation, growth and welfare.

Nevertheless, increasing global ties and trade imply that the sharing of risk is increasing. Olivei (2000) suggests that the reason less recent research reported low gains from risk sharing was because the practical integration of international financial flows driven by globalization would require data extending beyond the 1990s to manifest benefits. However, they do not find much evidence for their proposition, and in fact conclude that perhaps results from data based on earlier time periods were overstating the gains from risk sharing, linking this to more closely synchronised business cycles observed during that time period.[10]

[10] Kose *et al*. (2003a) report similar results.

Table 1: Summary of selected results in the international risk-sharing literature.

Reference	Regions	Measures	Method	Results
Lucas (1987)	US	Welfare gains	Regression on consumption data	Equivalent of < 0.1% increase in consumption
ASY (1996)	US	Actual risk sharing	Variance decomposition	75% of intrastate risk is shared
Canova & Ravn (1996)	G7, Australia, Switzerland	Test for existence of risk sharing	Consumption Correlations	There is evidence for risk sharing in the short term, but not in the long or medium terms.
Lewis (1996)	72 countries	Test for existence of risk sharing	Regressions on consumption data	Rejection of international risk sharing
AVW (1997)	49 countries	Potential welfare gains	"Information set" regression	6.6% for 49 countries 1.5% for 21 OECD countries (35 year horizon)
AVW (1998)	US	Actual risk sharing	"Information set" regression	71% of available welfare gains achieved
van Wincoop (1998)	20 OECD countries	Sensitivity of welfare gains measures	Sensitivity analysis of preferences specification, stochastic endowment processes and measures of endowment.	1.5% to 3.5% (for 50 year horizon)
Crucini (1999)	G7	Actual risk sharing	Two stage regression estimate of pooled income risk.	Intra US, 84-94% Intra Canada, 88%-90% Inter G7, 37-60%
Crucini & Hess (1999)	G7	Actual risk sharing	As Crucini (1999)	Intra-Canada, Japan, US 81-88% Inter OECD 40%
		Welfare gains	Variance decomposition of pooled regression estimates.	Canada/Japan 1%, US 7%, OECD 1.5%
Melitz & Zumer (2000)	EU	Actual risk sharing	Variance decomposition	20%-25%

Reference	Regions	Measures	Method	Results
Auffret (2001)	US	Welfare gains	Regression on consumption data	0.48% to 13.4% (35 year horizon)
Eijffinger & Wagner (2001)	G7	Welfare gains	Regression on consumption data	0.5%
Shiller & Athanasoulis (2001)	G7	Welfare gains	Variance decomposition and new tradable securities	2.4% to 6.4%
Auffret (2003b)	30 Countries / regions	Certainty Equivalent Growth rates	Regression on consumption data	Region (Growth, CEG) Caribbean (2.45, 0.79) Latin America (1.44, 0.75) Sub-Saharan Africa (0.9, -0.58) Middle East & North Africa (1.60, 0.37) Europe and Central Asia (1.49, 0.89) East Asia and Pacific (2.90, 2.55) OECD (2.5, 2.39)
Kalemli-Ozcan, Sørensen & Yosha (2003)	G7	Consumption insurance	Regression on consumption and income data	84% for Federations 23.8% for groups of countries
Pallage & Robe (2003)	33 African countries	Welfare gains	Regression on consumption data	0.26% to 2.27% for LDCs 0.01% to 0.09% for US
Becker & Hoffmann (2004)	G7	Actual risk sharing	Variance decomposition	50% for US States 0% for OECD countries
Bai & Zhang (2005)	21 industrial & 19 developing countries	Actual risk sharing	Regression on consumption and income data	76% to 78%
Hadzi-Vaskov (2006)	153 countries	Actual risk sharing	Regression on consumption and income data	40% for 'advanced' countries 17% for LDCs
Hoffmann (2007)	22 industrial nations	Actual risk sharing	Variance decomposition	80% of international risk

Risk Sharing in Developing Countries

Several researchers have pointed out that studies of international risk sharing amongst developed countries face a sampling bias. These countries have sophisticated financial systems and international linkages and may already be sharing risk in an efficient manner. Of the studies of developed countries, those measuring the extent of risk sharing find significant levels, whereas those that measure the welfare impact of eliminating consumption variability find low gains. Where a breakdown is given, Table 1 shows that including developing countries raises welfare gains. Whilst there is some evidence for risk sharing at the household level in the developing world (Townsend 1994, 1995; Ligon, 1998), there is evidently less risk sharing at the international level. Pallage & Robe (2003) provide the only study in the sample that specifically addresses developing world risk sharing. They apply the Lucas Model and two variations on it to Sub-Saharan African data, finding the welfare gains from eliminating consumption volatility to be 10 to 30 times higher than those estimated for the US.

That risk sharing may have higher benefits for developing countries may be related to the size of the economy (Ramussen, 2004), the physical size of the country (Head, 1995), poorly developed domestic financial institutions and restricted availability of insurance (Auffret, 2003a), lower diversity of output (Kalemli-Ozcan, *et al*, 2003), vulnerability to changes in direction of international financial flows (Kose, *et al.* 2003b) and the lack of resilience of infrastructure and economic activity to natural catastrophe (Chaveriat, 2000), amongst other factors. A body of research has developed that examines the implications of a variety of these factors. The present paper concentrates on natural catastrophes.

The Impact of Natural Catastrophes

Since the 1990s, a substantial focus has been placed on the effects of natural catastrophes in the developing world, particularly in qualitative and policy research regarding preparation for, mitigation of, and response to disasters. The literature stresses the advantages of strategic ex-ante action compared to often ad-hoc and tactical ex-post responses. (See e.g. Mahul & Gurenko, 2006; Ghesquiere *et al.*, 2006*;* Gurenko & Lester, 2004; Auffret, 2003a).

The economic impact of disasters is well illustrated in many case studies in the literature. For example, Benson & Clay (2001) provide a detailed case study relating disasters in Dominica to their economic effects, finding that hydrological and geotechnical hazards have significantly affected output, but that experience also stimulated risk mitigation measures reducing future vulnerability (e.g. hurricane proofing and new building codes). (See also: Benson & Clay, 2004; Freeman, 2000; Jha, 2006; and World Bank, 1999, 2000c).

Whilst the impact of an individual disaster is often clear on a local economic and human scale in terms of lost production and deaths, and some events are well documented, it has proven difficult to generalise. Precise estimates of the economic cost and effects of

disasters on aggregate macroeconomic variables are difficult to identify in regression analyses. Table 2 shows a summary of empirical results drawn from selected relevant literature; there is general agreement that declines in key variables can be expected immediately after disasters.

Table 2: Results of selected studies of the impact of natural catastrophes in LDCs

Reference	Study	Result
Charveriat (2000)	35 Latin American and Caribbean disasters	Median 2% decline in GDP followed by 3% increase
Crowards (2000)	Economic effects of Caribbean disasters	Median 3% reduction of growth in year following, with positive impact two years after
Auffret (2003b)	Economic effects of disasters in 16 Latin American & Caribbean Countries	9% decrease in total consumption growth and 43% decrease in investment growth in year following a disaster
Rasmussen (2004)	12 Large disasters in the Eastern Caribbean	Median 2.2% reduction in output following disaster
Ramcharan (2005)	Evidence for the benefits of production diversification from incidence of earthquakes	Median 0.75% of GDP decline in household expenditure
Gassebenr *et al.* (2006)	Impact of disasters on trade	0.1%-0.2% negative impact on trade

However, these averages mask a wide range of responses to natural disasters (e.g. a range spanning -14% to +4% in Charveriat, 2000), and the inclusion of many types of disaster. It is not clear if the economic effects of disasters have been adequately isolated from other explanations. Indeed, The World Bank finds that while disasters appear to have a significant impact on output volatility in the Caribbean, their direct impact on consumption volatility is statistically insignificant, and reports only weak evidence for a declining balance of trade and increased fiscal deficits due to disasters (World Bank, 2002, 2005).

The effects of disasters on longer term growth are also inconclusive; notably, Albala-Bertrand (1993 & 2006) suggests that growth may be increased in the long run by disasters, through a "creative destruction" process in which older capital stock is destroyed and replaced with newer capital, increasing efficiency (see also Cuaresma *et al.*, 2004). This may, however, be truer for developed nations than developing; larger, more diversified nations are better able to recover from a disaster than a small developing state which experiences a large loss relative to GDP.

