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Insurance and Other Financial Services

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EXECUTIVE SUMMARY

The financial services sector—defined as private and public institutions that offer insurance, banking, and asset management services—is a unique qualitative indicator of the potential socioeconomic impacts of climate change because the sector is sensitive to climate change and offers an integrator of effects on other sectors. This assessment highlights insurance and other components of the financial services sector because they represent a risk-spreading mechanism through which the costs of weather-related events are distributed among other sectors and throughout society. The effects of natural and human-induced climate change on the financial services sector are likely to become manifest primarily through changes in the spatial distribution, frequencies, and intensities of ordinary and catastrophic weather events. There is high confidence that climate change and anticipated changes in weather-related events that are perceived to be linked to climate change would increase actuarial uncertainty in risk assessment and thus in the functioning of insurance markets.

The costs of ordinary and catastrophic weather events have exhibited a rapid upward trend in recent decades. Yearly global economic losses[1] from catastrophic events increased from US$4 billion in the 1950s to US$40 billion yr^{-1} in the 1990s (all 1999 US$). Including events of all sizes increases these totals by approximately two-fold. The insured portion of these losses rose from a negligible level to US$9.2 billion annually during the same period, with a significantly higher insured fraction in industrialized countries. As a measure of increasing insurance industry vulnerability, the ratio of global property/casualty insurance premiums to weather-related losses—an important indicator of adaptive capacity—fell by a factor of three between 1985 and 1999. Chapter 15 discusses insurance issues for North America in depth.

The costs of weather events have risen rapidly despite significant and increasing efforts at fortifying infrastructure and enhancing disaster preparedness. These efforts dampen the observed rise in loss costs to an unknown degree, although the literature attempting to separate natural from human driving forces has not quantified this effect. Demographic and socioeconomic trends are increasing society's exposure to weather-related losses. Part of the observed upward trend in historical disaster losses is linked to socioeconomic factors such as population growth, increased wealth, and urbanization in vulnerable areas, and part is linked to climatic factors such as observed changes in precipitation, flooding, and drought events (e.g., see Section 8.2.2 and Chapter 10). Precise attribution is complex, and there are differences in the balance of these two causes by region and by type of event. Notably, the growth rate in the damage cost of non-weather-related and anthropogenic losses was one-third that of weather-related events for the period 1960–1999 (Munich Re, 2000). Many of the observed upward trends in weather-related losses are consistent with what would be expected under human-induced climate change.

Recent history has shown that weather-related losses can stress insurance companies to the point of bankruptcies, elevated consumer prices, withdrawal of insurance coverage, and elevated demand for publicly funded compensation and relief. Increased uncertainty regarding the frequency, intensity, and/or spatial distribution of weather-related losses will increase the vulnerability of the insurance and government sectors and complicate adaptation efforts.

The financial services sector as a whole is expected to be able to cope with the impacts of future climate change, although low-probability, high-impact events or multiple closely spaced events could severely affect parts of the sector. Trends toward increasing firm size, greater diversification, greater integration of insurance with other financial services, and improved tools to transfer risk all potentially contribute to this robustness. However, the property/casualty insurance and reinsurance

[1]Total economic losses are dominated by direct damages (insured and uninsured)—defined as damage to fixed assets (including property or crops), capital, and inventories of finished and semi-finished goods or raw materials and finished products—that occur simultaneously or as a direct consequence of the natural phenomenon causing a disaster. Economic loss data also can include indirect or other secondary damages such as business interruptions, personal loss (e.g., injuries and death), or temporary relocation expenses for displaced households and businesses, as well as the effect on flow of goods that will not be produced and services that will not be provided. More loosely related damages such as impacts on national gross domestic product (GDP) are not included. Insured losses are a subset of economic losses. The data presented here are based on a diversity of sources compiled by the Geosciences Group at Munich Re for the period 1950–1999, and are unadjusted for purchasing power parity. The particular costs included can vary somewhat among countries and over time. In some cases, country definitions of losses set minimum thresholds for inclusion; thus, the totals presented here are underestimates of actual losses. For example, because of the minimum cost threshold of US$5 million until 1996 and US$25 million thereafter in the United States, no winter storms were included in the statistics for the 46-year period 1949–1974, and few were included thereafter (Kunkel *et al.*, 1999). Although large in aggregate, highly diffuse losses resulting from structural damages from land subsidence (e.g., approaching as much as US$1 billion yr^{-1} during periods of low rainfall in the UK; see Figure 8-3) also would rarely be captured in these statistics.

segments have greater sensitivity, and small, specialized, or undiversified companies even run the risk of bankruptcy. The banking industry as a provider of loans may be vulnerable to climate change under some conditions and in some regions. However, in many cases the banking sector transfers its risk back to the insurers who often purchase debt products.

Adaptation to climate change presents complex challenges, but it also presents opportunities to the sector. [It is worth noting that the term "mitigation" often is used in the insurance and financial services sectors in much the same way that the term "adaptation" is used in the climate research and policy communities.] Regulatory involvement in pricing, tax treatment of reserves, and the (in)ability of firms to withdraw from at-risk markets are examples of factors that influence the resilience of the sector. Management of climate-related risk varies by country and region. Usually it is a mixture of commercial and public arrangements and self-insurance. In the face of climate change, the relative role of each can be expected to change. Some potential response options offer co-benefits (e.g., stemming from climate change mitigation opportunities), in addition to helping the sector adapt to climate changes.

The effects of climate change—in terms of loss of life, effects on investment, and effects on the economy—are expected to be greatest in developing countries. Several countries experience impacts on their GDP as a consequence of natural disasters; damages have been as high as half of GDPin one case. Weather disasters set back development, particularly when funds are redirected from development projects to recovery projects.

Equity issues and development constraints would arise if weather-related risks become uninsurable, prices increase, or availability becomes limited. Increased uncertainty could constrain the availability of insurance and investment funds and thus development. Conversely, more-extensive penetration of or access to insurance would increase the ability of developing countries to adapt to climate change. More widespread introduction of microfinancing schemes and development banking also could be an effective mechanism in helping developing countries and communities adapt.

The need for financial resources for adaptation in developing countries is addressed in the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. However, development of financing arrangements and analysis of the role of the financial services sector in developed and developing countries still is a relatively unexplored area.

This assessment of financial services identifies some areas of improved knowledge and has corroborated and further augmented conclusions reached in the Intergovernmental Panel on Climate Change's Second Assessment Report (Dlugolecki *et al.*, 1996). It also highlights many areas in which greater understanding is needed—in particular, improved knowledge of future patterns of extreme weather; better analysis of economic losses to determine their causation; exploration of financial resources involved in dealing with climate change damage and adaptation; evaluation of alternative methods to generate such resources; deeper investigation of the sector's vulnerability and resilience to a range of extreme weather event scenarios; and more research into how the sector (private and public elements) could innovate to meet the potential increase in demand for adaptation funding in developed and developing countries, both to spread and to reduce risks from climate change.

8.1. Introduction

Our definition of the financial services sector includes private and public institutions that offer insurance, disaster preparedness/recovery, banking, and asset management services. Analysis of the financial services sector provides a unique opportunity to quantify the potential socioeconomic impacts of climate change and offers a barometer of effects on other sectors (including the government sector). The Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report (TAR) highlights insurance and other components of the financial services sector because they represent a risk-spreading mechanism through which the costs of weather-related events are distributed among other sectors and throughout society. The sector also is among the world's largest and is captured less effectively in other parts of the TAR. The financial services sector also stands to play a central part in adaptation and mitigation activities and is a major source of global and regional data on the costs of weather-related events (Mills, 1996; Changnon *et al*., 2000; Kunreuther, 2000).

This chapter is about the impact of climate change on the financial services sector, as well as the way this sector can adapt and help society to adapt to climate change. Still, little can be said about the total financial cost of adapting to climate change. Short-term effects are likely to be felt most through changing frequencies and intensities of ordinary and catastrophic weather events.

The Second Assessment Report (SAR) chapter on financial services concluded that "within financial services the property insurance industry is most likely to be directly affected by climate change, since it is already vulnerable to variability in extreme weather events" (Dlugolecki *et al.*, 1996). Experience and analyses over the past 5 years has confirmed the trend of growing weather-related damage costs since the 1950s (see Section 8.2).

The vulnerability of and challenges for the insurance sector, private and public, are addressed in Section 8.3. Section 8.4 discusses the implications for other financial services, such as corporate, retail, and investment banking. There is evidence that the banking and insurance industries have become more aware of opportunities and threats with regard to climate change since the SAR. However, little information is available on climate change impact and adaptation implications for the banking sector.

Climate change impacts are expected to be greatest in the developing world. There is only limited penetration of or access to insurance in these regions. This situation makes these regions more vulnerable and will impair their ability to adapt. Over the past few years, several multilateral organizations and banks have taken initiatives to develop new financial schemes for coping with natural disasters in developing countries (see Section 8.5).

Issues regarding funding for adaptation are addressed in Section 8.6. Although knowledge about the financial services sector, private and public, generally has increased since the SAR, major questions remain. Research could help explore the potential roles of the sector in helping society respond to the challenge of climate change (see Section 8.7).

