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NATURAL CATASTROPHES AND SOVEREIGN BOND PRICES

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ABSTRACT

Aim/Purpose	This study investigates effects of natural catastrophes on the cost of sovereign debt in developing countries and discusses MNC financing strategies.
Background	Over the last decades, natural disasters have increased in both number and severity. The combination of higher event frequency and intensity, coupled with fragile economic conditions in emerging market countries, may affect sovereign bond prices—particularly in developing countries—and consequently may have effects on the financing strategy of MNCs
Methodology	Parametric and non-parametric analyses and event study method.
Contribution	The current literature in International Business research has overlooked natural catastrophes as a source of heterogeneity across countries for investment decisions. We develop the theory and demonstrate empirically that both researchers and practitioners should take into account natural disasters when making internationalization decisions.
Findings	We find that natural disasters have a material impact on the bond returns issued by developing country governments and consequently on MNCs' host-country financing costs.
Recommendations for Practitioners	Practitioners may consider the likelihood of natural disasters when making investment decisions in foreign countries.
Recommendation for Researchers	Researchers may consider including natural disasters when in internationalization research; our research adds in particular a new dimension to the location choice literature.
Impact on Society	Governments—in particular those in emerging markets—may rethink their strategies of how to "insure" themselves against natural disasters. Not being insured against these disasters result in negative secondary effects on economic development through higher cost of capital, and possible through lower FDI activities.
Future Research	Future research can be done. There are several avenues: using our insights and applying them to governmental reinsurance strategies would be a worthwhile topic. On a different level, one could also investigate further the contingencies

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of our findings and extend the theoretical framework towards developed markets.

Keywords natural disasters, location choice, multinational corporations, international strategy

INTRODUCTION

Natural disasters—hurricanes, earthquakes, floods, windstorms, and the like—have long been considered a tragic interruption to a country's development process.[1] They cause large and unexpected losses. Lives are lost, networks disrupted and capital investments destroyed. Over the last decades, the frequency and severity of natural disasters have substantially increased, and the devastating effects are particularly magnified in developing economies. For example, during 1990 to 1999, the total direct economic loss from natural disasters was some US$670 billion (Munich Re, 2004), imposing a significant financial burden particularly on emerging markets governments. Given their impact on emerging market economies, do these disasters matter for MNCs' international strategy?

In order to respond to that question, we investigate links between natural catastrophes, the cost of sovereign debt, and MNC financing strategies in developing countries. In particular, we examine evidence supporting the proposition that catastrophic events increase sovereign bond spreads in developing countries. We further examine under which conditions these events are associated with increasing bond spreads.

We study the effect of natural catastrophes in emerging market countries because the impact of a catastrophe can be very substantial relative to their gross domestic product and may result in long-term inability to sustain economic progress. Additionally, catastrophe risk insurance is primarily born by governments in developing countries and by public capital markets in industrialized countries. Seen though an obsolescing bargaining lens (Vernon, 1971, 1977), the host-country government's goals may shift towards rebuilding infrastructure, which increases potential conflicts with a MNC operating in that country. Constraints of host-country governments' have increased as well, as the financial burden of the recovery process primarily lies in the hands of the public institutions (Kunreuther & Linnerooth-Bayer, 2003). By awarding the host-country a higher risk premium, or increase the cost of financing, foreign-based investors perceive these changes in government goals and constraints.

Previous research as well as the commentary from public policy makers and business experts has suggested a link between the catastrophes and heavy cost to governments but surprisingly no previous research has implemented any systematic study designed to test for empirical evidence of such links. Our study attempts to address this gap. Catastrophe risks have peculiar features that distinguish them from many other types of risks often recognized by the international business literature and thus represent a promising alley for research.

For international business scholars, this research implies the necessity to consider host-country financing constraints contingent on catastrophic risks as part of the foreign direct investment decision. Bond spreads have been shown in the international finance literature as a good proxy for host-country risk perception (Lee and Kwok, 1988). International business ("IB") research has long recognized the importance of understanding the divergent interests of foreign investors and possible constraints of host states, and resulting risks investors perceive over time, particularly in non-industrialized country contexts (Vernon, 1971; Fagre & Wells, 1982; Kobrin, 1987; Minor, 1994; Wells

[1] Natural disasters and catastrophes are used interchangeably throughout this paper. A natural disaster typically refers to an extreme event caused by a natural force or hazard, which overwhelms the response capability within a geographic area and thus affects the social and economic activity of that region.

& Gleason, 1995; Eden & Appel-Molot, 2002). The last decade of IB research has re-examined these interests with greater emphasis on understanding what strategic actions host states can take to reduce perceived risks and attract international investment (Lenway & Murtha, 1994; Murtha & Lenway, 1994), and what legal and political institutions (Murtha, 1993; Henisz, 2000; Dixit, 2003) may constrain such state actions. In addition to these literature streams, traditional IB research including Perlmutter (1969), Kindleberger (1970), Porter (1986), and Bartlett and Goshal (1989) has discussed extensively adoption of host-country and home-country orientation of MNCs. Given that the financing function firms

The following section overviews literature related to this study. We start by briefly introducing conceptual issues on catastrophe financing. Then we proceed by outlining the idiosyncrasies of developing countries concerning natural disasters and the exposure of MNCs to catastrophe risks.

The third section develops the relationship between sovereign bond prices and catastrophes, and presents the hypotheses and empirical testing methods. This section also describes the data sources and samples in detail, and outlines the econometric methods used.

The fourth section presents our results and the last section concludes and discusses.

RESEARCH BACKGROUND AND RELATED LITERATURE

CATASTROPHE RISK PHENOMENON

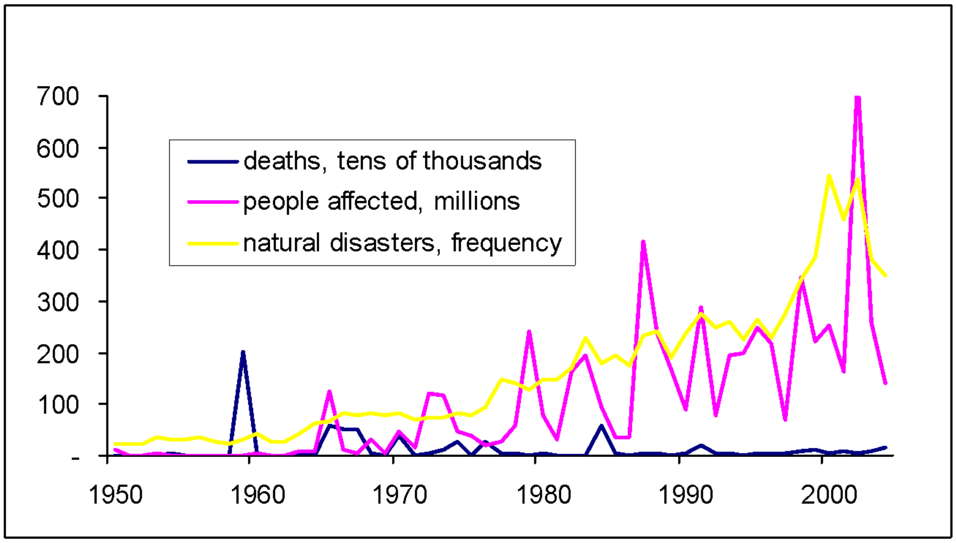
Several factors emphasize the concern to consider natural disasters as an added dimension of risk for both MNCs and sovereign governments. Over the past several years, catastrophes have increased both in number and severity (Stripple, 1998).[2] During the 1990s catastrophic events grew five-fold. In the period between 1990 to 1999, the total direct economic loss from natural disasters was some US$670 billion (Munich Re, 2004). In the last decade, the number of catastrophes has more than doubled, and the resulting economic loss for the world's economies multiplied by a factor of 6.7 compared to the decade of 1960s. Figure 1 provides a decade comparison of natural catastrophes between 1950 and 2003 and Figure 2 provides a frequency chart of the disasters for the same period with global number of people affected and killed.