Ex-ante measures to finance catastrophic loss include insurance, reinsurance and financial market instruments. In addition to international recovery loans, ex-post financing can also be obtained from the international capital markets, foreign aid, expansionary post-event domestic fiscal policy (Kunreuther, 1985) and charity & remittances from overseas citizens (Hadzi-Vaskov, 2006). These sources of funding may already be sufficient to effectively smooth disaster related consumption risk.

II. METHODOLOGY

The literature shows that the specifications of preferences, consumption processes, the risk free rate, and other parameters are critical when evaluating the potential for risk sharing. Intuitively, generating processes for macroeconomic aggregate variables in developing countries can be expected to be more complex, as consumption smoothing markets are less complete. Developing countries also experience greater frequencies of economic crises, exacerbating the problem. In addition, macroeconomic data are subject to greater uncertainty and are of lower quality (Summers, *et al* 2006), as are data on the incidence and economic consequences of disasters (Albala-Bertrand, 1993).

For these reasons, this paper focuses on measures of risk sharing that are the least data intensive and most robust to changes in the generating process. In addition, geographically, the focus is on the Caribbean. Whilst Caribbean economies have experienced economic crises, they have been less so exposed than other regions of the developing world, and have been largely politically stable throughout the time period in the data. The Caribbean is also exposed to natural hazards, and a dataset of high quality for the physical parameters of hurricanes is available.

Auffret (2001), EW (2003) and AVW (1997) have developed methods that do not depend sensitively on the precise specification of the generating process. In this section, the Auffret and the EW models are described in greater detail. The AVW methodology is not pursued, as it is data intensive, as noted in Section I.

CERTAINTY-EQUIVALENT CONSUMPTION GROWTH

Auffret (2001) defines risk sharing welfare gains as the percentage change in consumption *growth* that a representative consumer is willing to forgo in exchange for the elimination of variability in growth. The measure developed from this definition is robust to changes to process specification, preferences and the time horizon.

In the Lucas Model, welfare gains are derived by equating expected utilities V_1 and V_2, where g represents the fractional increase in initial consumption required to compensate an agent for exchanging the perfectly smooth consumption path in V_2 with the volatile path in V_1: c_0 represents initial consumption; μ, the rate of growth of consumption and σ^2 its volatility:

$$V_1\left((1+g)c_0, \mu, \sigma^2\right) = V_2\left(c_0, \mu, 0\right) \qquad [8]$$

Lucas applied this framework to a stationary process, deriving welfare gains [7], whereas subsequent researchers applied a similar framework to non-stationary processes, leading to greater complexity in the resulting measurements. The intuition behind Auffret's approach is that when consumption is non-stationary, growth should exhibit a relatively simple dependence; thus welfare gains are obtained by equating expected utilities V_3 and V_4.

$$V_3\left(c_0, \mu + \tau, \sigma^2\right) = V_4\left(c_0, \mu, \sigma'^2\right) \quad [9]$$

This general approach allows for changes to both the variance and growth rates of consumption. If consumption follows a Brownian motion with drift $dc/c = \mu\, dt + \sigma\, dz$, then:

$$c_t = c_0 e^{\left(\mu - \frac{1}{2}\sigma^2\right)t + \sigma\left(z(t) - z(0)\right)} \quad [10]$$

The expected utility from [4], using CRRA preferences [6], can be written (where the discounting function δ is represented as its continuous time counterpart; $\beta = -ln\ \delta$):

$$V\left(c_0, \mu, \sigma^2\right) = \frac{c_0^{1-\gamma}}{1-\gamma} \frac{1}{\beta + (\gamma - 1)\left(\mu - \frac{1}{2}\gamma\sigma^2\right)} - \frac{1}{\beta(1-\gamma)} \quad [11]$$

From [10], estimators for the instantaneous expected growth and its variance are derived:

$$\hat{\mu} = E\left[\log\left(\frac{c_t}{c_{t-1}}\right)\right] + \frac{1}{2}\sigma^2 \quad [12]$$

$$\hat{\sigma}^2 = \mathrm{var}\left[\log\left(\frac{c_t}{c_{t-1}}\right)\right] \quad [13]$$

Auffret shows that the welfare gains from moving from consumption process $dc_1/c_1 = \mu dt + \sigma dz$ to $dc_2/c_2 = \mu' dt + \sigma' dz$ can be written as

$$\tau = \bar{\mu}' - \bar{\mu} \quad [14]$$

Where:

$$\bar{\mu} = \mu - \frac{1}{2}\gamma\sigma^2 \quad [15]$$

The "certainty equivalent consumption growth" (CEG), μ_c, is then a special case of the move from c_1 to c_2, where $\sigma' = 0$ and $\mu' = \mu - \tau$.

$$\mu_c = \mu - \frac{1}{2}\gamma\sigma^2 \quad [16]$$

Thus, the principle determinants of CEG are the mean and variance of the (log of) historical consumption growth.

Auffret also considers a trend stationary process and an Ornstein-Uhlenbeck process for consumption, and Kreps-Porteus preferences (which separate the risk aversion rate from the intertemporal substitution rate), showing in each case that the expression for CEG remains the same.

This result has the appeal of being close to Lucas's original derivation [7], invariant with respect to several changes of specification, and straightforward to calculate given a sequence of consumption data.

Whilst this method exhibits a lesser dependence on the process used to characterise consumption, it is still assumed that the dynamics of consumption are exogenous to the model and that the stochastic process itself is unaffected (except in terms of its parameters) by risk sharing. The method implicitly takes a "single country" view of risk sharing. This may be appropriate when evaluating a small economy's risk sharing with world markets (which it cannot affect), but less appropriate when estimating the risk pooling benefits of a group of nations whose consumption and production processes may be co-integrated, through regional trade, for example.

This framework offers no insight into how the parameters of the consumption process are changed, but only into the welfare effects of the change. There may be additional costs associated with any risk sharing scheme, borne by the risk sharing nation, which are not included in these measures.

Counterfactual Welfare Gains

EW (2001) measure forgone welfare gains by estimating the gain in welfare that could have been achieved if the actual sequence of consumption data for a country *i* had in fact been equal to a 'fair' share of 'world' consumption over the available history, *m*. The welfare gains, *g*, are defined as follows:

$$0 = \sum_{t=1}^{m} \delta^{t} u\left(c_t^{*}\right) - \sum_{t=1}^{m} \delta^{t} u\left(c_t^{i}\left(1+g\right)\right) \qquad [17]$$

Consumption under complete smoothing, c^{*}, is defined as a share of world consumption c^{w}:

$$c_t^{*} = \alpha_i c_t^{w} \qquad [18]$$

where

$$\alpha_i \approx \left(\sum_{t=1}^{m} \delta^{t} c_t^{i}\right) \Big/ \left(\sum_{t=1}^{m} \delta^{t} c_t^{w}\right) \qquad [19]$$

And world consumption (with *N* countries) is defined:

$$c_t^{w} = \sum_{i=1}^{N} c_t^{i} \qquad [20]$$

Assuming CCRA preferences [6], an estimator for *g* can be written as follows:

$$\hat{g} = \left(\frac{\sum_{t=1}^{m} \delta^t c_t^{*1-\gamma}}{\sum_{t=1}^{m} \delta^t c_t^{1-\gamma}} \right)^{\frac{1}{1-\gamma}} - 1 \qquad [21]$$

By using historical consumption paths, the EW method makes no assumption on the generating process. It is, however, sensitive to the choice for preferences, the risk aversion parameter and the discount rate.

The estimation and use of the α parameters is straightforward in an ex-post sense, but presents problems in practice as it requires full knowledge of the results of the consumption process. In order to calculate α, one must project the total amount of world production and each country's future share. EW rationalise this by allowing that welfare gains computed from historical data "cannot (directly) deal with uncertainty", and state that approximately 80% of the computed gains should be available from ex-ante inter-temporal trade. Nevertheless, in order to implement a risk sharing scheme based on the EW method, it is necessary to estimate the α parameters, involving the selection of a generating process for future consumption, either explicitly or implicitly by computing the estimated future share as a function of present data (e.g. a rolling average). Either of these approaches may result in a sub-optimal risk sharing scheme.

In contrast to methods based on Lucas's approach, which are sensitive to both the time period used for calibration and the time horizon for prospective risk sharing (integrals may diverge if applied over a sufficiently long future period), the EW method is sensitive only to the length of time used for historical data. In particular, if each country's share of overall consumption changes significantly over the time period, then estimates of available welfare benefits will likely exceed any realisable benefits, as episodes of rapid growth or contraction tend not to repeat themselves.