8.2. Climate Change and Extreme Events that are Relevant to the Financial Services Sector

8.2.1. Present-Day Conditions

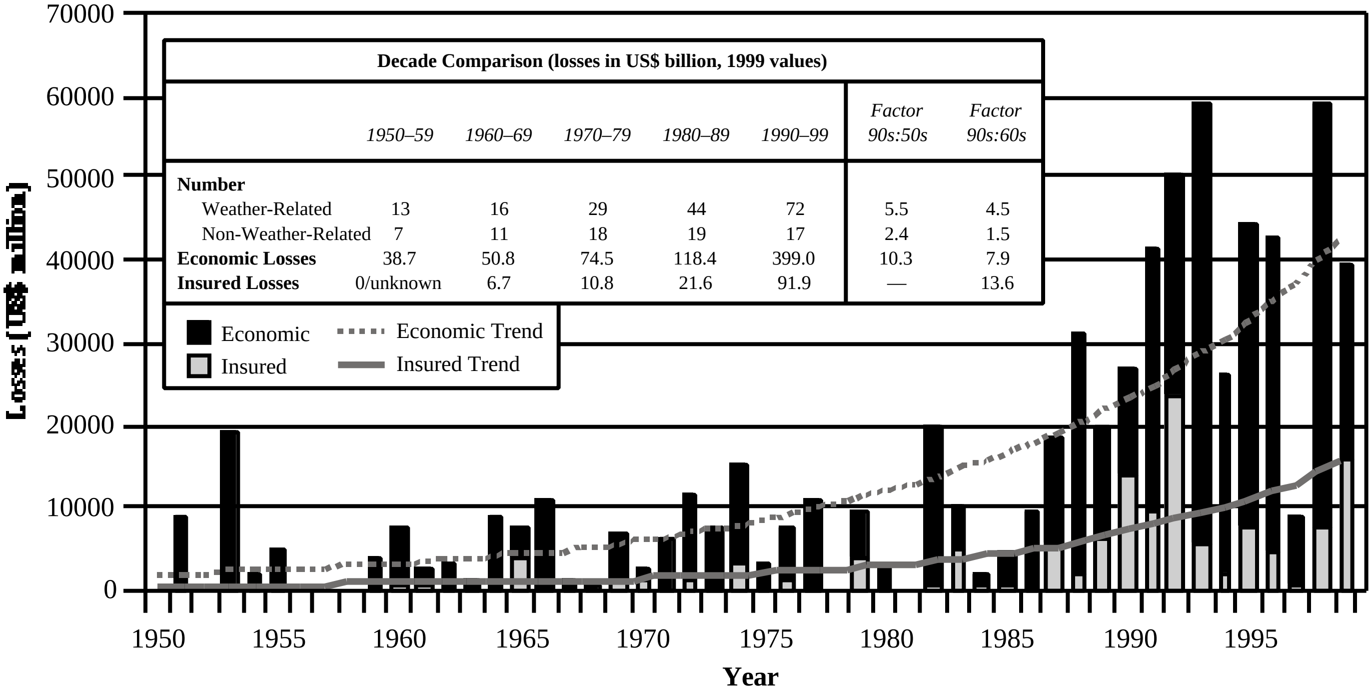
Present-day impacts of weather events on financial services are caused mainly by extreme events. Differences in vulnerability exist, caused by geographical location, population distribution, and national wealth. In developing countries, there may be very high mortality from extreme weather but relatively small costs to the financial sector because of low insurance penetration. In developed nations, the loss of life may be much less but may have enormous—even catastrophic—costs to the insurance industry (see Section 8.3.1). Swiss Re (2000b) has compiled lists of the 40 worst catastrophes between 1970 and 1999 in terms of insurance losses and fatalities. These lists show that:

- Of the 40 worst insured losses since 1970, only six were not weather related.
- Nineteen of the weather-related catastrophes affected the United States.
- Twenty-eight were related to windstorm (tropical and temperate latitudes).

In contrast, of the 40 worst events in terms of fatalities, only 16 were weather related, of which 13 occurred in Asia. A list of natural disasters causing billion-dollar losses drawn up by Munich Re (2000; see Table 8-3) shows that, of 30 such disasters, 15 affected the United States and seven affected Europe. Eighteen were related to windstorm. With the exception of earthquakes, all were weather related.

In recent decades, economic and insured losses related to weather extremes have increased rapidly (see Figure 8-1). An important part of this trend is related to socioeconomic factors; another part may be explained by climatic factors. Where trends in climate variables do occur, there are two possible principle causes:

- Variability in the natural modes of variability of the global climate system—for example, the Southern Oscillation, with its two characteristic modes of El Niño and La Niña. In the 1980s and 1990s, El Niño events occurred more frequently and lasted longer. The longest El Niño of the 20th century persisted from 1991 to 1995 and was rapidly succeeded by the most intense El Niño of the 20th century, in 1997–1998 (WMO, 1999).
- Anthropogenic global warming, which may be expected to lead to changes in all attributes of the climate system. Most obviously, we would expect it to lead to an increased frequency of high-temperature



Decade Comparison (losses in US$ billion, 1999 values)

	1950–59	*1960–69*	*1970–79*	*1980–89*	*1990–99*	*Factor 90s:50s*	*Factor 90s:60s*
Number							
Weather-Related	13	16	29	44	72	5.5	4.5
Non-Weather-Related	7	11	18	19	17	2.4	1.5
Economic Losses	38.7	50.8	74.5	118.4	399.0	10.3	7.9
Insured Losses	0/unknown	6.7	10.8	21.6	91.9	—	13.6

Figure 8-1: The costs of catastrophic weather events have exhibited a rapid upward trend in recent decades. Yearly economic losses from large events increased 10.3-fold from US$4 billion in the 1950s to US$40 billion per year in the 1990s (all in 1999 US$). The insured portion of these losses rose from a negligible level to US$9.2 billion annually during the same period, and the ratio of premiums to catastrophe losses fell by two-thirds. Notably, costs are larger by a factor of 2 when losses from ordinary, noncatastrophic weather-related events are included (e.g., as shown in Figure 8-6). The numbers generally include “captive” self-insurers but not the less-formal types of self-insurance (Munich Re, 2000).

extremes and a reduction in days with very low temperatures. There is evidence that the latter trend already is occurring (Easterling *et al.*, 2000b).

Whatever the cause, it is important to note that a relatively small change in the mean of a climate variable can lead to a large change in the occurrence of extremes. Meehl *et al.* (2000a) explore the implications for extremes of changes in the mean and/or variance; they show clearly that the relationship between a change in the mean and a change in the occurrence of extremes is nonlinear, as illustrated in Figure 8-2.

8.2.2. Attribution Analyses of Loss Trends

Weather-related events of all magnitudes resulted in US$707 billion in insured and uninsured economic losses between 1985 and 1999 (Munich Re, 2000). A longer term comparison of large catastrophic events over the past 50 years reveals that economic losses (adjusted for inflation) increased by a factor of 10.3 (Figure 8-1). Over this same period, population grew by a factor of 2.4.

One of the vexing dilemmas in analyzing such historical data is disentangling causal factors related to human-induced climatic change, natural variability, and those having to do with human activity that could accelerate or dampen measured impacts. Numerous human factors are in operation that contribute to the upward trends in real economic losses, including population growth, rising standard of living, urbanization and industrialization in high-risk regions, vulnerability of modern societies and technologies, environmental degradation, penetration of insurance, and changing societal attitudes toward compensation (the latter two factors may lead to an increase in losses reported). Data on the numbers of events also show an increase in many cases. The number of disasters (defined as annual requests from states for federal disaster declarations) has roughly doubled in the United States since the early 1980s (Anderson, 2000). It is relevant to note here that such requests involve considerations of significant social effects (Kunkel *et al.*, 1999); as a consequence, it is an indirect and subjective proxy for the frequency of events.

Growth trends in non-climate-related losses have been relatively constant over the past 3 decades. Losses from human-induced catastrophes have remained relatively constant (Swiss Re, 1999a). Earthquake losses have increased, but more slowly than weather-related losses (Bruce *et al.*, 1999). The number of disasters causing more than 1% GDPdamage to affected countries has increased two to three times as rapidly for weather-related disasters as for earthquakes in the period 1963–1992 (United Nations, 1994).