Decade	**1950-1959**	**1960-1969**	**1970-1979**	**1980-1989**	**1990-1999**	**Last 10 years**		**Last 10-60s**
Number of Events	20	27	47	63	91	60	The comparison of the last ten years with the 1960s shows a dramatic increase	2.2
Economic Losses	42.7	76.7	140.6	217.3	670.4	514.5		6.7
Insured Losses	-	6.2	13.1	27.4	126.0	83.6		13.5

Source: Munich Re, 2003

Figure 1: Decade Comparison of Economic and Insured Losses

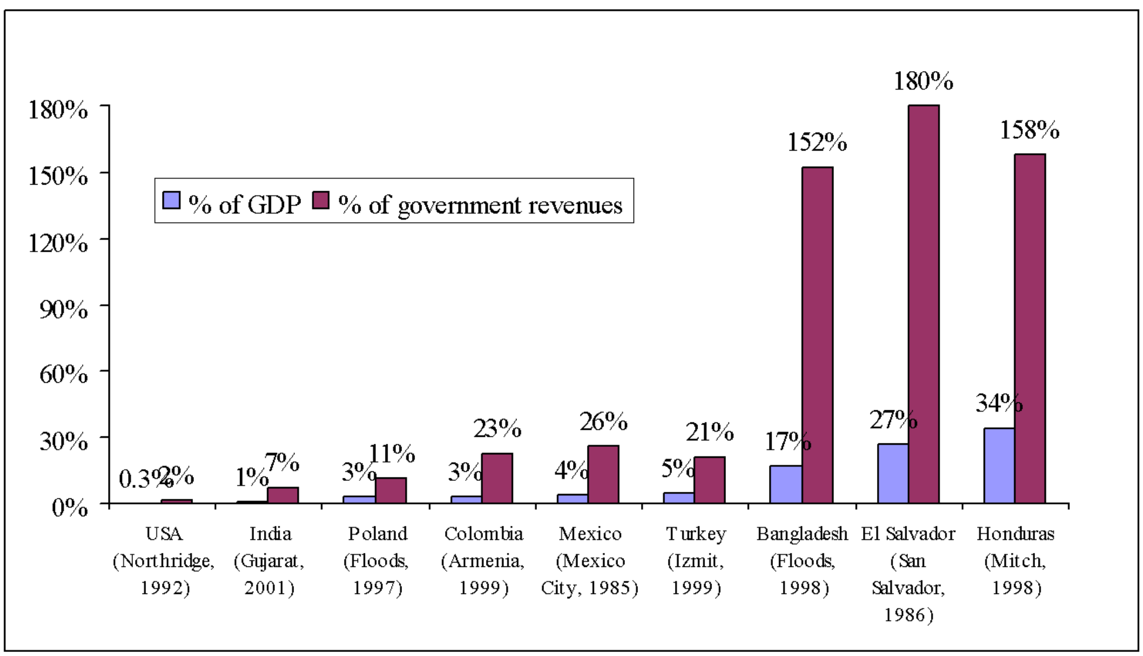
[2] There are many reasons for the escalation in the scope and frequency of natural disasters. Global climate change is accepted as one of the important factors. Stripple (1998) points out that, while the scientific community is not unanimous in its judgment, there is growing support for linking natural catastrophes to the increase in greenhouse gasses and the ensuing effects on regional climate regimes. The increase in extreme weather events we have seen in the last decade is consistent with the developments that climatologists expect in a warmer climate.



Source: EM-DAT: The OFDA/CRED International Disaster Database, Universite Catholique de Louvain, Brussels

Figure 2: Natural Disasters, Number of People Affected and Casualties between 1950-2003

Developing countries incurred the majority of the cost. In 1998, close to half of the economic losses caused by natural disasters were related to a single event in China: the Yangtze River flood. Likewise, when Hurricane Mitch struck, two-thirds of global losses affected the less developed economies of Central America (Freeman, 1999). In December 2004, a Tsunami devastated parts of least six countries in Asia. More than 220,000 people were killed, several million people were displaced from their homes, and governments incurred economic losses of at least $18 billion.



Source: Gurenko, 2004

Figure 3: Uninsured Economic Loss as Percentage of GDP and Government Revenues

The combination of higher event frequency and intensity, coupled with the fragile economies of the developing countries, increases the potential damage from natural disasters and pose a challenge to sustainable economic development. Economic losses from a single catastrophic event can be devastating for particularly small economies. El Salvador's earthquake of 1985 destroyed 27% of GDP and was equivalent to 158% of total government revenues. Even for larger economies, fiscal implications could be quite severe. The losses from the Gujarat earthquake, for example, amounted to 7% of government revenues and in subsequent years the Indian government faced an increase its fiscal deficit by a few percentage points (Gurenko, 2004). Figure 3 provides an overview of uninsured economic losses as percentage of GDP and government revenues for selected natural disasters in the last decade.

Developing economies are more vulnerable to disasters for a host of reasons. First, these nations often incur large losses as they are composed of densely populated neighborhoods, often developed with little, if any, planning, poor infrastructure, and degraded housing. Economic assets are more often built in exposed regions, which increase the risk for extended potential damage (Kleindorfer and Kunreuther, 1999a). Second, nascent insurance markets cannot readily absorb most of the losses resulting from a catastrophe. Most insurance for economic effects of natural disasters covers private assets in the developed countries, while developing countries are largely left without financial coverage (Swiss Re, 2000). Although insurance companies have started to expand their operations to emerging markets in the recent years, the most vulnerable countries remain highly exposed to disasters, which leave them reliant on external aid and post disaster funding to deal with natural disasters. Third, the indirect effects are often far higher and cause longer-term instabilities (National Research Council, 1999). Lack of liquidity in the aftermath of a disaster severely retards economic recovery. When a disaster strikes, funds targeted for development are often diverted to finance relief and reconstruction efforts, jeopardizing long-term goals. Many catastrophes have resulted in billion dollar costs. Relative to the small gross domestic product of a developing country, the impact can be difficult to bear and may result in long-term inability to sustain economic and social progress.

With infant insurance markets and low-income levels, governments are the primary financiers of the catastrophes in developing economies, and this makes host-countries in emerging markets particular sensitive to increase in perceived risk by investors, as governments become increasingly constraint through natural disasters.

Natural disasters can be characterized as low-frequency, high-severity loss events. These are types of losses that happen rarely, but with very high severity, where the covariance among the individual risks making up an insurance portfolio are also relatively high. It is difficult for the insurance industry to handle such losses because the usual pooling mechanisms in order to diversify risk do not apply.

As a result, managing catastrophic risk has its unique challenges. Catastrophic events are less probable but very large in terms of loss potential. Diversification is difficult even at a global level. Consequently, when a disaster strikes, aggregate losses tend to be very high. This highly correlated and large nature of the catastrophe risk makes it difficult for the private insurance companies to fully diversify the risk in the system.

Catastrophe risks, especially large ones, can threaten the solvency of individual insurance companies due to the extreme agglomeration of loss events. For example, a loss of $100 billion—which is probable from a single earthquake or hurricane—would seriously impair the capacity of the insurance industry (approximately 30% of the equity capitalization of the US insurance industry).[3] The same amount of loss, on the other hand, would be more manageable relative to the large size of stock and

[3] The capital of US Property/Casualty industry is about $350 billion, and the global reinsurance is about $125 billion. A loss of $100 billion would equal to about 30% of the equity capital of the US insurance industry, and about 80% of the global reinsurance.

bond markets (less than 0.5% of market value), and would partly be swamped in the normal trading volatility (Cummins *et al.*, 2000; Froot, 2001).[4] Thus, securitization of catastrophe risk and bringing it to capital markets, offers a potentially more efficient mechanism for financing catastrophe losses compared to conventional insurance and reinsurance structures.[5] This recognition led to analysis and development of innovative ways to transfer catastrophe risk to capital markets.

Many scholars documented the ineffectiveness of reinsurance markets for financing large infrequent events and the potential for securitization of catastrophe risk. Froot (1997, 1999) illustrates that very little insurance is in place for large event losses. He examines reinsurance buying patterns using data from property/casualty contracts and observes that reinsurance coverage as a fraction of exposure declines markedly with the size of the event, falling to a level of less than 20% for events of about $5 billion or greater. Froot concludes these losses are paid mostly *ex-post* by some combination of insurers and re-insurers, insureds, state and federal agencies, and taxpayers merely by the fact that there is relatively little insurance in place for such large event losses.