The definition of "world" consumption is a further point of sensitivity. EW define world consumption as the combined per capita consumption of G7 nations. The analogue in the present case is to compute risk sharing based upon the pooling of only Caribbean nations. By appropriate definition of world consumption, the EW method will allow the comparison of the effects of intra-regional risk pooling with extra-regional risk pooling.

The risk sharing regime is assumed to start immediately after a period in which risk is not (or is not as much) shared. This creates discontinuities in consumption for countries joining the risk sharing scheme; some experiencing an immediate increase, and some an immediate drop. Whilst overall regional production throughout time remains constant (and thus EW risk sharing does not imply creation or destruction of resources), this would be resisted by countries on the losing side of the transfer; some means of evaluating appropriate "entrance" and "exit" costs is necessary to align the measure more closely with practical implementation.

Finally, this counterfactual approach suffers from a perhaps insufficiently revisionist approach to history. No attempt is made to account for the possibility that consumption paths under risk sharing may be different, as agents may pursue different economic strategies under risk sharing than they actually did in its absence.

Caribbean Hurricanes

The National Oceanic and Atmospheric Administration's HURDAT database[11] will form the basis of testing the linkage between international risk sharing and natural hazards. Hurricanes and subtropical wind storms are the principal catastrophe exposure in the Caribbean, in terms of economic damage and frequency. Whilst geotechnical hazards have great damage potential, few damaging events have been observed during the sample period, thus they are neglected here, along with other less damaging hazards[12].

Models have been developed by the insurance industry[13] to assess loss potential from many different natural hazards using the framework shown in Figure 1. The analysis breaks phenomena into four components; hazard (H), exposure (E), vulnerability (V) and damage or loss (D), where $D = f(H, E, V)$.

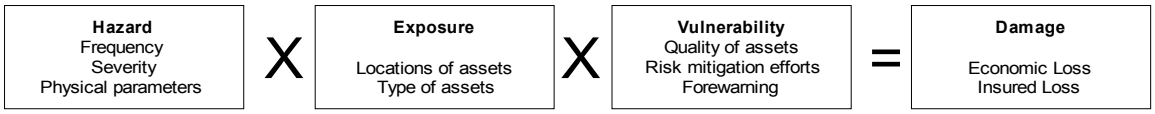

Figure 1: Natural hazards modelling framework

In general, these models rely upon large databases of asset values, types, locations and other attributes to estimate exposure and vulnerability. However, accurate data on assets are difficult or impossible to obtain at a national level. In order to assess the relationship between welfare gains from risk sharing and natural catastrophes, an approximate index based approach can be developed, alleviating the need for this complexity.

Engineering studies (e.g. Howard *et al.*, 1972) show that the amount of physical damage resulting from a wind storm scales approximately with the cube of the maximum sustained wind speed, v (i.e. $\lambda=3$, with C to be determined in [22])[14].

$$\frac{\partial^2 f}{\partial E \partial V} = Cv^{\lambda} \qquad [22]$$

This relationship enables an index of economic damage to be derived from data on historical events, assuming that the level of loss is related to the level of physical damage done by the event.

[11] Available at http://www.aoml.noaa.gov/hrd/hurdat/Data_Storm.html
[12] The 1995 volcanic eruption in Montserrat provides a notable counterexample to this assertion.
[13] Applied Insurance Research, EQECAT and Risk Management Solutions provide such models.
[14] Nordhaus (2006), gives an overview in the economic context.

By holding exposure and vulnerability constant, the index may overstate losses in the past and understate them in the future, particularly for rapidly growing countries. To address this, economic damage is calibrated as a fraction of contemporaneous GDP. However, in the time period in question, both the physical exposure growth and attendant economic multipliers of damage (e.g. lost tourist revenues) are likely to have increased significantly and possibly beyond real GDP growth rates thus magnifying the economic impact of hurricanes.

The HURDAT dataset stores the latitude, longitude, wind speed and pressure at six-hourly intervals for all known Atlantic basin wind storms since 1851. Since the 1970s, this data has been collected via several advanced methods, including satellite and radar.[15] To create the index, the time period 1970 to 2004 is used and the maximum wind speed observed as each storm that passed within $r_0=60$ nautical miles of the latitude and longitude of the principal city of one of the Caribbean islands studied was recorded. One value was recorded for each city that a storm passed over (thus, an individual storm may have several values associated with it). These values were then raised to the power of λ, to reflect economic damage potential. For a given storm, i, and island defined by the location of r_0:

$$HUI_{i,r_c} \propto \max\begin{pmatrix} v_{(i,t)}^{\lambda}, if\left(|\vec{r} - \vec{r}_c| < r_0\right) \\ 0, otherwise \end{pmatrix} \quad [23]$$

Whilst this index reduces reliance on economic loss data, it may only broadly approximate actual damage. Economic estimates are only available for a small subset of known storms, so the choice of exponent λ may be subject to some uncertainty. Regression tests are undertaken in Section IV.

The possible impact of climate change is also neglected; the linkage between climate change and direct effects on hurricane strength or frequency is a matter of intense current debate.[16] The choice of a fixed radius is intended to capture the majority of storms with significant damage potential, but may miss some damaging events and the maximum wind speed may be reached at any distance from the reference city. In addition, it is well known that wind speed alone is not the sole cause of economic damage (for example, a low speed storm can cause massive flooding and consequent loss). These omissions are not expected to be a significant driver of error in the majority of cases, as the wind fields have a significant geographical extent and were in fact the main driver of loss for many of the events for which economic data are available.

[15] See http://www.aoml.noaa.gov/hrd/hurdat/noaatechmemo.html for a detailed discussion of the limitations of the HURDAT database.

[16] See e.g. Emmanuel (2005). There is evidence that cyclical changes in the average temperature of the Atlantic affect these factors. The Atlantic has been in a "cold" cycle for most of the period of interest here.

III. DATA

The national aggregates data is drawn from a sample of 15 Caribbean nations[17] in the Penn World Table v6.2 (Summers *et al.*, 2006), at constant 1996 prices, expressed in international dollars[18]. The sample spans the time period 1970-2000. The Penn World Table contains a ranking of data quality (A to D). Puerto Rico, Cuba and Haiti's data ranks "D", whereas the rest of the Caribbean nations' data are ranked "C". All of the G7 nations except for Germany (which has a "B" grade) are ranked "A". Rankings are determined based upon the sensitivity of the price level measure used, the income levels of the country and the number of benchmarking exercises completed. These rankings illustrate that risk sharing measurements for the developing world, which are primarily measurements of volatility, will be inevitably subject to the impact of data collection imprecision, motivating the use of risk sharing measurement methods that do not depend upon a large number of fitted parameters.

Figure 2 shows the annual per capita growth rates of total consumption for the Caribbean compared with those of G7 countries, illustrating that the Caribbean has much greater volatility and lower correlation.

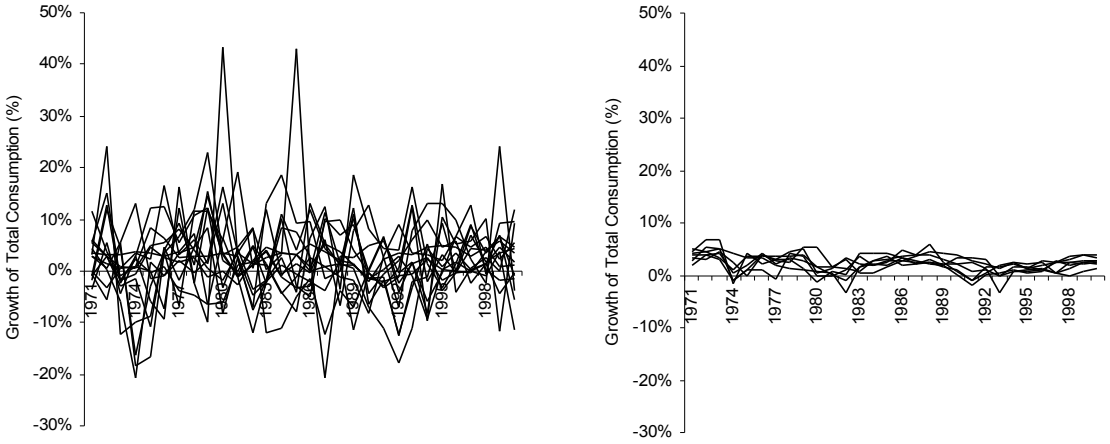

Figure 2: Growth rates (%) of consumption for Caribbean (left) and G7 nations (right)

Table 13 & Table 14 (Appendix 1) show descriptive statistics for the samples. Whilst the average annual growth rates are similar in both samples (2.2%), the average of the country specific standard deviations in the Caribbean (6.7%) is over four times as high as that in the G7 (1.6%). The G7 data also exhibit a much greater degree of co-movement than the Caribbean. That the standard deviation of the total regional consumption is 3.4%, compared with the country specific average, alludes to a potential for risk sharing across the business cycle within the Caribbean region.