Insurers have pointed out that local environmental factors such as soil degradation, loss of biodiversity, lack of drinkable water, pollution, deforestation, forest degradation, and land-use changes can amplify the impacts of weather-related catastrophes

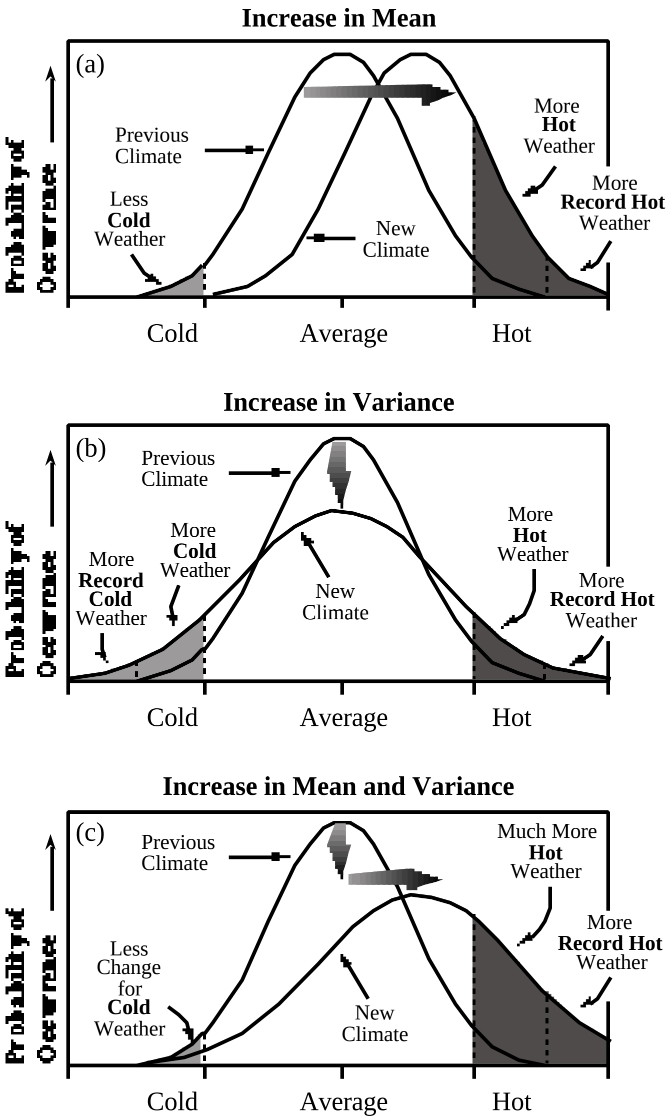


Figure 8-2: Schematic showing effect on extreme temperatures when (a) mean temperature increases, (b) variance increases, and (c) when both mean and variance increase for a normal distribution of temperature (TAR WGI, Figure 2.32).

(Zeng and Kelly, 1997). As an illustration, the extent of flood losses from Hurricane Mitch was attributed in part to deforestation in Central America.

Attempts to analyze the underlying causes of trends in natural disasters also must allow for the effects of human activities that offset growth factors (Kunkel *et al.*, 1999). A considerable leveling off or reduction in loss of life during U.S. disasters is one indicator that mitigation has been effective (Easterling *et al.*, 2000a). Loss-reduction efforts—typically unaccounted for in analyses we have seen—include considerable efforts to avert or reduce natural disaster impacts (e.g., coastal protection structures along coastlines; cloud seeding to deflect hailstorms; improved building codes; tightened land-use zoning; enhanced fire-suppression capacity; improved weather forecasts and early-warning systems; and improved disaster preparedness, response, and recovery). Within the insurance arena, increasing deductibles (the initial tier of loss costs paid for by the insured) and withdrawal of coverage from particularly high-risk areas have reduced observed losses. The literature has not attempted to quantify the contribution of these activities.

The relative contributions of human and climatic factors to the changing patterns of losses varies, depending on place and type of event (see Table 8-1; also see Easterling *et al.*, 2000a,b for a review). U.S. studies have found that demography largely explains increases in losses for hurricanes, wind, hail, and tornado events, whereas winter storm damage has mixed causation (Pielke and Landsea, 1998; Changnon, 1999; Changnon and Changnon, 1999; Kunkel *et al.*, 1999). In addition, decadal-scale trends have been discerned for tropical cyclones. There is good evidence that the intensity and frequency of precipitation and flood-related extreme events in the United States is increasing (Zeng and Kelly, 1997; Karl and Knight, 1998; Pielke and Downton, 2000). This trend also has been found for precipitation in many other parts of the world (see Chapter 3). In a study of hailstorms in France, Dessens (1995) used insurance loss information as a proxy for storm occurrence and found a statistically significant upward trend between 1946 and 1990.

In one global analysis, Munich Re (1999b) estimates that economic losses from large natural disasters increased two-fold between the 1970s and 1990s, after correcting for inflation, insurance penetration and pricing effects, and increases in the material standard of living. A similar result was reported for UK buildings in the SAR (Dlugolecki *et al.*, 1996).

Based on the findings of TAR WGI, the information summarized in Table 8-1, and the analysis presented above, we conclude that some part of the upward trend in the cost of weather-related disasters illustrated in Figure 8-1 is linked to socioeconomic factors (increased wealth, shifts of population to the coasts, etc.) and some part is linked to climatic factors such as observed changes in precipitation and drought events. There are regional differences in the balance of these two causes.

8.2.3. Climate Events that are Relevant to the Insurance and Other Financial Services Sectors

Most weather extremes have relevance for the financial sector, as shown in Table 8-1. Column 6 summarizes the impacts of extremes on the main sectors of activity considered by TAR WGII. The ways in which these impacts affect the insurance industry are shown in Column 7.

Hot Temperature Extremes. Hot summers are likely to become more common as a result of global warming. The nonlinear effect of global warming on extreme events (see Figure 8-2) can be clearly illustrated by the example of temperature. Hulme (1997) estimates for the UK that the change in mean annual temperature in 2035 relative to the 1961–1990 mean will be approximately 1°C. Yet as a result, temperature conditions similar to those in the exceptional (1-in-300 years) summer of 1995 should occur once every 10 years on average between

***Table 8-1**: Extreme climate-related phenomena and their effects on the insurance industry: observed changes and projected changes during the 21st century [after Table 3-10; Munich Re, 1999b (p. 106)].*

Changes in Extreme Climate Phenomena	Observed Changes (Likelihood)	Projected Changes (Likelihood)	Type of Event Relevant to Insurance Sector	Time Scale	Sensitive Sectors/Activities	Sensitive Insurance Branches[b]
Temperature Extremes						
Higher maximum temperatures, more hot days and heat waves[c] over nearly all land areas	Likely[a] (mixed trends for heatwaves in several regions)	Very likely[a]	Heat wave	Daily-weekly maximum	Electric reliability, human settlements	Health, life, property, business interruption
			Heat wave, droughts	Monthly-seasonal maximum	Forests (tree health), natural resources, agriculture, water resources, electricity demand and reliability, industry, health, tourism	Health, crop, business interruption
Higher (increasing) minimum temperatures, fewer cold days, frost days, and cold waves[c] over nearly all land areas	Very likely[a] (cold waves not treated by WGI)	Very likely[a]	Frost, frost heave	Daily-monthly minimum	Agriculture, energy demand, health, transport, human settlements	Health, crop, property, business interruption, vehicle
Rainfall/Precipitation Extremes						
More intense precipitation events	Likely[a] over many Northern Hemisphere mid- to high-latitude land areas	Very likely[a] over many areas	Flash flood	Hourly-daily maximum	Human settlements	Property, flood, vehicle, business interruption, life, health
			Flood, inundation, mudslide	Weekly-monthly maximum	Agriculture, forests, transport, water quality, human settlements, tourism	Property, flood, crop, marine, business interruption
Increased summer drying and associated risk of drought	Likely[a] in a few areas	Likely[a] over most mid-latitude continental interiors (lack of consistent projections in other areas)	Summer drought, land subsidence, wildfire	Monthly-seasonal minimum	Forests (tree health), natural resources, agriculture, water resources, (hydro) energy supply, human settlements	Crop, property, health

2021 and 2050. Insurance claims could rise because of land subsidence, business interruption, and crop failure. Although heat waves have been shown to lead to an increase in daily mortality and morbidity (see Section 9.4.1)—an impact that may be compounded by poor air quality—the effect is likely to be too small to noticeably affect the financial services sector.