Governments, Catastrophes and Developing Countries

Catastrophes have an added significance in developing countries as these countries often suffer higher losses as a proportion of their income. Poor housing, weak building codes, lack of urban planning and insufficient infrastructure further exacerbate their vulnerability. Hence, countries with high poverty levels are more exposed to the disruptive social effects of natural catastrophes, and tend to experience more fatalities and more severe economic damage (Freeman, 1999).

A primary difference between the developing world and the developed countries in financing catastrophe risk is the weighty involvement of the government. Even in developed nations with well-developed insurance markets, loss potential from cat-risk exposures can be so large that the insurance markets are unable to provide sufficient capacity at reasonable prices. In emerging economies, as there are no private insurance markets developed to absorb or manage catastrophic events, governments very often are forced to act as the reinsurers of the last resort.[6] Thus, the government becomes crucial.

The role of governments in compensation and disaster aid to the victims is controversial in the developed markets. On the one hand, some scholars argue that large catastrophes must be reinsured by the government (or in the financial markets) as the cost to the society is very high (Lewis and Murdock, 1996; Cutler and Zeckhauser, 1999). Lewis and Murdock (1996) studying the prospective role of the US Government and federal reinsurance, find that the insurance markets are limited in their ability to *inter-temporarily* diversify catastrophic risk. They propose a new form of federal reinsurance based on the auctioning of multiple peril catastrophe call spread options that cover industry losses in

[4] Publicly traded stocks and bonds have a total market value of about $60 trillion. The historical volatility of the stock market corresponds to a daily change in market value of about 1%, whereas the daily change in bond returns in about 0.7%. A loss of 100 billion dollars would be less than 0.5% of the market value of bonds and stocks.

[5] By efficiency, we refer to the theory of diversification based on the law of large numbers. The demand for global reinsurance as attributable to covariability of risk within the insurance/re-insurance industry can be reduced or eliminated through diversification of the risk to capital markets. This theory gives rise to a natural definition of market efficiency as the degree of risk remaining after the diversification to capital markets has taken place.

[6] According to a study by Swiss Re (1996), developing economies in Asia were hit highest with catastrophes (50% of all events and 70% of all catastrophes), but the region had lowest insurance cover (8.75% of losses), compared to the USA/Europe with relatively low catastrophes (15%/13% of total) and high insurance coverage (64%/22% of losses).

the range of $25-50 billion. The article argues that the sale of these contracts utilizes the unique inter-temporal diversification capabilities of federal government to expand the market for natural disaster risk while enhancing the private market equilibrium.

While private insurance should be more efficient at spreading risk, it assumes well-functioning, competitive markets. In the case of developing economies, however, there is low insurance penetration and markets are less efficient. Global insurance companies are expanding their coverage for natural hazards in less developed markets; nevertheless, this is often suboptimal from an economic standpoint. Small and poorly capitalized domestic insurers have little risk-bearing capacity of their own and have to rely predominantly on the global reinsurance markets to provide catastrophe insurance coverage in the domestic market (Gurenko, 2004). This strong dependency is usually associated with high costs and unaffordable premiums. International insurers may overcharge clients with small bargaining power. They may also reflect their reluctance to assume risks often lacking statistical record in higher premiums. Moreover, market segmentations and regulatory constraints can impose additional charge to insurance costs. Consequently, in almost all developing countries governments remain to be the primary source for funding disaster losses.[7]

Pollner (2001) demonstrates that in natural disaster prone small economies, difficulties in funding catastrophic risks become magnified. He studies hurricane-prone countries in the Eastern Caribbean and argues that in the Caribbean region, the problem of catastrophe risk insurance and constraints to expanding risk management strategies are linked to both the limited domestic risk bearing capacity and the dynamics of international market forces. He proposes sub-regional diversification and suggests that World Bank (and other international development institutions) assist in this risk reduction process. He argues that the combination of public, private, international and multilateral resources can jointly implement broader cost-effective risk management tools, which can minimize the economic and financial disruptions of disaster events in small economies.

Multinational Corporations and Catastrophe Risk

Prior IB research has established that the attractiveness of a foreign direct investment decision depends on different factors, including macro-economic, political, institutional, and competitive risks. All these dimensions are often labeled as the multidimensional construct of "country risk."

Cross-country variations in country risk have been widely documented (e.g., Economist Intelligence Unit, 2003). It is true, due to ongoing global shifts in ideology from the "state" to the "market," such risks appear to be declining over time; notwithstanding these trends, it is also true that, in many countries, such risks continue to remain salient (UNCTAD, 2002).

Given the ongoing and widespread prevalence of country risk, managers of MNCs rarely if ever have the strategic justification for avoiding it altogether. Many countries are characterized not just by relatively higher levels of risk but also by lower resource (including labor) costs and/or relatively larger markets. It is for these reasons that many MNCs find it strategically necessary to establish operations in relatively higher risk countries such as Mexico, Brazil, China, or India (Weiss, 1990).

Unfortunately, commercially available measures of country risk fail to anticipate significant economic or political changes. In a recent study, Oetzel et al. (2001) examined the performance of 11 widely used measures of country risk during a 19-year period across 17 countries. These authors found that none of the sampled measures was effective in predicting periods of significant volatility, their proxy for commercial risk.

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[7] The standard theory is that the cost of public risk bearing in the hands of each individual in a country is *de minimis* and should therefore be considered small in the hands of government. The cost of risk in each individual's hand approaches zero the smaller the risk is to the wealth of a country, or larger the population through which the risk can be transmitted using taxes.

International finance research employs as country risks the yield spread of domestic sovereign debt over the "riskless" US treasury bills.

HYPOTHESES DEVELOPMENT AND EMPIRICAL SETTING

HYPOTHESES DEVELOPMENT

As pointed out before, we focus our empirical test on the relationship between catastrophes and *ex-post* borrowing cost (yield spreads) of governments as a proxy for country risk. This section develops several hypotheses with this regard.

Kunreuther and Linnerooth-Bayer (2003) ask whether there are political or other constraints in arranging financing in the developing economies after a catastrophic event. Therefore, our first Hypothesis for this study is:

H1: Catastrophes are immediately associated with increasing sovereign bond spreads.

If the theoretical premises recalled above are true, it may be expected that the cost of borrowing for governments would increase after the catastrophes occurred. One would expect to see spreads increasing more in less developed countries with no funds in place. First, countries with low GDP per capita tend to have less efficient and less liquid bond markets than countries with high GDP per capita incomes. The lack of efficiency and market liquidity results in generally higher price volatility. Second, the higher risk of defaulting on their debt would make it difficult or expensive to raise funds especially after a major disaster. Hypothesis 2 is motivated by this notion and is structured in two subparts:

H_{2a}: Catastrophes are associated with higher increases in bond spreads of less developed market issuers.

H_{2b}: Catastrophes are associated with higher increases in bond spreads of countries with lower sovereign ratings.

One important factor that affects the countries' loss-bearing capacity is their ability to mobilize savings and the level of insurance penetration in those countries. If there is high savings in a country for insurance coverage, the bond market reaction is expected to be lower. Thus, the third Hypothesis is related to how much a country is able to mobilize its insurance savings:

H3: Catastrophes are associated with higher increases in bond spreads of countries with less insurance coverage.

Previous research argues that, as the incidence and severity of disasters increase, the financing of disaster relief and reconstruction becomes more of a concern for governments. This is especially true if the disasters produce a high damage relative to the country's GDP. Hypothesis 4 is motivated by this notion and seeks to answer if there is a size effect reaction to catastrophes. High damage relative to a country's GDP would provide us with important information regarding a country's ability to absorb losses:

H4: Large catastrophes have different post-catastrophic behavior in the market than smaller catastrophes.

Finally, it may be that there is natural hazard exposure already embedded in the current sovereign bond prices, particularly for disaster-prone countries. In other words, part of the sovereign risk premium for a country may be attributed to the natural hazard risk it is exposed to.

H5: Catastrophes are associated with lower increases in bond spreads for disaster-prone countries.