[17] Antigua, Bahamas, Bermuda, Barbados, Cuba, Dominica, Dominican Republic, Grenada, Haiti, Jamaica, St. Kitts & Nevis, St. Lucia, Puerto Rico, Trinidad & Tobago, and St. Vincent

[18] Series codes RGDPL, KC, KG, KI: Available at http://pwt.econ.upenn.edu/

Table 3: Economic damage due to Caribbean hurricanes 1970-2000.

Year	Hurricane	Estimated Damage (USD 000s)
1970	Dorothy	31,000
1973	Gilda	1,700
1974	Alma	5,000
1979	David	150,000
	David & Frederic	194,650
1980	Allen	313,790
1982	Alberto	85,000
1984	Klaus	4,115
1985	Kate	5,205
1986	Danielle	n/a
1987	Emily	129,000
1988	Gilbert	2,091,286
1989	Hugo	457,800
1990	Arthur	n/a
	Gustav	n/a
	Klaus	n/a
1992	Andrew	250,000
1993	Bret	57
	Cindy	n/a
1994	Debby	n/a
	Gordon	101,968
1995	Allison	n/a
	Luis	515,579
	Marilyn	146,000
1996	Hortense	n/a
	Lili	n/a
	Luis	2,000
	Marco	3,000
1998	Georges	2,121,500
1999	Floyd	n/a
	Irene	n/a
	Jose	n/a
	Lenny	78,450
	Grand Total	**16,948,397**

Source: EM-DAT

Table 3 lists the major hurricanes and the economic damages caused according to EM-DAT[19]. The dataset is sparse, with many damage estimates unavailable. 33 events are recorded (12 have no associated economic loss) during the time period 1970-2000, which suggests an average of approximately one event per year. By comparison, there are 70 events in the HURDAT data which pass within 60nm of a populated centre in the region during the period. Whilst unrecorded events (and events lacking economic loss estimates) would typically be smaller events, this illustrates the incompleteness of the economic loss data associated with disaster events.

[19] The OFDA/CRED International Disaster Database, available from www.em-dat.net - Université Catholique de Louvain - Brussels - Belgium

IV. Results

EW Risk Sharing

Table 4 shows the results of applying the EW welfare gains methodology to the Caribbean dataset, following EW in assuming that $\gamma=3$ and $\delta=0.95$. The results show that whilst some countries could expect to have been moderately worse off under complete risk sharing (Barbados), others could have gained substantially (St. Kitts & Nevis).

Table 4: EW counterfactual risk sharing welfare gains.

Country	α	g
Antigua	5.66%	14.24%
Bahamas	13.41%	0.27%
Bermuda	22.27%	-0.73%
Barbados	10.47%	-2.84%
Cuba	3.55%	12.51%
Dominica	3.99%	3.95%
Dominican Republic	3.14%	1.92%
Grenada	2.98%	-0.08%
Haiti	1.64%	-2.03%
Jamaica	3.47%	-2.83%
St. Kitts & Nevis	5.09%	16.96%
St. Lucia	3.50%	8.32%
Puerto Rico	9.33%	4.04%
Trinidad & Tobago	8.49%	-1.04%
St. Vincent	3.02%	12.70%
Average		**4.36%**
Weighted (on α) Average		**2.73%**

Source: Author's calculations based on PWT data.

The overall welfare gain for the region is 2.73% when weighted by each country's share of overall production. This result is slightly higher than Pallage & Robe's 2003 estimate for (African) developing countries, and is generally higher than estimates associated with developed economies detailed in Section I.

A closer examination of the effects driving the "winners" and "losers" of this arrangement is warranted. Figure 3 shows examples of the consumption paths for the nation that exhibits the greatest welfare gain from the scheme (St. Kitts & Nevis) and that which exhibits the greatest welfare loss (Barbados). Barbados takes an initial consumption loss. Consumption then tracks upwards, crossing the actual consumption path resulting in a final gain. Evidently, the discounted benefits of this future gain are not sufficient to compensate a Barbadian agent for its initial loss.

Initially, for St. Kitts, risk sharing results in a 50% increase in consumption, which then increases in line with regional production until the actual consumption path of St. Kitts

crosses it in the late 1980s. In reality, by 2000, the consumption of the representative St. Kitts agent is actually higher than would be permitted by the EW risk sharing scheme. The utility of this discounted loss is insufficient to counteract the combination of an early increase in endowment and an overall reduced volatility.

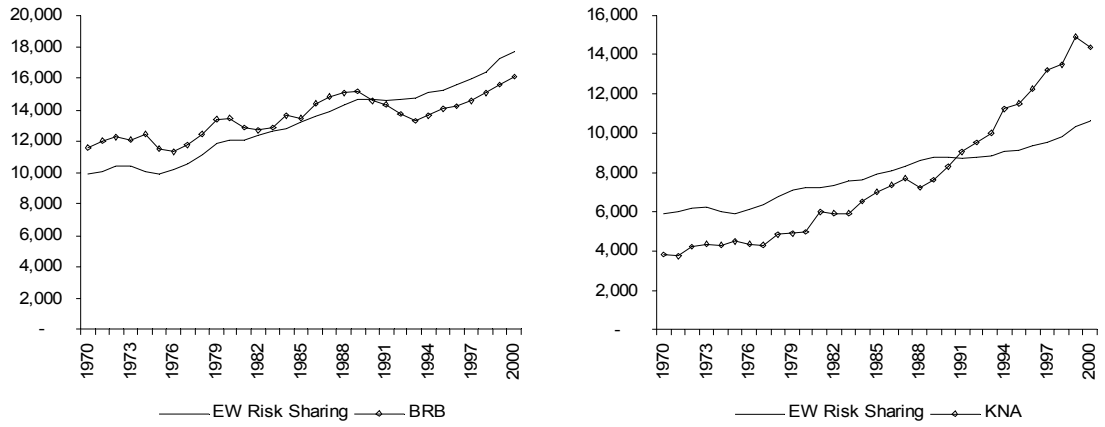

Figure 3: Consumption before & after EW risk sharing (Barbados and St Kitts & Nevis)

To the extent that either Barbados's below average output or St. Kitt's above average output is sustainable, the EW welfare gains are biased towards events which occur towards the beginning of the risk sharing scheme. However, to the extent that regional convergence occurs, these gains or losses respectively will revert to average production and the risk sharing scheme's benefits or costs will remain.

The initial decade of these results illustrates the magnitude of likely entrance costs. Unless the population of Barbados could be convinced in 1970 that their consumption would be eventually higher in the year 2000 as a result of the policy, and so the marginal loss in welfare would only be of the order of the estimates here in the long run, it is unlikely that they would accept an immediate drop in per capita consumption of the order of 20%.

Table 16 & Table 17 (Appendix 2) show the results of sensitivity tests on the two free parameters of the EW method and on the time period used. For the latter, a rolling window of a decade in length has been used. The results indicate that the degree of welfare gains is dependent upon the length of time used, and in particular the period 1980-90 is a time of particular divergence for the region, with many countries experiencing sharply higher welfare gains from risk sharing than compared to other decades. Throughout the time period, the highest welfare loss experienced by any island as a result of EW risk sharing is -0.65%.

The sensitivities to the time preference rate, δ, and the risk aversion rate, γ, behave intuitively. The spread between the largest and smallest welfare gains rises along with δ (as δ rises, agents attach a greater value to future consumption). With lower values of δ,

the risk sharing results are more strongly aligned towards initial differences in consumption levels. As γ increases (and agents are more averse to risk) the benefits from risk sharing increase for all countries that benefit (and costs increase for those that do not).

It is instructive to compare the results of regional risk sharing with the results obtained for risk sharing between the Caribbean nations and G7 countries (representing world markets). This is shown in Table 5.