Cold Temperature Extremes. As a result of global warming, cold extremes of winter weather are likely to become rarer. In temperate latitudes, this development generally would be beneficial for business activities in, for example, the construction and transport sectors, with concomitant reductions in claims for business interruption. Although cold conditions should become rarer, a more active hydrological cycle might lead to more episodes of heavy snowfall, provided that temperatures remain below freezing. Regional shifts in the occurrence of phenomena such as ice storms may be expected. Ice storms occur when precipitation falls as rain but freezes on contact

Table 8-1 (continued)

Changes in Extreme Climate Phenomena	**Observed Changes** (*Likelihood*)	**Projected Changes** (*Likelihood*)	**Type of Event Relevant to Insurance Sector**	**Time Scale**	**Sensitive Sectors/Activities**	**Sensitive Insurance Branches**[b]
Rainfall/Precipitation Extremes (continued)						
Increased intensity of mid-latitude storms[c]	Medium likelihood[a] of increase in Northern Hemisphere, decrease in Southern Hemisphere	Little agreement among current models	Snowstorm, ice storm, avalanche	Hourly-weekly	Forests, agriculture, energy distribution and reliability, human settlements, mortality, tourism	Property, crop, vehicle, aviation, life, business interruption
			Hailstorm	Hourly	Agriculture, property	Crop, vehicle, property, aviation
Intensified droughts and floods associated with El Niño events in many different regions (see also droughts and extreme precipitation events)	Inconclusive information	Likely[a]	Drought and floods	Various	Forests (tree health), natural resources, agriculture, water resources, (hydro) energy supply, human settlements	Property, flood, vehicle, crop, marine, business interruption, life, health
Wind Extremes						
Increased intensity of mid-latitude storms[c]	No compelling evidence for change	Little agreement among current models	Mid-latitude windstorm	Hourly-daily	Forests, electricity distribution and reliability, human settlements	Property, vehicle, aviation, marine, business interruption, life
			Tornadoes	Hourly	Forests, electricity distribution and reliability, human settlements	Property, vehicle, aviation, marine, business interruption
Increase in tropical cyclone peak wind intensities, mean and peak precipitation intensities[d]	Wind extremes not observed in the few analyses available; insufficient data for precipitation	Likely[a] over some areas	Tropical storms, including cyclones, hurricanes, and typhoons	Hourly-weekly	Forests, electricity distribution and reliability, human settlements, agriculture	Property, vehicle, aviation, marine, business interruption, life

with a solid surface. Air temperatures close to freezing are ideal for ice storm occurrence. Thus, in colder regions where the weather currently is well below freezing in the winter, ice storms may become more common as a result of global warming, although they could become less frequent in areas where they occur at present (Francis and Hengeveld, 1998). An ice storm that occurred 7-10 January 1998, in the northeastern United States and eastern Canada, led to insured damage estimated at US$1.2 billion (Lecomte *et al.*, 1998).

Heavy Rainfall and Flooding. TAR WGI Chapter 9 indicates that “many models” now project that conditions in the tropical Pacific may become more El Niño-like, with associated changes in precipitation patterns (Meehl *et al.*, 2000b). This would lead to more frequent patterns of El Niño-like floods and drought conditions in areas where teleconnections to the El Niño-Southern Oscillation (ENSO) exist. Observational studies assessed in TAR WGI Chapter 2 suggest that there has been a widespread increase in heavy and extreme precipitation

Table 8-1 (continued)

Changes in Extreme Climate Phenomena	**Observed Changes**	**Projected Changes**	**Type of Event Relevant to Insurance Sector**	**Time Scale**	**Sensitive Sectors/Activities**	**Sensitive Insurance Branches**[b]
	Likelihood					
Other Extremes						
Refer to entries above for higher temperatures, increased tropical and mid-latitude storms	Refer to relevant entries above	Refer to relevant entries above	Lightning	Instant-aneous	Electricity distribution and reliability, human settlements, wildfire	Life, property, vehicle, aviation, marine, business interruption
Refer to entries above for increased tropical cyclones, Asian summer monsoon, and intensity of mid-latitude storms	Refer to relevant entries above	Refer to relevant entries above	Tidal surge (associated with onshore gales), coastal inundation	Daily	Coastal zone infrastructure, agriculture and industry, tourism	Life, marine, property, crop
Increased Asian summer monsoon precipitation variability	Not treated by WGI	Likely[a]	Flood and drought	Seasonal	Agriculture, human settlements	Crop, property, health, life

[a] Likelihood refers to judgmental estimates of confidence used by Working Group I: *very likely* (90–99% chance); *likely* (66–90% chance). Unless otherwise stated, information on climate phenomena is taken from Working Group I's Summary for Policymakers and Technical Summary. These likelihoods refer to observed and projected changes in extreme climate phenomena and likelihood shown in first three columns of this table.
[b] All findings in this column are high confidence, as described in Section 1.4 of the Technical Summary.
[c] Information from Working Group I, Technical Summary, Section F.5.
[d] Changes in regional distribution of tropical cyclones are possible but have not been established.

events in regions where total precipitation has increased (i.e., the middle and high latitudes of the Northern Hemisphere). Flooding is responsible for 40% of total economic losses and 10% of weather-related insurance losses globally.

Tropical hurricanes can lead to landslides. Hurricane Mitch probably is the most well-known event in recent years. This system, the strongest ever October tropical storm in the Atlantic Basin, stalled over Central America and produced more than 600 mm of rainfall in 48 hours. Resulting landslides and mudslides led to an estimated 9,000 deaths and insured losses of US$513 million (Swiss Re, 2000b). In disasters of this magnitude, preparedness and planning can make a huge difference in loss of life and the amount of damage sustained.

Large river basin floods develop over huge areas following weeks of unusually high rainfall. In July and August 1997, flooding in central Europe caused 54 fatalities in Poland and required the evacuation of 162,000 people (Kundzewicz *et al*., 1999). The value of the economic losses throughout central Europe amounted to approximately US$5 billion, with insured losses of US$940 million. The intensity of such flood events is driven not only by climatology but also by human management of the watershed.

Low Rainfall—Drought, Land Subsidence, and Wildfire. Drought is important for the financial sector through impacts on commercial agriculture, building foundations, and wildfire occurrence. Figure 8-3 shows the cost of subsidence claims to the industry from 1975 to 1997 in England and Wales. There is a clear relationship with rainfall (with some lag effects). Similar effects are seen in France (Radevsky, 1999). Where insurance is used as the mechanism to finance repairs to building

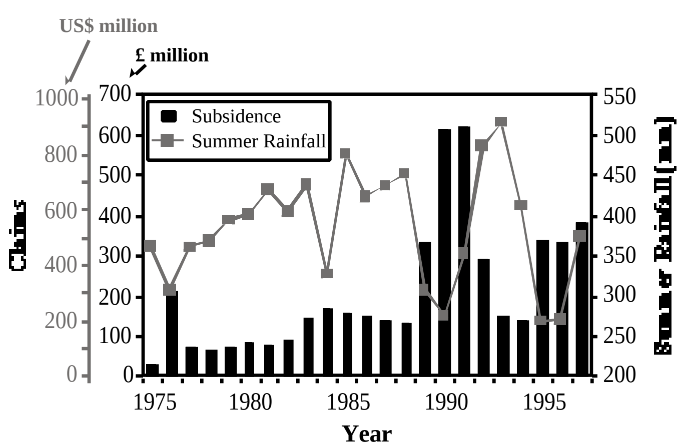


Figure 8-3: Summer rainfall and subsidence claims in the UK: 1975–1997. Rainfall data are for England and Wales, April to September (from Climatic Research Unit, University of East Anglia, UK). Subsidence claim costs are in original-year values (from Association of British Insurers).

foundations, as in the UK and France, costs for domestic properties can be higher than where the damage is not insured, as in Australia. Adaptive responses such as stronger foundations in new buildings and repairs to older housing capital should reduce the problem.

The worst drought of recent decades has occurred (indeed, it persists) in the Sahelian region of West Africa, where since 1968 rainfall has been below the long-term average in almost every year (Nicholson *et al.*, 2000). The strength and persistence of this deficit is unparalleled in recent times. Despite the drought's severity, it has had minimal impact on the commercial financial sector because of the low penetration of insurance in the region. However, the drought's role in the development of the region has been significant.

Wildfire is an increasingly important insurance issue, as illustrated by the US$140 million economic losses sustained in the Los Alamos fire of 2000 (Hofmann, 2000b). Outdoor fire occurrence is likely to increase in a future warmer climate, particularly along the increasingly popular urban-rural fringe (Swiss Re, 1992; Torn *et al*., 1998). Whereas in Europe most wildfires are of human origin (either deliberate or accidental), lightning (see below) is still the leading cause of forest fires in the western United States and Alaska (the regions of North America with the greatest number of wildfires).

Even if rainfall amounts are unchanged by global warming, higher temperatures will increase the level of risk associated with these hazards because of increased water loss through evaporation and transpiration.

Lightning Strikes. Model experiments are not able to tell us anything directly about changes in lightning occurrence as a result of global warming. Any increase in convective activity should lead to more frequent electrical storms and lightning discharges, and it seems likely that global warming will have such an effect in the tropics (Lal *et al*., 1998) and in extratropical latitudes (White and Etkin, 1997). Reeve and Toumi (1999) suggest that a 1°C increase in average wet-bulb temperature can be accompanied in mid-latitudes by a 40% increase in lightning. Of relevance to insurers, lightning is a cause of fires and damage to electrical equipment, with associated business interruption claims (Mills *et al*., 2001).

Tropical and Extratropical Windstorm. Experiments with climate models to date have not produced a consensus regarding the likely future occurrence of tropical and extratropical wind storms. Both have a very large capacity to cause damage. Hurricane Andrew, for example, occurred in 1992 in the Atlantic Basin and made landfall over the United States, causing US$21 billion (1999 US$) in insured damage. Hurricane Floyd, which caused US$2.2 billion in insured losses in 1999, required the evacuation of 2 million people and imposed huge stress on infrastructure, resources, and ultimately health. The most damaging extratropical windstorm was Daria in 1990, which caused US$6.8 billion in insured losses in northwestern Europe. In December 1999, windstorms Martin and Lothar tracked south of the normal route, affecting France, northern Spain, and central Europe. Together they caused 140 fatalities and US$8.4 billion in insured damage.