We use an event study methodology to examine the primary Hypothesis 1 and we build a multivariate regression model to examine Hypotheses 2 through 5.

DATA SOURCES AND SAMPLES

Two types of core data are collected for our analysis. First, we collected bond data in the format of "total returns" and "yield spreads" issued by developing country sovereigns over the period of January 1994 to December 2003. Second, we compiled a list of natural catastrophes with strike dates, affected countries, type and magnitudes within the same period.

Apart from the core data on catastrophes and government bond returns that we use for our event study, we gathered macroeconomic and financial variables that determine country risk and insurance data. We utilize the latter in the cross-section analysis to explain the determinants of the variation in the bond returns.

Our bond data set consists of daily series of J.P. Morgan Emerging Market Bond Index Plus (EMBI+) composite index, EMBI+ country-level total return indices, EMBI+ sovereign spreads. J.P. Morgan produces EMBI+ series that tracks total returns for a cocktail of traded external debt instruments in the emerging market countries.

The catastrophe data is sourced from Emergency Disaster Database (EM-DAT)—the OFDA/CRED International Disasters Data Base.[8] EMDAT contains essential core data on the occurrence and effects of mass disasters in the world from 1900 to present and it is compiled from various sources, including UN agencies, non-governmental organizations, insurance companies, research institutes and press agencies.

We start with the entire dataset of "Natural Disasters" during the period between January 1994 to December 2003 for the developing countries as listed above. Then, we eliminate the type of natural disasters Epidemic, Insect Infestation, Drought, Famine, and Wild Fire from the dataset, as the initial strike dates for these types of disasters are either not available or imprecise in the dataset. It is critical for the event study methodology we apply to be able to identify the event date with some level of certainty. We are left with natural disaster of the type Earthquake, Extreme temperature, Flood, Slides, Volcano eruption, Wave/surge, Windstorm.

To build our dataset, we follow the disaster defining criteria used by Swiss Re Sigma. Accordingly, a disaster is included in our sample if any of the following conditions are present:[9]

- 20 or more people reported killed
- 20 or more people reported injured
- 2,000 or more people reported homeless.

Our sampling procedure yields 156 events for the market model and 211 for the yield spread model.[10] The sample involves 85 floods, 55 windstorms, 28 slides, 26 earthquakes, 12 extreme temperatures, 4 volcano eruptions, and 1 tidal wave. We work with clean events—such that the events do not overlap in windows of +/- 15 days. We eliminated as well events when we found significant news with an material impact on bond market during 8 days before and after the event. Table 1 presents the breakdown of the sample by country and disaster type.

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[8] EM-DAT: The OFDA/CRED International Disaster Database - www.em-dat.net - Université Catholique de Louvain - Brussels – Belgium. WHO Collaborating Centre for Research on the Epidemiology of Disasters (CRED) has been maintaining an Emergency Events Database since 1988. EM-DAT is created with the initial support of the WHO and the Belgian Government. OFDA (USAID's Office of U.S. Foreign Disaster Assistance) and CRED joined initiatives to expand and make available this specialized database on disasters.

[9] Swiss Re Sigma is the research arm of Swiss Reinsurance Company, and provides theoretically and empirically sound analyses on strategic topics of insurance and reinsurance and is commonly accepted as one of the most reliable market information source in the industry.

[10] We have additional bond spread data for Algeria, Chile, Croatia, Guatemala, Indonesia, Jordan, South Korea, Thailand and Vietnam.

Table 1: List of Disasters in the Sample

Country	Flood	Windstorm	Earthquake	Volcano	Extreme Temperature	Wave/Surge	Slide	Total
Argentina	5	1	-	-	-	-	-	6
Brazil	12	1	-	-	-	-	6	19
Bulgaria	-	1	-	-	1	-	-	2
Colombia	4	1	-	-	-	-	4	9
Ecuador	4	-	2	1	-	-	3	10
Egypt	1	-	-	-	-	-	-	1
Mexico	4	10	1	2	4	-	-	21
Morocco	3	-	-	-	-	-	-	3
Nigeria	7	1	-	-	-	-	2	10
Peru	4	1	2	-	-	-	3	10
Philippines	7	17	4	1	-	1	2	32
Poland	2	1	-	-	3	-	-	6
Russia	2	4	2	-	2	-	2	12
South Africa	3	2	-	-	-	-	-	5
Turkey	1	1	6	-	1	-	-	9
Venezuela	4	-	1	-	-	-	-	5
Algeria	4	-	2	-	-	-	-	6
Chile	2	-	-	-	1	-	-	3
Croatia	-	-	1	-	-	-	-	1
Guatemala	-	-	-	-	-	-	1	1
Indonesia	4	-	5	-	-	-	4	13
Jordan	-	2	-	-	-	-	-	2
Korea, Rep	5	4	-	-	-	-	-	9
Thailand	5	1	-	-	-	-	-	6
Viet Nam	2	7	-	-	-	-	1	10
Total	85	55	26	4	12	1	28	211

As control variables, we collected annual data for the period 1994-2003 a range of macroeconomic and financial characteristics linked to emerging market countries using the World Bank's World Development Indicators ("WDI") (World Bank, 2003).

We further obtained information on sovereign risk ratings published by Standard and Poor's and Moody's Rating Services for our list of countries for the period between 1994 through 2003. We obtained this information using Bloomberg International on-line sources. For each catastrophic event date, the published sovereign risk rating on that particular date, measured on a 17-point (0= country in default to 16 = riskless) scale, is noted.

Finally, we obtained insurance data for the same period from Swiss Re, Sigma World Insurance database (Swiss Re, 2003). The database provides world insurance data covering 88 countries and 17 regional aggregates around the world.

EMPIRICAL METHODS

EVENT STUDY

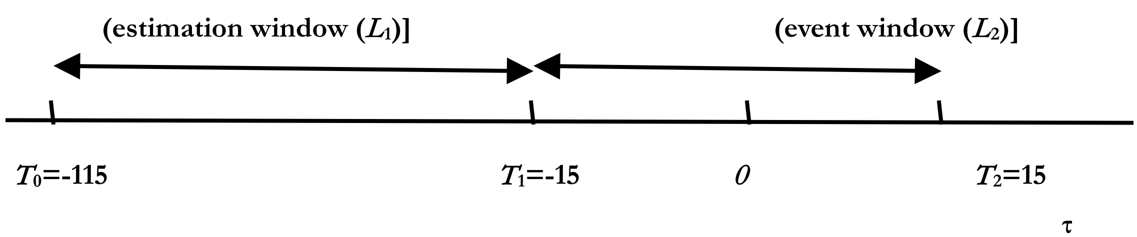
We start our analysis by using the event study methodology to test whether natural disasters affect sovereign bond prices in emerging markets (Hypothesis 1). Event studies have been widely used in accounting and finance literature to evaluate the impact of a wide variety of firm-specific or economy-wide events on asset prices. An event study is an econometric procedure to measure the effects of an event (or a set of events) on the value of assets by examining the asset price movements in short intervals around the event date.

The usefulness of this methodology finds its basis on the efficient market hypothesis. That is, the effect of an event will be immediately reflected in the asset prices, thus, its economic impact can be studied observing asset prices over a relatively short time period.

Some seminal papers that introduced the foundations of the methodology include Ball and Brown (1968) where they examine the information content of earnings. Subsequently, Fama, Fisher, Jensen and Roll (1969) established the methodology still in use today with their study on the effects of stock splits. Brown and Warner (1980, 1985) provide important contribution by presenting basic modifications to the methodology to handle the complications due to violations of certain statistical assumptions.

There are several advantages of event study methodology with specific reference to studying catastrophes. Since the occurring and timing of catastrophes is not predictable, the use of this methodology is particularly reasonable. It allows for utilization of data that are available over short enough intervals to narrowly focus on the event. In our study, the changes in the bond spreads assess the predicted cost increase to sovereigns by catastrophic events. Thus, it can provide us with the market's forecast of the consequences of natural disasters for the countries' credit risk. It also allows for joint tests of the impact across the type of events (*i.e.*, hurricanes, earthquakes) and across countries.