Table 5: Caribbean risk sharing with G7

Country	g
Caribbean Total	-0.21%
G7 Total	0.33%
Weighted Average (on α)	**1.42%**

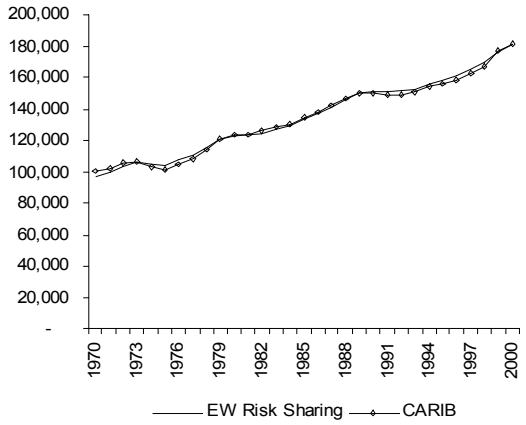

Figure 4: Caribbean & G7 EW risk sharing

These results suggest an overall welfare loss to the Caribbean of sharing risk with world markets. However, the magnitude of the loss is not great, and the welfare gain or losses for individual countries within the region remain broadly similar to the previous result (as evidenced by the weighted average result). Aggregate Caribbean consumption, both before and after risk sharing with G7 nations is very similar (Figure 4). This result also suggests that the benefits from risk sharing can be achieved substantially within the Caribbean region – a result that is in line with the assessment of risk sharing groupings conducted by Imbs & Mauro (2007), and motivates further research into optimal risk sharing groups within the region.

Certainty Equivalent Growth

Table 6 shows the results of applying CEG measurements to the Caribbean data, assuming again that $\gamma=3$. The μ, σ, and μ_c columns represent the risk adjusted mean growth rate [12], its standard deviation [13], and the CEG estimate respectively. The next column expresses the difference between the estimated growth rate and CEG, and the final column expresses this difference as a percentage of the original growth rate. Thus, this is the share of current consumption growth that the representative agent is willing to forgo in order to obtain a perfectly smooth growth path.

Striking amongst these results are two instances (Bahamas and Jamaica) in which μ_c is negative. This implies that consumption growth is sufficiently volatile in these

countries that the representative agents would in fact prefer contraction in the economy. This has interesting implications for policy. If a policy pursues growth as its primary objective, without regard to the volatility of growth, welfare may be damaged as a result.

Table 6: Caribbean certainty-equivalent growth rates.

Country	μ	σ	μ_c	$\mu - \mu_c$	$(\mu-\mu_c)/\mu$
Antigua	3.57%	6.82%	2.87%	0.70%	20%
Bahamas	0.74%	8.13%	-0.25%	0.99%	133%
Bermuda	1.57%	3.29%	1.40%	0.16%	10%
Barbados	1.15%	3.56%	0.96%	0.19%	17%
Cuba	2.84%	7.94%	1.89%	0.95%	33%
Dominica	2.34%	7.12%	1.58%	0.76%	33%
Dominican Republic	2.91%	3.32%	2.74%	0.17%	6%
Grenada	2.38%	5.32%	1.95%	0.43%	18%
Haiti	0.69%	5.69%	0.20%	0.49%	71%
Jamaica	0.16%	3.88%	-0.07%	0.23%	143%
St. Kitts & Nevis	4.58%	5.56%	4.11%	0.46%	10%
St. Lucia	3.05%	5.76%	2.55%	0.50%	16%
Puerto Rico	3.16%	3.83%	2.93%	0.22%	7%
Trinidad & Tobago	1.95%	7.00%	1.21%	0.74%	38%
St. Vincent	4.02%	8.12%	3.03%	0.99%	25%
Regional Average (unweighted)	**2.34%**	**5.69%**	**1.81%**	**0.53%**	**23%**

Source: Author's calculations based on PWT data

In both cases, volatility is considerable. Despite significant periods of growth, there have also been significant periods of contraction, leading to a "boom bust" cycle. This is illustrated in Figure 5, which compares the actual consumption path 1970-2000 with a perfectly smooth growth path, with the same initial endowment, but a growth rate of μ_c. In each case, the representative consumer is slightly worse off in terms of final endowment, but the elimination of the cycle over the period raises utility for the risk averse consumer.

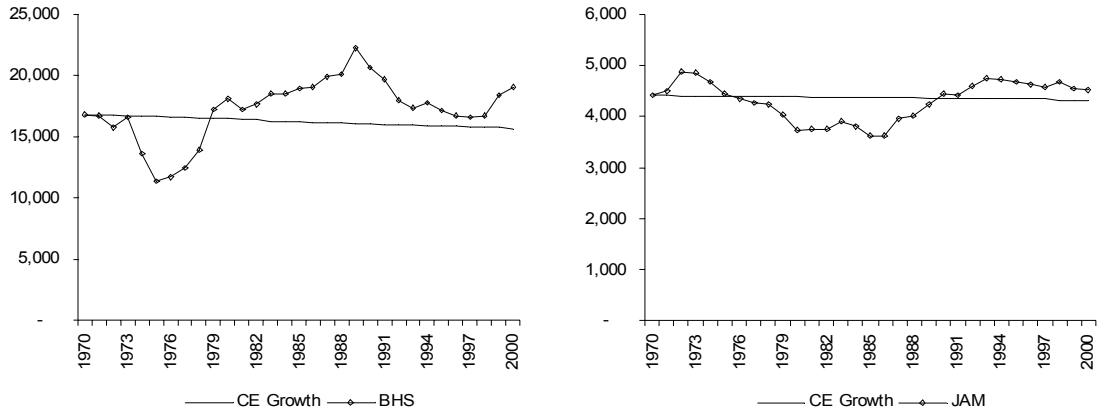

Figure 5: Certainty-equivalent consumption (Bahamas and Jamaica)

The CEG measure must be evaluated over a sufficiently long period of time in order to reflect structural growth, rather than cyclical variability. For example, if the CEG measure for Jamaica is evaluated on the period 1970-1985 only, then μ_c=*-1.48%*. Whilst this may express the utility preference of a representative agent that just experienced a contracting economy, common sense suggests that it would be foolish for such an agent to "lock in" a negative growth rate at that time.

DISCUSSION

The CEG & EW measures are not directly comparable. However, some inferences can be drawn from the ranking of results under each. Table 7 shows the welfare gain under the EW measure against the CEG measure $(\mu-\mu_c)/\mu$. In each case, the measurements are ranked in order of welfare gain from greatest (1) to least (15).

Table 7: Comparative rankings under EW and CEG risk sharing

Country	EW Rank	CEG Rank
Antigua	2	8
Bahamas	9	2
Bermuda	11	12
Barbados	15	10
Cuba	4	5
Dominica	7	6
Dominican Republic	8	15
Grenada	10	9
Haiti	13	3
Jamaica	14	1
St. Kitts & Nevis	1	13
St. Lucia	5	11
Puerto Rico	6	14
Trinidad& Tobago	12	4
St. Vincent	3	7

The rankings under each scheme are quite different. This highlights the difference between a measure, which whilst robust to several possible theoretical configurations, is based on a theoretical growth process, and a measure which is based on actual growth. Under CEG, those countries with stable growth rates have little to gain from risk sharing, but under EW, those countries whose current production is below their potential (and eventually realised) production with respect to the regional average benefit the most from risk sharing in the absence of entrance costs.

The EW results in Figure 6, below, depict the moral hazard issue faced by countries that consider forming a risk sharing scheme. Under EW risk sharing, Jamaica experiences a consistent benefit after its production falls below its 1970-2000 share of the regional average in the early 1980s. Under such conditions, there would be little incentive to pursue growth oriented policies to restore the balance.