Sea-Level Rise. Increases in sea level pose a major potential risk to coastal zones (TAR WGI Chapter 6), especially if they are associated with an increase in storminess. The mid-range increase in sea level by the year 2100 as a result of anthropogenic climate change is 49 cm, taking into account atmospheric aerosol concentrations, with estimates ranging from 26 to 72 cm (TAR WGI Chapter 11). The main risk to the financial sector is in the effect that this change in mean sea level may imply for the occurrence of tidal surges, which already cause enormous damage and loss of life, especially in the developing world (see Box 8-4). One of Europe's greatest natural disasters in terms of loss of life was the 1953 storm surge in the North Sea, which led to almost 2,000 fatalities in The Netherlands and the UK.

8.3. Private and Public Insurance

This section examines the sensitivity, vulnerability, and adaptability of private- and public-sector insurance to climate change. Activities within these segments are significantly interrelated, and the role of each varies widely from country to country and over time (Van Schoubroeck, 1997; Ryland, 2000). Government programs exist primarily to correct market failures in the private sector, when insurance cannot be provided at a reasonable rate, or when insufficient capacity exists to pay claims (Mittler, 1992). In addition, the nature of events anticipated under climate change (e.g., increased flooding) draws into question their very insurability by private companies (Denenberg, 1964; Mittler, 1992; White and Etkin, 1997; Hausmann, 1998; Kunreuther, 1998; Nuttall, 1998).

Insurers are sensitive to a diversity of potential climate changes (Ross, 2000). Understanding and adapting to weather-related losses are high priorities in the insurance industry. Loss growth has resulted in the absence of commercial insurance for the most vulnerable risks, such as flood or crop damage in many countries. Changes in weather-related events associated with global climate change would increase the sector's vulnerability (Vellinga and Tol, 1993; Changnon *et al*., 2000; TAR WGI Chapters 9 and 10). Recent history has shown that weather-related losses can stress insurance firms to the point of elevated prices, withdrawal of coverage, and insolvency (bankruptcy).

The private insurance sector is highly heterogeneous, and the penetration of insurance varies dramatically across regions and within countries, as does the exposure and vulnerability of human populations and property to natural disaster events. Analyses that are meaningful to local policymakers, governments, and economies must adopt a variety of perspectives: regional, state, municipality, company, and the growing number who are self-insured.

Based on observations over the past decade, the property/casualty (P/C) segment is more vulnerable to weather-related events than the life/health segment (Table 8-2). The P/C segment is extremely diverse. The single most vulnerable branch appears to be property insurance, including business interruption (Bowers, 1998). Other lines, such as personal automobile insurance, have more limited exposure.

Of 8,820 loss events analyzed worldwide by Munich Re between 1985 and 1999, 85% were weather related, as were 75% of the economic losses and 87% of the insured losses (Munich Re, 1999b, 2000). The weather-related share of total losses is as high as 100% in Africa and 98% in Europe. Global weather-related insurance losses from large events[2] have escalated from a negligible level in the 1950s to an average of US$9.2 billion yr^{-1} in the 1990s (Figure 8-1)—13.6-fold for the 1960–1999 period for which detailed data are available. Insurance losses have grown significantly faster than total economic losses and insurance reserves and assets (i.e., adaptive capacity). Since the 1950s, the decadal number of catastrophic weather-related events experienced by the insurance sector has grown 5.5-fold.

Table 8-2*: Distribution of the global insurance market, including life/health and property/casualty, by region (Swiss Re, 1999b). Note that weightings between property/casualty and life/health vary considerably among countries. Swiss Re (1999b) provides detailed information by country. In some cases (e.g., Japan), life insurance premiums include annuities, which eventually are reimbursed to the insured.*

Total Business	Premiums in 1998 (US$M)	Share of World Market in 1998 (%)	Premiums as % of GDP in 1998	Premiums per capita in 1998 (US$)	Property/Casualty Premiums as % of Total
America	817,858	38.0	7.7	1,021	54
– North America	779,593	36.2	9.0	2,592	53
– Latin America	38,265	1.8	2.0	77	72
Europe	699,474	32.5	6.9	614	42
– Western Eurpe	684,848	31.8	7.3	1,466	42
– Central/Eastern Europe	14,626	0.7	2.1	23	75
Asia	571,272	26.5	7.8	36	23
– Japan	453,093	21.0	11.7	3,584	20
– South and East Asia	107,430	5.0	3.8	34	31
– Middle East	10,749	0.5	1.7	42	67
Africa	28,792	1.3	4.8	36	25
Oceania	37,872	1.8	9.4	1,378	41
World	2,155,269	100.0	7.4	271	41
– Industrialized countries[a]	1,955,406	90.7	8.8	2,132	41
– Emerging markets[b]	199,863	9.3	3.0	37	43
OECD[c]	2,016,084	93.5	8.5	1,805	41
G7[d]	1,725,007	80.0	8.9	2,498	41
EU[e]	672,939	31.2	7.4	1,651	40
NAFTA[f]	785,901	36.5	8.3	1,960	53
ASEAN[g]	11,711	0.5	2.6	26	42

[a] North America, Western Europe, Japan, Oceania.
[b] Latin America and Caribean, Central and Western Europe, South and East Asia, Middle East, Africa.
[c] 29 members.
[d] USA, Canada, UK, Germany, France, Italy, Japan.
[e] 15 members.
[f] USA, Canada, Mexico.
[g] Singapore, Malaysia, Thailand, Indonesia, The Philippines, Vietnam; the three remaining members—Brunei, Laos, and Myanmar—are not included.

These trends would be exacerbated by increased vulnerability resulting from development of high-hazard zones and increasingly sensitive infrastructure (Swiss Re, 1998a; Hooke, 2000; see Chapter 4).

Insurers have differing views on climate change (Mills *et al*., 2001). Although several insurers have devoted significant attention to the issue (especially in Europe and Asia), the vast majority have given it little visible consideration. Some have taken definitive precautionary positions in stating that there is a material threat (Swiss Re, 1994; UNEP, 1995, 1996; Jakobi, 1996; Nutter, 1996; Zeng and Kelly, 1997; Berz, 1999; Bruce *et al.*, 1999; Munich Re, 1999b; Storebrand, 2000), whereas others have taken a different view (Mooney, 1998; Unnewehr, 1999). Some have elected to focus on disaster preparedness; others have adopted a "wait-and-see" stance.

8.3.1. Major Market Segments: Property/Casualty and Life/Health

The world insurance market enjoyed revenues of US$2.155 trillion in 1998 (7.4% of global GDP) (Table 8-2). Although insurance penetration is relatively low in developing countries and economies in transition, their insurance market growth rate averages approximately twice that in industrialized countries. Expenditures on insurance in developing countries typically represent between 0.5 and 4% of GDP, compared to 5–15% percent in developed countries (Swiss Re, 1999c). With 36% of total global insurance premiums, North America is the largest regional market (see Chapter 15), closely followed by Western Europe at 32%. Reinsurance is particularly focused on high-value loss situations, in developing countries, or for smaller primary insurers. Reinsurers typically collect US$100 billion in premiums globally each year from primary insurers from whom they assume various (mostly property) risks.

The P/C insurance segment represented 41% of global industry premiums collected in 1998. As shown in Figure 8-4, the segment as a whole exhibits sensitivity to major natural disaster events, as evidenced by the reductions in U.S. insurer profitability during 1992 (Hurricane Andrew and Iniki) and 1994 (Northridge earthquake). A list of the most costly events is presented in Table 8-3. Over the past 15 years, the global ratio of P/C premium income to natural catastrophe losses has decreased from 351:1 to 122:1—almost a three-fold rise in "exposure" (Figure 8-5; see Figure 15-6 for North America).

Climate- and weather-related risks faced by life/health insurers include injuries or death resulting from extreme weather episodes, water- or vector-borne diseases, degraded urban air quality, pressure on the quality and adequacy of food and water supplies, and increased vulnerability to power failures (see Chapters 4, 5, 9, 15; TAR WGIII Chapter 8; World Bank, 1997a; Epstein, 1999). In some areas, climate changes may yield health benefits, but negative health impacts are expected to outweigh positive ones if no actions are taken to adjust (Chapter 9). Such impacts will not be significant for the global financial sector in the near term, because life/heath insurance penetration currently is low in developing countries; the burden will fall largely on the informal and government sectors.

Owing to structural changes underway in the industry, the financial distinction between life and P/C insurers is blurring somewhat as a result of consolidation and mergers. Life insurers also are major holders of real estate and providers of mortgage lending; thus, they participate as property owners in weather-related property risks and may additionally assume property risk as investors in catastrophe bonds or other weather derivatives.

8.3.2. Risk Sharing between the Private and Public Sectors

The private insurance industry is part of a larger community that bears the costs of weather-related events (Ryland, 2000). The nature and cost of weather-related losses vary considerably around the globe, as does the portion of the loss that is privately insured. Private insurance pays a higher proportion of benefits for storm-related losses than for any other weather-related event, although flood insurance has a particularly low rate of coverage (Figure 8-6).