We use a 31-day event window and define day-zero as the event date. The timing sequence used in this analysis is illustrated in the Figure below.[11]



L_1 ($L_1 = T_1 - T_0$) and L_2 ($L_2 = T_2 - T_1$) are the lengths of "estimation window" and the "event window," respectively. We use the estimation window to estimate the market model parameters. We set the event window wider than the interval under consideration to measure the impact of catastrophes on sovereign bond prices. This setup, commonly used in literature, allows us to study the pre- and post-performance of the bonds around the catastrophe date and provide comparisons. We measure the changes in the returns for the days 1 through 15 following the event date to calculate cumulative returns and test Hypothesis 1.

The day-zero event date is the first date in which the catastrophe takes place for all but the windstorms. Because windstorms (*i.e.*, hurricanes) can be tracked with a fair amount of accuracy, we expect that there is significant information leakage prior to the windstorms hitting land. For this reason, we treat the day-zero event for windstorms as the being two calendar days before they strike (Ward, 1997).

To assess the events' impact we require a measure of "abnormal return." The abnormal return is the actual *ex-post* return over the event window minus the normal (expected) return of the security over the same period. For each security i and event period t, the equation follows

$$AR_{it} = R_{it} - E[R_{it} | X_t] \tag{1}$$

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[11] We have also run the analysis for the event windows of 41, 51, and 61 and reviewed the results for the days 1through 20, 1 through 25, and 1 through 30 days after the catastrophes, respectively. The results were consistent with our findings of 31-day event window.

where AR_{it}, R_{it} and $E(R_{it})$ are the abnormal, actual and normal returns, respectively, for the time period *t*. Normal return is the return that would be expected if the event did not take place (*i.e.*, if the catastrophe did not occur). Thus, the computation of abnormal return requires estimation of the normal return.

Most event studies in financial economics focus on abnormal returns of equities surrounding a defined event and utilize Market Model for estimation of normal returns. For debt securities, however, there is no clear consensus on an appropriate theoretical model that generates returns. Yield spread analysis is the most commonly used model applied to sovereign bonds.[12] In our analysis, we use two approaches to define abnormal returns. First, we use standard Market Model approach following MacKinley (1997). Second, we use yield spread analysis as commonly applied to event studies with debt securities following Hand *et al.* (1992). Once we calculate the abnormal returns, we aggregate the results in both models to test our primary hypothesis H_{1a}

The market model is a statistical model that assumes a linear relationship between the market return and the security return. In other words, it relates the return of any security to the return of the market portfolio. For each security, the market model assumes the asset returns are given by

$$R_{it} = \alpha_i + \beta_i R_{mt} + \varepsilon_{it} \text{, where}$$

$$E[\varepsilon_{it}] = 0 \text{ and } Var[\varepsilon_{it}] = \sigma_{\varepsilon_i}^{2} \qquad (2)$$

where R_{it} and R_{mt} are returns on security and the market portfolio, respectively at time *t,* during event *e* and ε_{it} is the zero-mean disturbance term. a_i and β_i are the parameters of the market model (regression intercept and the beta coefficient of the regression).

We use the EMBI+ Composite as the benchmark index for calculating market portfolio returns. The level of R^2 for the regression runs are considerably high and we believe the power to detect the abnormal performance is strong.

The first series of regressions are performed using the daily returns on the country-specific indices, regressed against the daily returns of EMBI+ for the estimation window (T_0=-15 to T_1=-115) as in equation (2) above.

The market model parameter estimates, $\hat{\alpha}_i$ and $\hat{\beta}_i$ obtained from these first-round regressions are then used to predict "normal returns." Hence, we calculate the Abnormal Returns during the event window (T_1 =-15 to T_2 = 15) as follows:

$$\hat{A}R_{iet} = R_{iet} - (\hat{\alpha}_{ie} + \hat{\beta}_{ie} R_{met}) \qquad (3)$$

where R_{iet} represents the actual return on the country index *i* during event *e* at event time *t* and R_{met} represents the return of the market portfolio (EMBI+) for the same time period. a_{ie} and β_{ie} are the parameters calculated from the market model regression above on the return observations obtained from T_0=-15 to T_1=-115.

[12] Many of the recent event studies with bond data follow Hand, Holthausen and Leftwich (1992) which provide one of the most thorough analysis using daily prices. Yield Spread is defined as the yield of the referred bond minus the yield of the appropriate US Treasury. Cantor and Packer (1996) provide adjustment to Hand *et al.* focus on "relative" yield spreads—yield spreads divided by the appropriate US treasury rate—suggesting that they are more stable than absolute spreads and fluctuate less with the general level of interest rates. Both methods have been commonly utilized.

In order to draw overall inferences, we aggregate abnormal return observations along two dimensions—through time and across events following MacKinlay (1997) for cumulative abnormal returns (CARs) and Campbell *et. al.* (1997) for standardized cumulative abnormal returns (SCARs).

Cross-sectional Regression Analysis

Our second empirical analysis consists of a cross-sectional regression of observed bond spread changes on event specific or country specific factors. With this model, we attempt to further distinguish the characteristics that drive variation in abnormal bond returns and shed additional light on how catastrophes affect sovereign bond prices.

The empirical model, which examines the determinants of the abnormal returns, is defined in the equation (4) below. More specifically, this multivariate regression model is used to explain the variation in the abnormal returns, thus, test for Hypotheses 2 through 5. The model follows:

$$\begin{aligned} CAR_{iet} &= \beta_0 + \beta_1 GDPCAP_{ie} + \beta_2 RATING_{ie} + \beta_3 INSURANCE_{ie} \\ &+ \beta_4 SEVERITY_{ie} + \beta_5 DUMMYWIND_e + \beta_6 DUMMYFLOOD_e \\ &+ \beta_7 (DUMMYWIND * SEVERITY)_e + \beta_8 (DUMMYFLOOD * SEVERITY)_e \\ &+ \beta_9 DISPRONE_i + \varepsilon_{ie} \end{aligned} \quad (4)$$

where the subscript *i* indicates the country, *e* is an event counter and *t* is the number of days after the event.

The dependent variable *CAR* designates the cumulative abnormal returns measured according to the methodology laid out in above. It represents the cumulative abnormal return for the bonds of country *i* during the event *e* from the event day 0 through day *t*.

GDPCAP is GDP per capita. This regressor is used in order to examine whether countries with low GDP per capita are affected more by catastrophes then those with higher GDP per capita. *RATING* is the 17-level (0-16) sovereign risk rating. It is used to test if countries with higher sovereign ratings are less affected by catastrophes than countries with lower sovereign ratings. Sovereign rating, on the other hand, has particular importance for bond pricing. Sovereign rating is an important measure for bond pricing and spreads are sensitive to these ratings. Accordingly, we use the two variables—*GDPCAP* and *RATING*—to test Hypothesis 2_a and 2_b.

We follow Munich Re's application strategy and take the paid *insurance premium per capita* as an approximation for the percentage of insured people or households in a given country. Thus, *INSURANCE* refers to the *insurance premium per capita* in the referred country, which is used specifically to test Hypothesis 3.

SEVERITY is an index variable which describes the magnitude of the disaster as a combination of; *i) number of people killed (relative to population), ii) number of people affected (relative to population),* and *iii) estimated economic damage (relative to GDP),* which are the standard industry measures for assessing the "size" of catastrophes. The severity index is created based on the percentile ranks of these three variables. Specifically, we break each of these variables into percentiles and generate a new variable that is categorized on a scale from 1 to 100. Finally, we obtain the weighted average of the three categorized variables. The severity, for each event is defined as[13]

[13] We found no previous research in insurance literature to guide our choice of weights for the variables above. However, the market commonly defines the "size" the catastrophe in the developing economies by the *number of people killed,* as it is easily available and a more reliable source of information. Therefore, we have given the highest weigh to this variable. *Economic damage* is weighted in the middle, as it is the second important measure to define the size of disasters in developing economies. Finally, we have given the lowest weight to the

$$SEVERITY = 0.5 * percentile\left(\frac{\# killed}{population}\right) + 0.2 * percentile\left(\frac{\# affected}{population}\right)$$
$$+ 0.3 * percentile\left(\frac{\$loss}{gdp}\right)$$

DUMMYWIND (windstorms and extreme temperatures) and *DUMMYFLOOD* (floods and slides) are the dummy variables that control for the type of the catastrophe. *DUMMYEARTH* (earthquakes, volcano and wave/surge) is the third dummy left out from our regression. We also introduce interaction variables for the type of the catastrophe and severity. These interactions allow us to assess the impact of severity of the event on the bond returns for the different types of catastrophes.