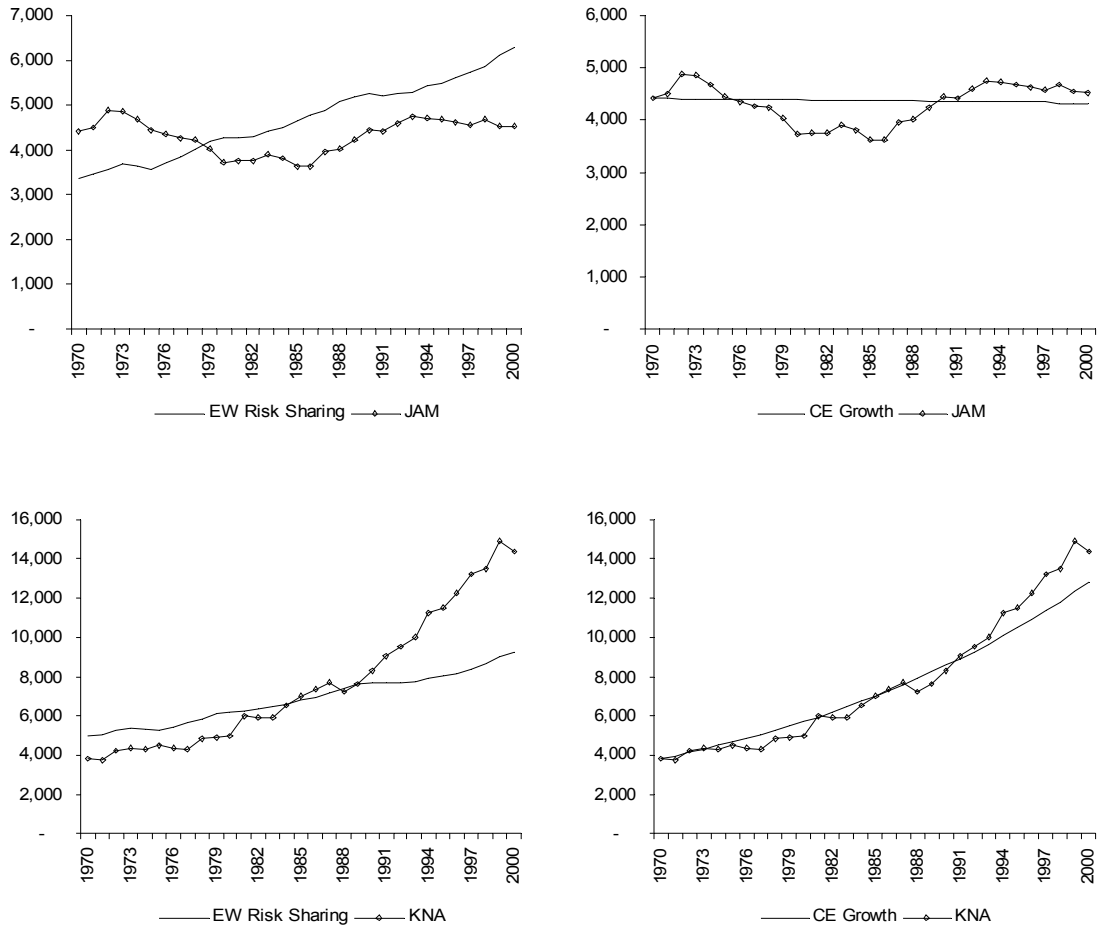

Figure 6: EW (left) and CEG risk sharing (right) for Jamaica (top) and St Kitts & Nevis (bottom)

Although total production and consumption is maintained throughout time in the EW scheme, effectively, consumption is appropriated from those countries that produced more than their overall average share during that time period, such as St Kitts & Nevis, in order to raise the consumption of countries that produced less than their overall share. This in turn would remove the incentive for those countries to continue to increase their production. EW risk sharing schemes are perhaps best considered at the same time as growth and consumption convergence policies, as without measurable convergence, an EW risk sharing scheme would be subject to increasing stresses as a result of this kind of divergent experience.

Relationship to hurricane exposure

In order to calibrate the hurricane index, regression tests were conducted. The EM-DAT data in Table 3 are split by island and expressed as a %age of GDP in Table 19. This was used in conjunction with the HURDAT derived results shown in Table 18 to test the λ exponent in the hurricane index. In total, 83% of corresponding entries in the tables either have no value in either table (no storm activity in that island), or a non-

zero value in both (storm landfall). The remaining 17% have either an economic loss where there was no named storm within 60nm of the major city, or a storm that has no economic loss in the EM-DAT database, leaving 28 data points for testing.

Following [22] (and taking logs), a regression test of *ln(D)* against *ln(v)* was performed, to identify an appropriate constant and exponent λ from the regression equation $ln(D) = ln(C) + \lambda\, ln(v)$. The results are shown below in Table 8.

Table 8: Hurricane index calibration test

		Standard Error	T-Ratio	p-Value
ln(C)	-14.9713	5.4596	2.7422	0.011
λ	2.544	1.2154	2.0931	0.046

Both co-efficients are statistically significant at the 5% level. Using these co-efficients implies the following levels of economic damage, on average, for a hurricane of the minimum strength required to qualify for each of the five Saffir-Simpson categories, passing within 60nm of a Caribbean city (Table 9).

Table 9: HUI indicative economic loss values

Saffir-Simpson Category	v, kts	HUI (as %GDP)
1	64	1.2%
2	83	2.4%
3	96	3.5%
4	114	5.4%
5	135	8.3%

The results of the EW and CEG risk sharing measurements suggest that each measurement is likely to have a different relationship to the hurricane index. If natural hazards are significant drivers of consumption volatility then a rise in exposure should be linked to an increased benefit from sharing this risk. Thus, a positive linkage between the hurricane index and risk sharing measurements can be expected. In the introduction, it was hypothesised that the EW measure may be more closely correlated to hurricane exposure, as measured by the index, than other measures, as it relates directly to the actual data (as does the index). To this end, regression tests are carried out on the risk sharing results against the cumulative value of the index over the 30 year period, for each island in the study.

Table 10: Link between hurricanes and EW risk sharing

EW *g on ΣHUI*		Standard Error	T-Ratio	p-Value
Constant	-0.001	0.035	-0.036	0.972
Slope	0.670	0.363	1.844	0.095

Table 11: Link between hurricanes and CEG risk sharing

CEG $(\mu-\mu_c)/\mu$ *on ΣHUI*		Standard Error	T-Ratio	p-Value
Constant	0.649	0.259	2.506	0.031
Slope	-2.990	2.658	-1.125	0.287

The relationship between the EW *g* values and the hurricane index has the expected sign and a slope that is statistically significant at the 90% level. However, the relationship between CEG values has the opposite sign than expected and is not statistically significant at a conventional level.

The significance of the constants in each regression is interesting. In the first regression, the constant is not significantly different from zero; however, a positive value would be expected as benefits from risk sharing can emerge in the absence of natural hazards exposure. In the second regression, the constant has statistical significance, and the expected sign, suggesting a benefit from risk sharing that does not depend on natural hazard exposure. Whilst the relationship between the EW values and the hurricane index is suggestive of a linkage, it is far from conclusive.

V. Conclusions

The risk sharing literature has documented an "international risk sharing puzzle" as there is a low level of actual international risk sharing *and* also potentially high benefits available from increasing it. In part, this is because much of the analysis has been performed on developed economies, which have achieved a measure of economic convergence. The situation for developing countries is much less clear; less research has been conducted on developing country data, and the research that has is subject to uncertainty as data from developing countries is subject to a greater measurement difficulty.

Separately, an emerging literature documents the effects of natural catastrophes on developing nations. Whilst the long run implications upon growth are subject to debate, there is agreement that a clear benefit can be obtained from policies which focus on ex-ante strategic plans to mitigate exposure to natural hazards, rather than ex-post tactical responses. The CCRIF is an example of an ex-ante strategy in this context that has recently been established. Its success or failure will be a clear signal as to the future significance of formalised international risk sharing mechanisms in the developing world.

This paper has examined the counterfactual risk sharing measure devised by Eijffinger & Wagner (2001) and compared it to an index developed to measure exposure to economic losses as a result of hurricane damage in the Caribbean. These results have been compared to a "certainty equivalent growth rate" (CEG) measure developed by Auffret (2001) that is closer to the original Lucas model, but shows greater robustness in the event of a misspecification of the consumption generating process.

The results of the counterfactual risk measure show that most nations in the Caribbean could have benefited from a risk sharing scheme that provided each nation with a share of overall regional consumption during the period 1970-2000. Those that would not have benefited failed to do so by a small margin. Further, the risk sharing measurements indicate that most of this benefit is obtainable within and between the economies in the Caribbean region, as adding the G7 nations to the risk sharing scheme does not substantially alter the results, a finding which is similar to that of Imbs & Mauro (2007). The weighted average welfare benefit associated with risk sharing in the region is 2.73%, compared with EW's 2001 estimate for G7 economies of 0.5%. This increase over developed nations is in keeping with other results in the literature (Table 1) and suggests that the marginal benefits of risk sharing are higher in the developing world than the developed world.

The results from the CEG formulation differ substantially from those developed in the EW framework, and indicate that certain Caribbean countries would be prepared to exchange volatile, but positive, growth for a low level of annual contraction in the economy. The magnitude of these results raises questions about policies designed to deliver growth and motivates the inclusion of stability as a policy goal.