Insurers bear only 20% of the total economic costs of weather-related events globally. The ratio is far lower in developing countries (e.g., 7% in Africa and 4% in Asia for the year 1998) (Munich Re, 1999b). Even in countries where insurance penetration is high, insurance can account for less than half of the weather-related payouts—for example, 27% in Europe, 30% in the United States, 34% in Australia (Munich Re, 1999b), and 20% in Canada (EPC, 2000). In a review of four major wildfire and flood catastrophes in Australia, Leigh *et al.* (1998a,b) found that private-sector insurers bore 9–39% of the total economic losses; a comparable amount was provided by local and federal governments. Other entities assuming such costs include federal disaster relief providers, local governments, and uninsured property owners (Pielke and

[2]Economic losses are defined in footnote 1. The definition of "large" weather-related events is those in which the response capacity is overtaxed and interregional or international assistance becomes necessary, often in cases where thousands of people are killed, hundreds of thousands are left homeless, or the economic loss is substantial (Munich Re, 2000). Thus, events that are small but frequent tend to be excluded from these statistics. For example, land subsidence losses from two droughts during the 1990s in France resulted in losses of US$2.5 billion, and even more in the UK, but these losses are largely absent from the "large" event data series. Asimilar case involves frequent but relatively small winterstorm events in northern latitudes and their losses. Figure 8-6 includes a fuller range of events, which tend to result in an adjusted loss level that is approximately twice that indicated by data on "large" events alone. "Large" events represent only 1% of the total number of events globally.

Landsea, 1998)—as in the case of Hurricane Andrew, in which only half of the losses were insured (Pielke, 1997).

One important risk-assuming group, the corporate self-insurance market, is growing rapidly. In the United States, such premiums are approaching the level of the traditional commercial insurance market (roughly US$134 billion) (Best's Review, 1998; Bowers, 1999).

Where insurers will not or are directly or indirectly regulated not to accept specific catastrophe risks, governments in many countries—including Belgium, France, Japan, The Netherlands, New Zealand, Norway, Spain, and the United States—may adopt the role of insurer or reinsurer or of regulator in establishing risk-pooling mechanisms (III, 2000b). Programs in France, Japan, and New Zealand explicitly define the governments' role as paying for "uninsurable damages" (CCR, 1999; Gastel, 1999). In some countries (e.g., Canada, Finland, France, Norway, the United States) this is the case for drought or other agricultural risks, and in others (e.g., Japan) this is limited to earthquake risks. Such schemes can grow rapidly, as illustrated by the jump in the numbers of policies under the Florida Windstorm Underwriting Association from 62,000 to 417,000 between 1992 and 1997 (Anderson, 2000).

Government's role in providing resources for disaster preparedness and recovery and insurance products related to natural disasters also is a key moderating factor in insurers' involvement in such risks. It can be a two-edged sword: It provides a platform for private industry to participate, but it

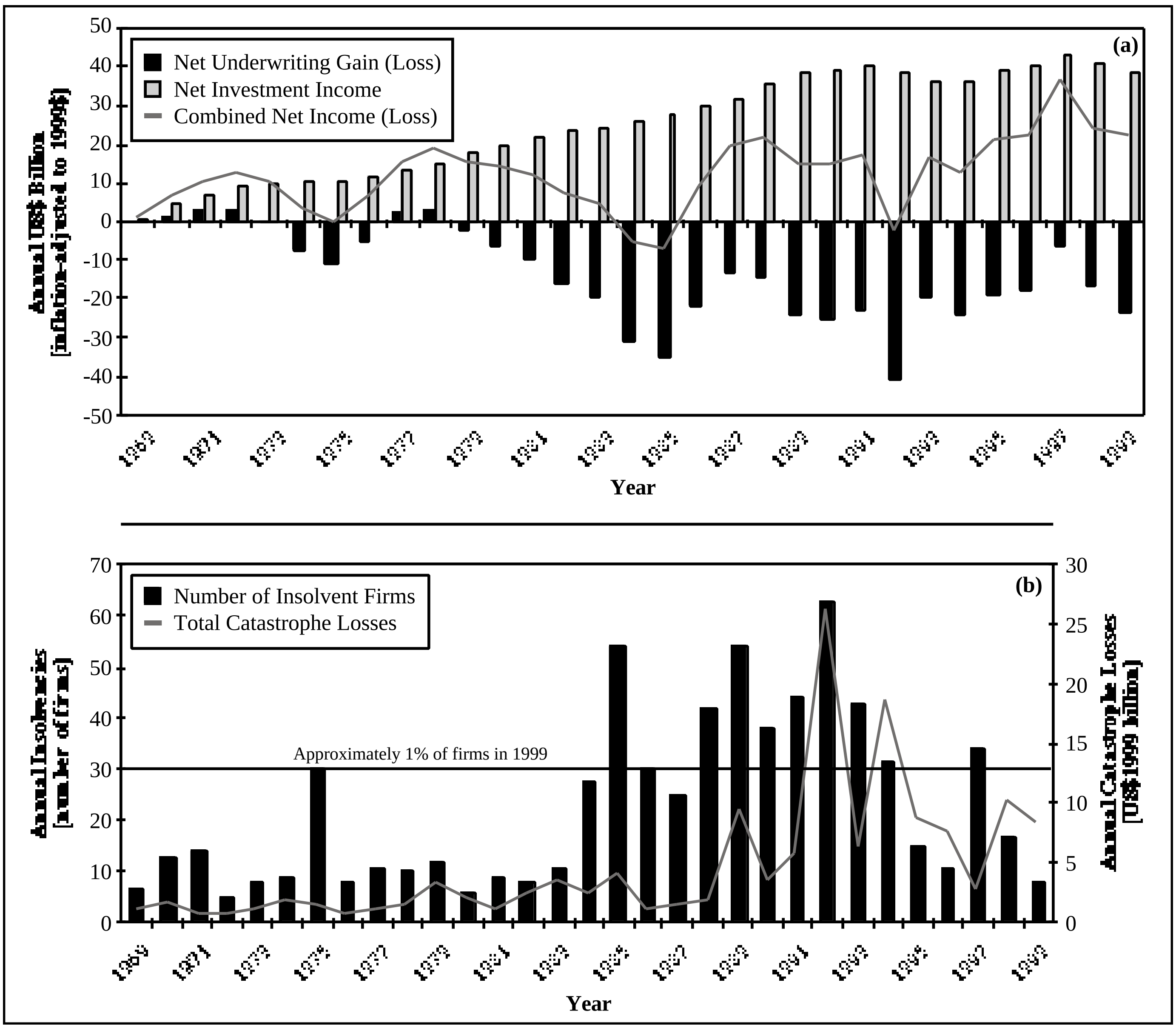


Figure 8-4: Trends in U.S. natural disasters, insurance industry profitability, and solvency, 1969–1999: (a) Sensitivity of property/casualty insurance sector net financial results to investment income and underwriting gain/loss. Upper bars indicate investment income; lower bars indicate net result of core business (premium revenues vs. claims paid). Curve is the net result. (b) Annual number of insolvencies and natural disaster losses (Mills *et al*., 2001).

***Table 8-3**: Billion-dollar and larger insurance losses, 1970–1999, as of December 2000 (Munich Re, 2000). Figures are adjusted for inflation (1999 values).*

Year	Event	Area	Insured Losses (US$M)	Economic losses (US$M)	Ratio of Insured/ Economic Losses
1992	Hurricane Andrew	USA	20,800	36,600	0.57
1994	Northridge earthquake	USA	17,600	50,600	0.35
1991	Typhoon Mireille	Japan	6,900	12,700	0.54
1990	Winterstorm Daria	Europe	6,800	9,100	0.75
1989	Hurricane Hugo	Caribbean, USA	6,300	12,700	0.50
1999	Winterstorm Lothar	Europe	5,900	11,100	0.53
1987	Winterstorm	Western Europe	4,700	5,600	0.84
1998	Hurricane Georges	Caribbean, USA	3,500	10,300	0.34
1995	Earthquake	Japan	3,400	112,100	0.03
1999	Typhoon Bart	Japan	3,400	5,000	0.60
1990	Winterstorm Vivian	Europe	2,800	4,400	0.64
1999	Winterstorm Martin	Europe	2,500	4,100	0.61
1995	Hurricane Opal	USA	2,400	3,400	0.71
1999	Hurricane Floyd	USA	2,200	4,500	0.49
1983	Hurricane Alicia	USA	2,200	3,500	0.63
1991	Oakland fire	USA	2,200	2,600	0.85
1993	Blizzard	USA	2,000	5,800	0.34
1992	Hurricane Iniki	Hawaii	2,000	3,700	0.54
1999	Winterstorm Anatol	Europe	2,000	2,300	0.87
1996	Hurricane Fran	USA	1,800	5,700	0.32
1990	Winterstorm Wiebke	Europe	1,800	3,000	0.60
1990	Winterstorm Herta	Europe	1,800	2,600	0.69
1995	Hurricane Luis	Caribbean	1,700	2,800	0.61
1999	Tornadoes	USA	1,485	2,000	0.74
1998	Hailstorm, tempest	USA	1,400	1,900	0.74
1995	Hailstorm	USA	1,300	2,300	0.57
1993	Floods	USA	1,200	18,600	0.06
1998	Ice storm	Canada, USA	1,200	2,600	0.46
1999	Hailstorm	Australia	1,100	1,500	0.67
1998	Floods	China	1,050	30,900	0.03

also can drive consumers away from commercial market solutions (Klein, 1997; Pullen, 1999a). The absolute value of government payments for natural disasters is poorly documented, and the statistical record is fragmented. The United States made disaster-related payments of US$119 billion (1993 US$) over the 1977–1993 period, equivalent to an average of US$7 billion yr^{-1} (Anderson, 2000). The Japanese government has devoted 5–9% of its national budget to disaster preparedness and recovery in recent decades (Sudo *et al.*, 2000).