Finally, *DISPRONE* is a dummy variable that takes a value of 1 if the country is considered to be "disaster-prone." We define disaster-prone based on the historical frequency of occurrence of the natural disasters in a particular country. If a country is hit more than 100 times since 1900 (which is the start date of our disaster dataset), it is considered to be disaster prone, thus gets a value of 1.

Turning to the hypotheses developed in section 3, equation (4) facilitates straightforward tests. *GDPCAP* and *RATING* are used to test Hypothesis 2a and 2b that catastrophes will result in higher yield spreads for the countries with less development level. This implies a negative coefficient sign on *GDPCAP* and *RATING*. In terms of each equation, the null hypothesis test then reduces to

H_{2a}: $\beta_1 > 0$

H_{2b}: $\beta_2 > 0$

To test the prediction of Hypothesis 3, which is the ability to mobilize insurance savings, equation (4) reduces to

H_3: $\beta_3 > 0$

Equation (4) is also used to test the prediction of Hypothesis 4, which is that the catastrophes will result in higher yield spreads as the severity increases. An interesting analysis here is to interact the *SEVERITY* with the different types of catastrophes. The impact of severity on yield spreads may be different for floods, earthquakes and windstorms. These hypotheses tests reduce equation (4) to

H_{4a}: $\beta_4 < 0$

H_{4b}: $\beta_4 + \beta_7 < 0$

H_{4c}: $\beta_4 + \beta_8 < 0$

Finally, Hypothesis 5 predicts that sovereign bonds react less for disaster-prone countries as the natural hazard exposure may be embedded in the current bond prices. Thus, equation (4) reduces to

$H5$: $\beta_9 > 0$

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number of people affected, as this measure could be more sensitive to types of disasters or countries. We have also assigned different weights to the variables above for sensitivity analysis. Re-estimating our model with alternative weights did not change our results.

Estimation Strategy

We use ordinary least squares ("OLS") approach to estimate equation (4) following MacKinley (1997) and consistent with earlier event study research.[14] Equation (4) is estimated using both $SCAR_{i\varepsilon T}$ and $CAR_{i\varepsilon T}$ as dependent variables.

The advantage of using SCAR as a dependent variable is that it provides an automatic adjustment for heteroscedasticity, since, in each event period, CARs are scaled such that SCAR is a random variable with a distribution of Normal (0,1). The disadvantage of the SCAR is that it is more difficult to gain economic meaning from the estimated coefficients (Ward, 1996).

Our results are checked for clustering of countries and heteroscedasticity using Huber/White robust standard errors in STATA (Huber 1967 and White 1982).

Results

Event Study Results

With respect to the behavior of the markets in the days following the catastrophes, the evidence supports the hypothesis that the information of catastrophes is assimilated by the market and is reflected in the country bond values or increased credit risk.

The results are illustrated in Figures 4a and 4b. The divergence in CARs after the event date can be clearly seen in these figures. As expected, in Figure 4a the divergence is negative since we use bond index returns as the underlying data in the market model and in Figure 4b it is positive as we employ bond spread data.

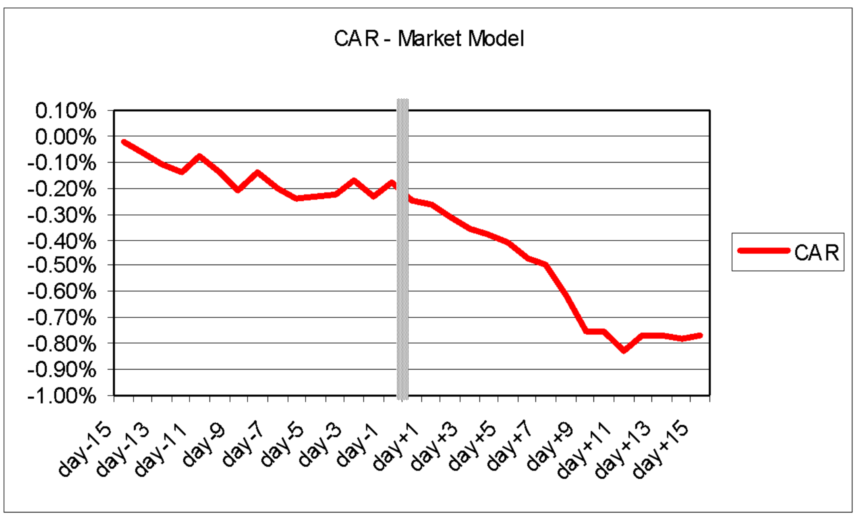

Figure 4a: Plot of cumulative abnormal returns from event day -15 to event day +15
The abnormal returns are calculated using the market model as the normal return measure.

[14] Journal of Financial Economics 15 (1986) includes several articles with event studies on equity offerings. Some of these include Asquith and Mullins (1986), Mikkelson and Partch (1986), Masulis and Korwar (1986).

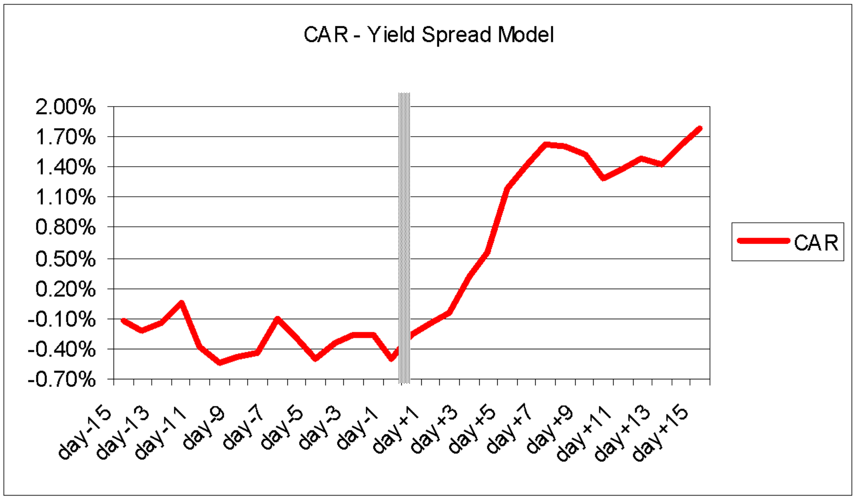

Figure 4b: Plot of cumulative abnormal returns from event day -15 to event day +15
The abnormal returns are calculated using the yield spread model as the normal return measure.

This continued divergence as indicated by the CARs after the event date shows that the market gradually absorbs the information. The gradual reaction is expected as the information about the level of damage reaches the market slower in emerging economies.

Table 2 presents CARs and the statistics for the period between day-0 and day-15. For the market model, average CARs tend to drift down slowly but steadily, taking a sharper decrease in days 7 thorough 9. The average standardized cumulative abnormal returns (SCARs) are significantly different from zero, for the windows of 5 to 15 days after the event day. Similarly, CARs are significantly different from zero for the days 8 to 15 days after the event day.