The results of comparing EW risk sharing measurements to the hurricane index are suggestive of a linkage, but inconclusive. There is no evidence for a link between the CEG results and exposure to hurricanes. Whilst the levels of economic loss associated with hurricane damage appear to be large in both the observed events and the developed index, their impact on the data appears to be elusive, as there are many other sources of volatility. However, natural hazards are an example of a shock that has limited scope for diversification through these traditional channels, but is easily identifiable and distinct from other causes of economic volatility, and thus schemes similar to the CCRIF can be expected to have measurable value wherever there is a clear definition of causation.

This finding is in line with the limited evidence for a simple relationship between consumption or output and the incidence of natural disasters at the macroeconomic aggregate level. This motivates further collection and study of disaggregated data, in order to identify a robust effect. It is likely that further study of individual effects (natural catastrophes or other specific exogenous shocks) will illuminate the potential for international risk sharing. An application of the AVW (1997) method to Caribbean data may also provide evidence on this point. Further research on applications of the ASY (1996) method, or similar, to developing country data is motivated where there is natural scope for regional risk sharing– whether as a result of common geography, currency areas, trade federations or similar– in order to identify if risk sharing is taking place between these nations through more conventional channels.

The results and discussion indicate that risk sharing policy cannot be separated from discussions on economic convergence; if risk sharing mechanisms are to have longevity, then participants cannot persistently receive or give transfers and be expected to remain in the scheme. Perpetual receivers of transfers will be pushed out and perpetual donors will walk out. This suggests that the benefits of risk sharing measured in the literature thus far (including the present paper) are higher than those which can be practically achieved through formal mechanisms. A market based approach, similar to that suggested by Shiller & Athanasoulis (2001) or a regional network of bilateral and short or medium term swaps (motivated in Imbs & Mauro, 2007) may be an appropriate means of sharing non-identifiable risk.

The literature shows that developed economies are able to share a large portion of their idiosyncratic risk within their own borders. With this and the results of the EW and CEG risk sharing measures in mind, the primary recommendation for developing world nations must be to focus on developing policies that foster well functioning local credit, insurance and financial markets (e.g. through moderated financial liberalization, sound macroeconomic policy, and building robust financial and regulatory institutions) before engaging in the development of transnational schemes to share GDP risk. The convergence benefits of these policies may then facilitate regional risk sharing of the kind described above, but such risk sharing is unlikely to be feasible in their absence.

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APPENDIX 1: TABLES

Table 12: Natural catastrophe pooling schemes

Scheme Name	Abbrev.	Country
California Earthquake Authority	CEA	United States
National Flood Insurance Program	NFIP	United States
Florida Hurricane Catastrophe Fund	FHCF	United States
Hawaii Hurricane Relief Fund	HHRF	United States
Disaster Financial Assistance programme	DFA	Canada
New Zealand Earthquake Comission	NZEQ	New Zealand
Caisse Centrale de Reassurance	CCR	France
Japan Earthquake Reinsurance Company	JER	Japan
Norsk Naturskadepool	NNP	Norway
Turkish Catastrophe Insurance Pool	TCIP	Turkey
Indonesia Catastrophe Insurance Pool	ICIP	Indonesia
Taiwan Residential Earthquake Insurance Pool	TREIP	Taiwan
Natural Disasters Fund	Fonden	Mexico
Caribbean Catastrophic Risk Insurance Facility	CCRIF	Caribbean (International)

Table 13: Descriptive statistics for Caribbean data sample

Country	Average Growth Rate (%)	Standard Deviation of Growth (%)	Correlation with Average Growth Rate (%)
Antigua	3.7%	10.5%	35.5%
Bahamas	1.3%	8.3%	60.8%
Bermuda	1.5%	3.4%	14.1%
Barbados	0.7%	5.9%	52.0%
Cuba	2.1%	9.6%	27.1%
Dominica	1.7%	6.4%	53.7%
Dominican Republic	2.6%	4.8%	-7.1%
Grenada	2.3%	6.7%	2.1%
Haiti	1.3%	7.1%	25.2%
Jamaica	1.0%	5.3%	-2.5%
St. Kitts & Nevis	4.4%	8.7%	44.8%
St. Lucia	2.3%	5.7%	32.8%
Puerto Rico	2.3%	2.3%	7.2%
Trinidad & Tobago	2.2%	7.7%	23.1%
St. Vincent	3.1%	8.5%	48.3%
Average	**2.2%**	**6.7%**	**27.8%**

Source: Author's calculations using PWT data.

Table 14: Descriptive statistics for G7 data sample

Country	Average Growth Rate (%)	Standard Deviation of Growth (%)	Correlation with Average Growth Rate (%)
Canada	1.8%	1.8%	67.8%
France	2.0%	1.2%	76.0%
Great Britain	2.3%	1.9%	76.3%
Germany	2.3%	1.4%	70.3%
Italy	2.4%	1.7%	59.3%
Japan	2.7%	1.9%	68.5%
USA	2.1%	1.6%	62.7%
Average	**2.2%**	**1.6%**	**68.7%**

Source: Author's calculations using PWT data.

Table 15: Island name abbreviations

Abbreviation	Full name
ATG	Antigua
BHS	Bahamas
BRB	Barbados
CAY	Cayman
CUB	Cuba
DMA	Dominica
DOM	Dominican Republic
JAM	Jamaica
MSR	Montserrat
PRI	Puerto Rico
KNA	St. Kitts and Nevis
LCA	St. Lucia
VCT	St. Vincent and the Grenadines
TTO	Trinidad and Tobago

Appendix 2: Sensitivity Tests for the EW Results

Table 16: Sensitivity of the EW welfare gain results (*g*)

	Discount Rate						*Risk Aversion Parameter*						*Time Period*				
δ	0.80	0.85	0.90	0.95	1.00	1.05	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
γ	3	3	3	3	3	3	2	2.5	3	3.5	4	4.5	3	3	3	3	3
Period Start	1970	1970	1970	1970	1970	1970	1970	1970	1970	1970	1970	1970	1970	1975	1980	1985	1990
Period End	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	1980	1985	1990	1995	2000
	g						*g*						*g*				
Antigua	1.32%	3.47%	7.85%	14.24%	19.70%	20.64%	10.69%	12.62%	14.24%	15.59%	16.69%	17.58%	-0.12%	2.83%	7.47%	4.68%	0.75%
Bahamas	2.30%	2.04%	1.36%	0.27%	-0.83%	-1.38%	-0.03%	0.10%	0.27%	0.49%	0.77%	1.08%	3.17%	4.67%	-0.02%	0.52%	0.19%
Bermuda	0.74%	0.62%	0.13%	-0.73%	-1.57%	-1.88%	-0.59%	-0.67%	-0.73%	-0.77%	-0.79%	-0.79%	1.08%	-0.65%	-0.39%	-0.17%	-0.17%
Barbados	-0.59%	-1.13%	-1.95%	-2.84%	-3.29%	-2.97%	-1.98%	-2.42%	-2.84%	-3.24%	-3.61%	-3.96%	-0.19%	-0.64%	-0.15%	0.00%	-0.16%
Cuba	5.12%	8.05%	11.14%	12.51%	10.71%	6.96%	8.64%	10.65%	12.51%	14.22%	15.77%	17.15%	2.14%	5.86%	7.43%	3.05%	1.26%
Dominica	0.74%	1.07%	2.06%	3.95%	5.98%	6.77%	2.85%	3.43%	3.95%	4.42%	4.84%	5.23%	0.80%	1.06%	4.04%	1.45%	0.90%
Dominican Republic	1.56%	1.72%	1.83%	1.92%	2.08%	2.30%	1.30%	1.61%	1.92%	2.22%	2.52%	2.82%	0.97%	0.25%	-0.55%	0.25%	2.45%
Grenada	-0.13%	-0.23%	-0.27%	-0.08%	0.44%	1.08%	0.00%	-0.03%	-0.08%	-0.13%	-0.19%	-0.26%	-0.13%	-0.28%	0.51%	0.57%	0.94%
Haiti	0.61%	0.21%	-0.76%	-2.03%	-2.81%	-2.67%	-1.41%	-1.73%	-2.03%	-2.31%	-2.57%	-2.82%	1.60%	-0.01%	0.46%	0.81%	-0.25%
Jamaica	-0.19%	-0.74%	-1.71%	-2.83%	-3.38%	-3.02%	-1.99%	-2.42%	-2.83%	-3.21%	-3.56%	-3.88%	0.21%	-0.54%	-0.24%	1.17%	-0.49%
St. Kitts & Nevis	2.92%	5.49%	10.24%	16.96%	22.80%	24.28%	12.64%	14.97%	16.96%	18.66%	20.11%	21.34%	0.63%	2.40%	2.58%	3.62%	4.77%
St. Lucia	1.46%	2.83%	5.29%	8.32%	10.06%	9.16%	6.04%	7.25%	8.32%	9.24%	10.04%	10.72%	0.13%	0.82%	6.03%	1.72%	-0.45%
Puerto Rico	0.71%	1.21%	2.30%	4.04%	5.70%	6.27%	2.98%	3.54%	4.04%	4.47%	4.84%	5.16%	0.55%	-0.47%	1.80%	1.67%	0.76%
Trinidad & Tobago	1.41%	1.03%	0.11%	-1.04%	-1.62%	-1.15%	-0.73%	-0.89%	-1.04%	-1.19%	-1.32%	-1.44%	2.18%	0.29%	3.64%	0.25%	1.63%
St. Vincent	2.33%	4.12%	7.66%	12.70%	16.79%	17.18%	9.31%	11.12%	12.70%	14.07%	15.25%	16.26%	0.83%	3.67%	3.83%	4.81%	0.78%
Weighted avg(g)	**1.14%**	**1.43%**	**1.92%**	**2.73%**	**3.66%**	**4.10%**	**1.98%**	**2.38%**	**2.73%**	**3.05%**	**3.33%**	**3.58%**	**1.13%**	**0.97%**	**1.69%**	**1.25%**	**0.75%**