Flood insurance merits special mention, given the magnitude of risks and losses, the difficulty of establishing fair and actuarially based rates, and the connection between flood and climate change (see Chapter 4; Aldred, 2000). Recent analyses in the United States found that 25% of homes and other structures within 150 m of the coastline will fall victim to the effects of erosion within 60 years (Heinz Center, 2000). Sea-level rise will impact flood insurance through inundation and erosion resulting from storm surge (see Chapter 6). Countries differ widely with regard to their approach to defining and financing flood risks via private-sector (re)insurance versus public mechanisms (Van Schoubroeck, 1997; Gaschen *et al.*, 1998; Hausmann, 1998). Hybrid public-private systems and government-only systems also can be found (e.g., in the United States), as can systems with no formal flood insurance whatsoever.

Acentral question is whether changes in natural disaster-related losses will generate increased reliance on already overburdened government-provided insurance mechanisms and disaster assistance. Governments already are showing decreased willingness to assume new weather-related liabilities, and tensions concerning risk-sharing between local and federal government bodies also are evident (Fletcher, 2000).

8.3.3. Insurers' Vulnerability and Capacity to Absorb Losses

A central component of vulnerability for public and private insurers alike is actuarial uncertainty in the dimensions, location, or timing of extreme weather events. This is particularly true

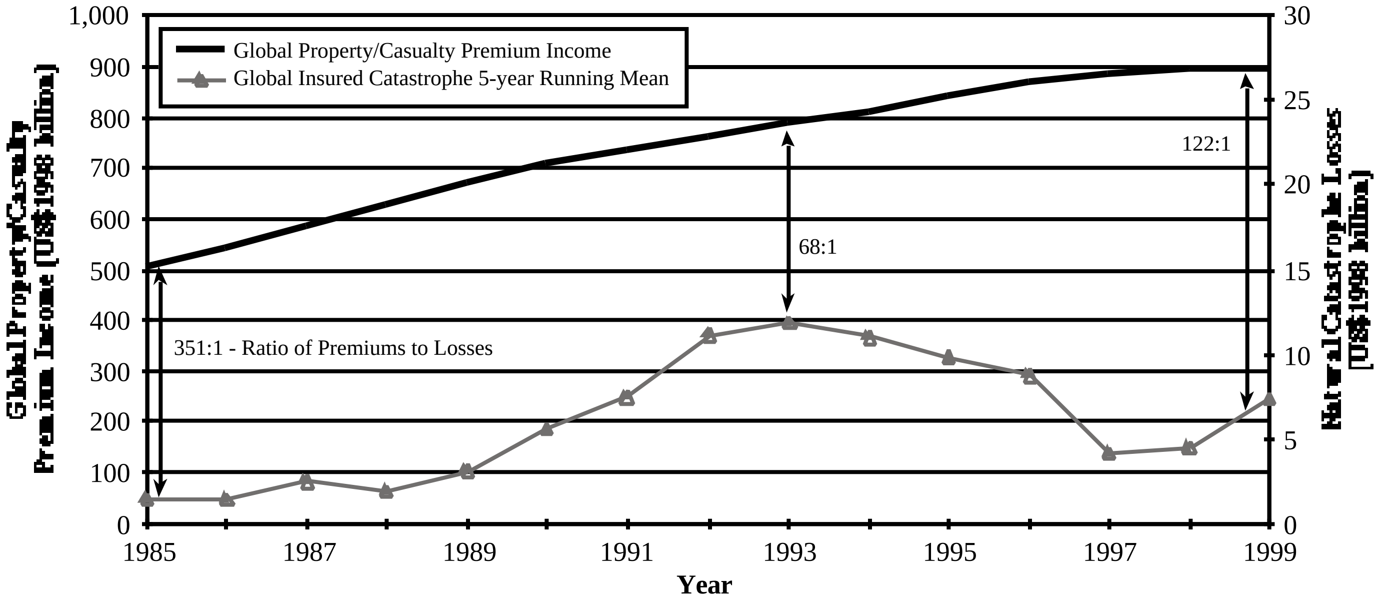


Figure 8-5: Global insured natural catastrophe losses (right-hand scale) vs. property/casualty premium income (left-hand scale), using a 5-year running mean. Global losses are from Munich Re (2000) and premiums from Swiss Re (1999b and earlier years). Note that these data include only major weather-related losses (approximately half of total weather-related losses). Premiums include considerable revenues (and associated reserves and surplus, not usable to pay catastrophe losses) from non-weather-related business segments and from self-insurers. The numbers generally include "captive" self-insurers but not the less-formal types of self-insurance. Exposure—measured as the ratio of premiums to losses—increased by a factor of 2.9 between the endpoints and by 5.2 in the worst single year (1993) within this time interval.

for insurance where the rate of damage rises faster than the driving weather phenomenon. Examples include the relationships between peak wind speeds and structural damages (Dlugolecki *et al*., 1996), average temperature changes and lightning strokes (Price and Rind, 1994; Dinnes, 1999; Reeve and Toumi, 1999), extreme temperature events and electric power reductions or crop damages (Colombo *et al*., 1999) and heat stress mortality (see Chapter 9), and precipitation and flooding (White and Etkin, 1997).

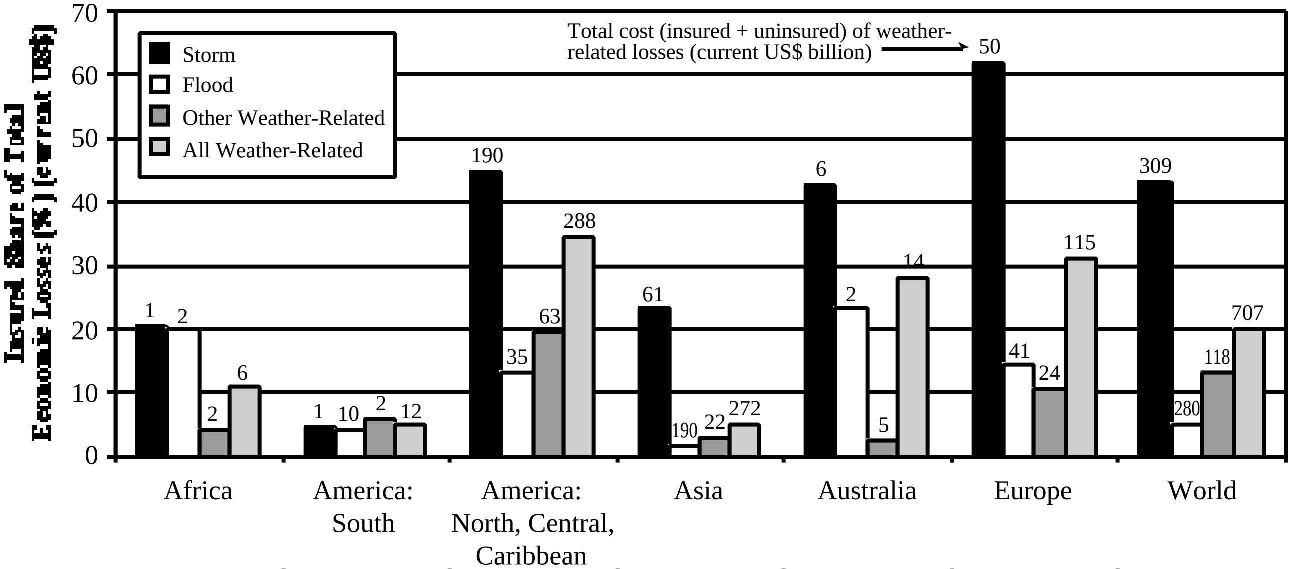
Changes in the spatial distribution of natural disasters pose special risks and challenges for the insurance sector. Localities to which risks shift will tend to be relatively inexperienced and unprepared to handle such risks, potentially resulting in a net societal increase in losses. A given insurer's vulnerability often extends internationally. For example, U.S. insurers collected nearly 15% of their premiums overseas in 1997, and the ratio has been growing (III, 1999). Reinsurers have a particularly high degree of international exposure.