Table 2: Event Study Results

	Market Model (n=156)					Yield Spread Model (n=211)				
Event Day	CAR	J1		J2		CAR	J1		J2	
day-0	-0.073%	(1.04)		(1.18)		0.245%	1.00		0.95	
day+1	-0.084%	(0.85)		(0.79)		0.356%	1.03		0.98	
day+2	-0.129%	(1.06)		(0.82)		0.464%	1.10		0.86	
day+3	-0.179%	(1.28)		(0.90)		0.810%	1.66	*	2.02	*
day+4	-0.199%	(1.26)		(1.53)		1.045%	1.92	*	2.39	**
day+5	-0.233%	(1.35)		(1.75)	*	1.693%	2.84	***	2.90	***
day+6	-0.293%	(1.57)		(2.00)	**	1.920%	2.98	***	3.52	***
day+7	-0.320%	(1.61)		(1.83)	*	2.121%	3.08	***	3.66	***
day+8	-0.433%	(2.06)	**	(2.24)	**	2.097%	2.87	***	3.48	***
day+9	-0.572%	(2.57)	**	(2.19)	**	2.025%	2.63	***	2.83	***
day+10	-0.574%	(2.46)	**	(2.30)	**	1.776%	2.20	**	2.22	**
day+11	-0.654%	(2.69)	***	(2.71)	***	1.883%	2.23	**	2.26	**
day+12	-0.592%	(2.34)	**	(2.42)	**	1.979%	2.25	**	2.42	**
day+13	-0.591%	(2.25)	**	(2.17)	**	1.931%	2.12	**	2.10	**
day+14	-0.605%	(2.22)	**	(2.28)	**	2.124%	2.25	**	2.35	**
day+15	-0.587%	(2.09)	**	(1.98)	**	2.278%	2.34	**	2.43	**

Cumulative abnormal returns and standardized cumulative abnormal returns for the sample size of 156 for the market model and 211 events for the yield spread model. CARs and SCARs are calculated for the specified day in the event day 0 through the specified day. Test-statistics J_1 and J_2 are as follows:

$$J_1 = \frac{CAAR(\tau_1, \tau_2)}{\sqrt{\text{var}(CAAR(\tau_1, \tau_2))}} \sim N(0,1) , \quad J_2 = \left(\frac{N(L_1 - 4)}{L_1 - 2}\right)^{1/2} SCAAR(\tau_1, \tau_2) \sim N(0,1)$$

*Cars and Scars with z-statistics at the 10% confidence level

** Cars and Scars with z-statistics at the 5% confidence level

*** Cars and Scars with z-statistics at the 1% confidence level

The conclusions using the abnormal returns from the yield spread model are stronger than those from the market model are. Sovereign spreads rise significantly after the catastrophes and within all windows starting from day-3, the average SCAR and CAR variables have significant positive values. [15]

Based on these findings, we reject the null hypothesis H_o that the catastrophes have no impact on sovereign bond prices. It is clear from each of the tests presented in Table 2 that the catastrophes have a material impact on the bond returns of the developing country governments. Average CARs drift up steadily taking significant levels at $p < 0.05$ on day-4 for the spread model and on day 6 for the market model. The impact of the events on the bond returns persists throughout the first 11 days—probably as new information is released on the magnitude of losses—and starts to stabilize.

CROSS-SECTIONAL REGRESSION RESULTS

Table 3 presents descriptive statistics for the dependent and independent variables used in our model of bond returns. Our original sample involves 85 floods, 55 windstorms, 28 slides, 26 earthquakes, 12 extreme temperatures, 4 volcano eruptions and 1 tidal wave. We have regrouped the catastrophes under three categories for the purposes of creating dummies in our multivariate regression model. After this regrouping, we have 113 data points for *dummyflood* (including floods and slides), 31 for *dummyearth* (including earthquakes, volcano eruptions and a tidal wave), and finally 67 for *dummywind* (including windstorms and extreme temperatures).

The first part of Table 3 presents descriptive statistics for the dependent variables used in our model. We have 54% positive movement in spreads for 8-day CARs and SCARs, and 51% positive movement for 11-day CARs and SCARs. The mean movement in SCARs are higher than the mean movement in CARS.

The second part of Table 3 provides the summary statistics for independent variables. The mean sovereign *rating* in our sample is 4.25 (approximately equal to a BB- S&P rating), for *GDP per capita* ($US 5,518) and *insurance per capita* (US$ 42) variables exhibit characteristics typical of developing countries. Eight of the countries in our dataset are considered as *disaster-prone*. These countries are Brazil, Colombia, Indonesia, Mexico, Peru, Philippines, Turkey and Vietnam.

Finally, the third part of Table 3 exhibits the statistics for the three variables we have used to create the Severity Index. The maximum number of casualties in our dataset is 30,000 which is caused by the earthquake in Turkey in 1999. The maximum estimated economic loss of $10 billion also corre-

[15] The event study results are consistent with results obtained by piece-wise regression analyses, which are not reported in this study but available from the authors.

sponds to this disaster. On average, loss-to-gdp is 0.2% with the maximum amount reaching 7.6% during the Algeria earthquake of May 2003.

Table 3: Descriptive Statistics

Dependent Variables							
Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**	**>0**	**<0**
CAR (8-days)	211	2.0%	12.0%	-20.4%	70.9%	114	97
SCAR (8-days)	211	24.2%	171.5%	-346.4%	1605.2%	114	97
CAR (11-days)	211	1.8%	13.0%	-23.2%	73.5%	107	104
SCAR (11-days)	211	15.7%	161.1%	-282.1%	1441.7%	107	104

CARs and SCARs are calculated as in equations (5) and (13) in Chapter 5, respectively.

Independent Variables					
Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Severity	204	49.59	25.33	2.40	98.40
Rating	193	4.25	2.36	-	10.00
Insurance	211	42.52	60.73	0.01	369.40
GDP per capita	211	5,518	2,897	774	15,574
Dummy Variables	**Freq.**	**Percent**			
DummyEarth	31	14.76			
DummyWind	67	31.75			
DummyFlood	113	53.49			
Disasterprone	123	58.29			

Severity Index Variables					
Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
# killed	204	229	2,105	-	30,000
# killed-to-population	204	0.0008%	0.0089%	0.0000%	0.1265%
# total affected	210	209,713	525,926	7	3,504,412
# total affected-to-population	210	0.3485%	0.7950%	0.0000%	5.3388%
estimated loss (USD 000's)	208	256,000	982,000	64	10,000,000
loss-to-gdp	208	0.1985%	0.7482%	0.0001%	7.5766%

Table 4 presents OLS results related to our four hypotheses regarding the effects of different variables on bond spreads during times of natural catastrophes. We have not been able to get significant results for the hypotheses for the entire dataset as very small catastrophes created noise disturbances. This caused us to eliminate the lowest 15% severity events in our regression analysis.

Table 4: Cross-Sectional Regression Results

Cross-sectional Regression Results with Dependent Variable as CARs and SCARs
Estimated coefficients and t-statistics (in parenthesis) from regressing
8-day and 11-day excess returns on sovereign bonds

	CARS		SCARS	
Variable	**8-days**	**11-days**	**8-days**	**11-days**
GDPCAP [β1]	-0.000011**	-0.000013**	-0.000139**	-0.000141**
	(2.28)	*(2.24)*	*(2.35)*	*(2.23)*
RATING [β2]	-0.003948	-0.004622	-0.512602	-0.556470
	(1.04)	*(1.10)*	*(1.03)*	*(1.22)*
INSURANCE [β3]	0.000379***	0.000525***	0.004486***	0.005224***
	(2.89)	*(3.46)*	*(2.60)*	*(3.23)*
SEVERITY [β4]	0.000693	0.000516	0.007794	0.004589
	(0.75)	*(0.79)*	*(0.73)*	*(0.64)*
DUMMYWIND [β5]	0.116710**	0.077032	1.334644**	0.0849103
	(2.13)	*(1.44)*	*(2.10)*	*(1.42)*
DUMMYFLOOD [β6]	0.001649	-0.055048	-0.142062	-0.737083
	(0.03)	*(0.99)*	*(0.21)*	*(1.20)*
*DUMMYWIND*SEVERITY [β7]*	-0.001540	-0.0012889	-0.018114	-0.012185
	(1.38)	*(1.43)*	*(1.38)*	*(1.52)*
*DUMMYFLOOD*SEVERITY [β8]*	0.000046	0.000573	0.001027	0.007287
	(0.04)	*(0.66)*	*(0.08)*	*(0.75)*
DISPRONE [β9]	-0.042747**	-0.049208**	-0.492635**	-0.469244*
	(2.36)	*(2.00)*	*(1.98)*	*(1.68)*
R-squared	0.0947	0.1148	0.0847	0.1021
Observations	167	167	167	167

* significant at 10% level, ** significant at 5% level, *** significant at 1% level
Ordinary Least Squares estimator with clustering on countries and based on the top 85 percentile of data as per severity index

GDP per capita and Sovereign Rating of Countries

We find strong evidence that more developed countries' bonds react less to the catastrophes. In other words, more developed countries' bonds are associated with less positive spread movements post catastrophes. The coefficient for *GDPCAP* is negatively correlated to bond spreads, as expected, and is significant at $p < 0.05$ level. Results are consistent for both event windows (8-days and 11-days) and for both dependent variables (CARs and SCARs). This clearly illustrates that GDP per capita of each country is an important variable that drives an effect on the bond spread movements after the countries are hit by the catastrophes.