Source: Author's calculations using PWT data.

Table 17: Sensitivity of the EW production share values (α)

	Discount Rate						*Risk Aversion Parameter*						*Time Period*				
δ	0.80	0.85	0.90	0.95	1.00	1.05	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
γ	3	3	3	3	3	3	2	2.5	3	3.5	4	4.5	3	3	3	3	3
Period Start	1970	1970	1970	1970	1970	1970	1970	1970	1970	1970	1970	1970	1970	1975	1980	1985	1990
Period End	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	1980	1985	1990	1995	2000
			α						α						α		
Antigua	4.89%	4.98%	5.22%	5.66%	6.24%	6.78%	5.66%	5.66%	5.66%	5.66%	5.66%	5.66%	4.67%	4.66%	5.50%	6.79%	7.75%
Bahamas	14.62%	14.28%	13.89%	13.41%	12.85%	12.28%	13.41%	13.41%	13.41%	13.41%	13.41%	13.41%	14.00%	13.18%	14.14%	13.19%	11.48%
Bermuda	22.36%	22.49%	22.48%	22.27%	21.86%	21.40%	22.27%	22.27%	22.27%	22.27%	22.27%	22.27%	22.95%	23.71%	22.72%	21.57%	20.51%
Barbados	11.33%	11.15%	10.86%	10.47%	10.05%	9.68%	10.47%	10.47%	10.47%	10.47%	10.47%	10.47%	11.34%	10.66%	10.27%	9.75%	9.10%
Cuba	3.00%	3.16%	3.36%	3.55%	3.65%	3.65%	3.55%	3.55%	3.55%	3.55%	3.55%	3.55%	2.97%	3.62%	4.35%	4.42%	3.53%
Dominica	4.02%	3.96%	3.94%	3.99%	4.11%	4.25%	3.99%	3.99%	3.99%	3.99%	3.99%	3.99%	3.80%	3.51%	3.75%	4.20%	4.53%
Dominican Republic	3.01%	3.06%	3.10%	3.14%	3.19%	3.23%	3.14%	3.14%	3.14%	3.14%	3.14%	3.14%	3.06%	3.26%	3.17%	3.03%	3.21%
Grenada	2.99%	2.99%	2.98%	2.98%	2.98%	3.00%	2.98%	2.98%	2.98%	2.98%	2.98%	2.98%	3.01%	3.00%	2.87%	2.90%	3.02%
Haiti	1.79%	1.78%	1.73%	1.64%	1.52%	1.40%	1.64%	1.64%	1.64%	1.64%	1.64%	1.64%	1.86%	1.92%	1.70%	1.38%	1.20%
Jamaica	4.17%	4.00%	3.75%	3.47%	3.21%	3.02%	3.47%	3.47%	3.47%	3.47%	3.47%	3.47%	4.14%	3.42%	2.88%	2.88%	2.91%
St. Kitts & Nevis	4.10%	4.28%	4.59%	5.09%	5.71%	6.31%	5.09%	5.09%	5.09%	5.09%	5.09%	5.09%	4.05%	4.46%	4.95%	5.85%	7.15%
St. Lucia	3.12%	3.19%	3.31%	3.50%	3.70%	3.86%	3.50%	3.50%	3.50%	3.50%	3.50%	3.50%	3.08%	3.13%	3.54%	4.15%	4.21%
Puerto Rico	8.78%	8.87%	9.04%	9.33%	9.70%	10.08%	9.33%	9.33%	9.33%	9.33%	9.33%	9.33%	8.89%	8.84%	8.91%	9.87%	10.73%
Trinidad & Tobago	9.18%	9.14%	8.92%	8.49%	7.96%	7.50%	8.49%	8.49%	8.49%	8.49%	8.49%	8.49%	9.64%	10.03%	8.30%	6.53%	6.66%
St. Vincent	2.63%	2.68%	2.80%	3.02%	3.29%	3.54%	3.02%	3.02%	3.02%	3.02%	3.02%	3.02%	2.53%	2.59%	2.94%	3.51%	4.02%

Source: Author's calculations using PWT data.

Appendix 3: Hurricane Index Calibration

Table 18: Peak wind speed within 60nm of city (kts)

Year	Storm	ATG	BHS	BRB	CAY	CUB	DMA	DOM	JAM	MSR	PRI	KNA	LCA	VCT	TTO
1970	DOROTHY			60			55						60		
1973	GILDA				30										
1974	ALMA														40
1979	DAVID						125	150							
1979	FREDERIC	50				65		40		50	45	50			
1980	ALLEN			110					115				115	115	
1984	KLAUS										45				
1985	KATE					80									
1986	DANIELLE													50	
1987	EMILY			40				105					45	45	
1988	GILBERT				125		40		110				40		
1989	HUGO	125					120			125	110	125			
1992	ANDREW		125												
1993	BRET														50
1993	CINDY						35	35					35		
1994	DEBBY			45									60		
1994	GORDON								40						
1995	LUIS	115								115		115			
1995	MARILYN	80					75			80	95	80	70		
1996	HORTENSE	55					55			60	70	0			
1998	GEORGES	100						95		100	90	100			
1999	IRENE					65									
1999	JOSE	85								80		80			
1999	LENNY	60								60		85			
2001	IRIS			30					75				30	30	
2001	MICHELLE		75												
2002	ISIDORE			0	60										25
2002	LILI			50					45					50	
2003	ODETTE							40							
2004	CHARLEY				80	105									
2004	FRANCES		90												
2004	IVAN				135				135						
2004	JEANNE	35					30	65		35	60	50			

Source: Author's calculations using HURDAT data.

Table 19: Economic losses as % GDP

Year	Storm	ATG	BHS	BRB	CAY	CUB	DMA	DOM	JAM	MSR	PRI	KNA	LCA	VCT	TTO
1970	DOROTHY														
1973	GILDA														
1974	ALMA														0.1
1979	DAVID														
1979	FREDERIC														
1980	ALLEN							0.2	0.8				20.2		
1984	KLAUS						0.5								
1985	KATE								0.1						
1986	DANIELLE														
1987	EMILY			2.6				0.1						1.2	
1988	GILBERT								10.3				122		
1989	HUGO	12.7					4.7			56.9		14.5			
1992	ANDREW		5.3												
1993	BRET														
1993	CINDY														
1994	DEBBY														
1994	GORDON					0.2									
1995	LUIS	39.2					0.7					43.1			
1995	MARILYN														
1996	HORTENSE														
1998	GEORGES	6.7						4.1							
1999	IRENE														
1999	JOSE														
1999	LENNY											7.1			
2001	IRIS														
2001	MICHELLE		5.4		1.4	0.2			0.5						
2002	ISIDORE														
2002	LILI													1.2	
2003	ODETTE														
2004	CHARLEY				0.1	1.6			2.5						
2004	FRANCES		18.1												
2004	IVAN			0.1	77.9				5.0					0.6	
2004	JEANNE							0.5							

Source: Author's calculations using HURDAT & PWT data.