The regression results for *RATING,* on the other hand, is not significantly different from zero, although the coefficient estimate has the expected sign.

Insurance Penetration

We find no evidence to support the hypothesis that bonds of countries with high insurance penetration are affected less by the catastrophic events (H_3). Contrary to our expectations, the parameter estimate of *INSURANCE* is positive for both CAR and SCAR cross-sectional regressions and is significant at the $p < 0.01$ level. This finding is particularly interesting and contrasts with our earlier predictions. The reason for this may lie in the fact that sovereign bond market assumes insurance coverage in the less developed countries—at their infant stage—to be regulated and supported by the governments. Institutional differences with regard to the role of governments may be an important factor and these differences, in turn, may substantially influence the type and extent of private versus government-sponsored coverage in these countries. Hence, the validity of direct statistical comparison may be impaired by the fact that the relative importance of state and private insurance varies greatly from one country to another.

Catastrophe Size Effects

In our first round of regressions, the coefficient estimates of *SEVERITY* were not significantly different from zero. We have then introduced interaction variables with the type of catastrophes to better understand the size effects. Table 5 presents the results for the linear combination coefficient estimates and t-statistics. We find that the bond yield response to severity of events depends on the type of the catastrophe. The regression results show that for *floods* there is a size effect as predicted in our hypothesis. The coefficient of the interaction variable of floods and severity is positive and significant at $p < 0.10$ level for 8-day event window and at $p < 0.05$ level for 11-day event window. In other words, severe foods are associated with larger bond spread movement. For earthquakes and windstorms, there is no detectable statistical relation between the size of the catastrophe and the cumulative abnormal bond returns. Although the increase in bond spreads may represent a size effect, there is no evidence to support the proposition that the larger earthquakes and windstorms cause larger spread movements immediately after the natural disasters.

Table 5: Cross-Sectional Regression Results–Related Linear Combination Coefficient Estimates

Cross-sectional Regression Results with Dependent Variable as CARs and SCARs
Related "linear combination" coefficient estimates \and t-statistics (in parenthesis) from regressing
8-day and 11-day excess returns on sovereign bonds

	CARS		**SCARS**	
Variable	**8-days**	**11-days**	**8-days**	**11-days**
SEVERITY	0.000693	0.000516	0.007794	0.004589
[β4]	*(0.75)*	*(0.79)*	*(0.73)*	*(0.64)*
*SEVERITY + DUMMYWIND*SEVERITY*	-0.000848	-0.000772	-0.010320	-0.009595*
[β4+β7]	*(1.54)*	*(1.29)*	*(1.61)*	*(1.69)*
*SEVERITY + DUMMYFLOOD*SEVERITY*	0.000739*	0.001089**	0.008821	0.011877**
[β4+β8]	*(1.75)*	*(1.96)*	*(1.56)*	*(2.01)*
R-squared	0.0947	0.1148	0.0847	0.1021
Observations	167	167	167	167

* significant at 10% level, ** significant at 5% level, *** significant at 1% level
This table reports results from calculation of linear combinations of coefficients estimated in Table-9 above.

While results indicate some differences between the types of the catastrophes, the reason for these differences is not apparent. Although we are able to report that, for floods, severity is a significant variable to explain the magnitude of abnormal bond returns, the performance of earthquakes and windstorms keeps us from concluding that bond performance comes from largest catastrophes.

Disaster-prone Countries

We find evidence that the magnitude of abnormal returns associated with catastrophes is indeed less for the disaster-prone countries (H_5). The sovereign bond spreads are negatively correlated to *DISPRONE,* as expected, and the coefficient is different from zero at $p < 0.05$ level for both 8-day and 11-day event windows. Thus, the results indicate disaster-prone countries may have natural hazard exposure embedded in their bond prices.

DISCUSSION AND CONCLUSION

We set out to understand whether and how natural disasters may affect sovereign bond spreads and consequently the country risk and host-country borrowing costs and strategies for MNCs. Examining 211 catastrophic events in 25 countries over the period of 1994 through 2003, we show that, on average, catastrophes have a material impact on the bond returns of the developing country governments. In other words, sovereign bond spreads increase after a catastrophes hit these countries, thus, raising the cost of borrowing for those governments and firms domiciled in these countries. This increase is both statistically and economically significant. Our results are supported with the two methodologies—the market model and the sovereign yield spread model—we utilized to calculate abnormal returns for our event study analysis. Bond spreads widen after the catastrophic events and the post-event bond spreads slope is significantly higher than pre-event bond spreads slope. These results indicate that, for a reasonable time horizon after the catastrophes, we do see the effects of catastrophes on sovereign bond prices. Foreign portfolio investors adjust sovereign bond prices for catastrophic events, increasing country risk premium.

Examination of the factors that drive the change in observed premiums revealed that the *development level* of a country, whether a country is *disaster-prone* or not, and the *severity* of the catastrophes (in some cases) were most important influencing factors. Although our analysis provided support for many of the traditional arguments related to why bond markets could react to catastrophes, it also revealed some anomalies. The most noticeable one was that higher insurance penetration (measured in paid premium per capita terms) did not conform to smaller price movements in the sovereign bond spreads. We suggested that this could be explained by institutional differences with regard to the role of governments in these countries, which, in turn, may substantially influence the type and extent of private versus government-sponsored coverage available. Accordingly, the validity of direct statistical comparison may be impaired by the fact that the relative importance of state and private insurance varies greatly from one country to another.

These results have implications for IB research. First, it demonstrates that natural catastrophes affect host-country risk and consequently should be part of evaluating FDI attractiveness. Further research may examine the interaction between a given country risk and the isolated catastrophe risk. Second, given a spectrum of local responsiveness-global integration of activities, IB research may be directed towards a better understanding how to "unbundle" the finance (or other) operations in otherwise locally responsive firms from other operations in countries that bear high catastrophe risk. To this date, IB research has always assumed that local responsiveness is on all levels of operations. This assumption should be relaxed in the future as the case of catastrophe finance shows.

The implications of this research are not limited to the "traditional" MNCs. A new class of MNC—those from emerging market countries—are particularly exposed to the catastrophe risk phenomenon. Their main source of financing is domestic and therefore subject to the eventuality of price increases after catastrophic events. Are these emerging-market MNCs prisoners of their domestic capital markets? One implication of our research is that this new class of MNCs should consider becoming a polycentric MNC with easier access funds outside of their home country. A second implication is that issuing securities in foreign markets seems even more attractive for MNCs domiciled in catastrophe-prone countries.

These findings also raise several broader questions about catastrophe risk and their economic implications for developing countries. If governments in these countries are not undertaking institutional reforms that enable a shift of catastrophe financing from the public sector towards the private sector, than IB actors might be increasingly wary of demanding a risk premium for both portfolio and foreign direct investments. As a result, a host-country may become increasingly unattractive as a domicile for MNCs' operations. Strategic managers charged with evaluating developing countries for major investment projects might draw similar implications.

Overall, our analysis provides insights with respect to the behavior of sovereign bond markets after catastrophes. The increase in bond spreads after the catastrophic events document the increased country risk premium from the investors' perspective. The higher risk of defaulting on their debt is expected to make it difficult or expensive for the developing country governments to raise funds after a major disaster. This evidence, in its simplest form, supports the use of hedging mechanisms for emerging country governments. Further research about in-depth understanding of a country's risk exposures, a thorough analysis of potential benefits of mitigation efforts, and cost tradeoffs between different types of risk-financing instruments would provide a valuable contribution to the growing literature in financing and managing catastrophe risk in developing economies. IB scholars may also develop this study further into the direction of understanding how MNCs can mitigate the host-country risk.

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