8.3.3.1. *Quantifying Vulnerability and Adaptive Capacity*

For insurers, vulnerability can be viewed broadly in terms of the sector's capacity to pay for extreme events, together with the temporal sequence of such events. The key to vulnerability is the probable maximum loss (PML), which is the best estimate of the cost that is likely to emanate from an event with a specified probability of occurrence. In recent times, PMLs often have been revised upward significantly. The European winter storms Lothar and Martin of 1999 (US$8.4 billion insured losses) caught European insurers and reinsurers offguard, presenting losses that substantially exceeded prevailing expectations. These storms constituted the most serious natural disaster ever covered by insurance in France, with about 3 million claims (FFSA, 2000). One recent estimate for the United States was a combined PML of US$155 billion for 1-in-100-year (i.e., 1% yr^{-1} likelihood) for all types of natural disasters nationally (see Figure 15-8).

Unnewehr (1999) segmented the market and estimated that 17% of 1997 U.S. P/C insurance premiums were associated with "significant" exposure to weather-related loss. The paper did not explore other measures or sources of vulnerability and exposure, such as total insured property values at risk (US$4 trillion in insured property in the Gulf and Atlantic coastal counties of the United States) (Hooke, 2000), or the extent of insolvency risk. These results are not transferable to other regions, where insurance systems and natural hazards can be very unlike those in the United States (see Figure 8-6).

The particular role of weather in vehicle-related losses is not well studied. Vehicle insurance represents 48% of U.S. P/C premiums; it is ranked in the aforementioned study as having "minor" weather sensitivity. Of total vehicle-related accidents, 16% of those in the United States are caused by adverse weather conditions (NHTSA, 1999); 33% of those in Canada are weather related (White and Etkin, 1997). Physical damage to vehicles during U.S. natural catastrophes between 1996 and mid-2000 represented an additional $3.4 billion (10%) of total insured property losses, ranging as high as 55% for individual events (PCS, 2000; Mills *et al*., 2001).



Number of Events	810	610	2,260	2,730	600	1,810	8,820
Weather-Related	*91%*	*79%*	*87%*	*78%*	*87%*	*90%*	*85%*
Fatalities	22,990	56,080	37,910	429,920	4,400	8,210	559,510
Weather-Related	*88%*	*50%*	*72%*	*70%*	*95%*	*96%*	*70%*
Economic Losses (current US$ billion)	7	16	433	433	16	130	947
Weather-Related	*81%*	*73%*	*84%*	*63%*	*84%*	*89%*	*75%*
Insured Losses (current US$ billion)	0.8	0.8	119	22	5	40	187
Weather-Related	*100%*	*69%*	*86%*	*78%*	*74%*	*98%*	*87%*

Figure 8-6: Regional insurance coverage for weather- and non-weather-related natural disasters, 1985–1999. The role of insurance in paying weather-related losses varies by event type and region, generally dominated by windstorm (Munich Re, 1999b). "Other" includes weather-related events such as wildfire, landslides, land subsidence, avalanches, extreme temperature events, droughts, lightning, frost, and ice/snow damages (Munich Re, 2000). The numbers generally include "captive" self-insurers but not the less-formal types of self-insurance. Total costs are higher than those summarized in Figure 8-1 because of the restriction of Figure 8-1 losses to those from large catastrophic events. Rounding errors may appear in data labels.

Although aggregate industry assessments are useful, analyses of vulnerability clearly must take into account the complexity and specialized structure of the insurance sector (GAO, 2000a). Although an *aggregate* U.S. insurance surplus of US$200–350 billion often is cited (Doherty, 1997; GAO, 2000a), roughly 80% of this surplus is required for non-weather-sensitive branches (e.g., workers' compensation), assuming proportionality with premium-based risk figures quoted by Unnewehr (1999). In addition, insurers are independent and have radically different mixes of risks, so individual firms may become insolvent long before losses approach the industry's aggregate capacity (Doherty, 1997; Klein, 1997). Single-state PML events at the 1% likelihood level would result in economic stress ranging from 5 to 60% of insurers by market share (Pullen, 1999b). Moreover, catastrophes can disrupt insurance markets and harm insurance companies and consumers even in cases in which all claims are paid (GAO, 2000a; Ryland, 2000).

Reinsurance adequacy is another issue in vulnerability assessment. Swiss Re (1997) concluded that the availability of reinsurance coverage for natural disasters in 14 major markets was insufficient and that following a major event, primary insurers'(the customers of reinsurers) equity base (surplus) would come under considerable strain. For PML windstorm events in Australia, Japan, and the United States, the impact on aggregate surplus would be reductions of 24, 41, and 11%, respectively (Swiss Re, 1997). Solvency analyses typically give only "partial credit" to primary insurers for reinsurance (e.g., 50% in the European Union) because of the uncertain viability of reinsurance contracts or reinsurers themselves following catastrophic losses (Doherty *et al.*, 1992; Swiss Re, 2000a).

Aside from issues of solvency, past extreme weather events clearly have measurable short- to medium-term impacts on insurance and reinsurance profitability—even at a national scale (Figure 8-4a) and on the availability of insurance following the event (Davidson 1996; Pullen, 1999b). Catastrophe losses during 1999 and 2000 contributed to marked short-term depressions in earnings and stock prices for several large insurers and reinsurers (Edgecliffe-Johnson, 1999; Carpenter, 2000; Lonkevich, 2000). This development can restrict insurers' ability to raise new capital for expansion or even to continue the operations of highly exposed branches.

The overarching insurance business environment also is a key factor in determining vulnerability. Cyclical pressures or incidental broad-based stresses on the industry—such as major tobacco litigation (Bradford, 2000; Clow, 2000; Hofmann, 2000a), the crisis in environmental liability insurance (U.S. Superfund, asbestos, and lead paint claims), the Asian financial crisis, or increased competition from Internet sales (Ceniceros, 2000)—could place considerable demands on surplus (Mooney, 1999; GAO, 2000a; Swiss Re, 1998b, 2000a). Developments in financial markets can influence the level and availability of insurance surplus (Cummins *et al*., 1999; GAO, 2000b; Swiss Re, 2000a). More than three-quarters of the growth in the U.S. insurance industry's surplus since 1995 resulted from capital gains (GAO, 2000a).

On one hand, the trend toward convergence between banking and insurance potentially increases diversification and robustness. On the other hand, it exposes one sector to risks faced in the other, and, in some cases, geographical diversification of a company's insurance business has moved it into the path of increased disaster losses (Berry, 2000; Greenwald, 2000; Howard, 2000b; Lonkevich, 2000). Weather-related vulnerability could increase if insurers participate in emerging capital market alternatives for risk financing (Marcon, 1999). In general, such convergence is more likely for the life insurance segment.

8.3.3.2. Natural Catastrophes and Insurer Solvency

Historical weather-related insolvencies illustrate the vulnerability of large and small insurers to the types of natural disasters that potentially are associated with climate change (Stipp, 1997; Swiss Re, 2000a; Mills *et al*., 2001). Nearly 650 U.S. insurers became insolvent between 1969 and 1998 (Figure 8-4b) (Matthews *et al.*, 1999).

Of the 36 of 426 specifically attributed insolvencies occurring primarily as a result of natural catastrophes, more than half occurred between 1989 and 1993—the period of Hurricanes Hugo, Iniki, and Andrew—despite increased insurer capacity (Davidson, 1997; Doherty, 1997; Matthews *et al.*, 1999; Swiss Re, 2000b). Given the multi-factorial nature of most insolvencies, weather-related losses were no doubt a contributing factor in other cases as well. Although small or geographically specialized firms are most vulnerable, insolvencies of larger and more regionally diversified companies have occurred in the European Union (Swiss Re, 2000a) and in the United States (see Section 15.2.7). As a result of Hurricane Andrew, the largest U.S. home insurer, State Farm Fire and Casualty, was brought to the brink of insolvency by a US$4 billion loss and had to be rescued by its parent company (Stipp, 1997). The second largest U.S. home insurer, Allstate, paid out US$1.9 billion (which was US$500 million more than it had made in profits from its Florida operations from all types of insurance, including investment income, over the 53 years it had been in business) and also had to be rescued by its parent company (III, 2000a).

Little analysis of historic insolvencies in relation to natural catastrophes has been conducted outside the United States. Data for property/casualty firms in France, Germany, the UK, and the United States show that annual "baseline" insolvencies range from 0 to 0.5% of all firms to more than 2% in years with larger natural disasters (Swiss Re, 2000a). Natural disasters contributed to the severe difficulties experienced by the London market, including Lloyd's of London's near insolvency.

Future-oriented analyses of insurer solvency also have been conducted; these analyses show PMLs of US$45–100 billion, which—despite several recognized conservatisms in the analyses—would result in serious levels of insolvency in the industry (ISO, 1996; Cummins *et al.*, 1999; Kelly and Zeng, 1999). As many as 45% of insurers in the United States (representing 62% of the market share) could be placed in this position (GAO, 2000a,b). These findings are comparable to an earlier study showing that the rise in PMLs is stretching insurers' adaptive capacity (AIRAC, 1986).

Although much attention is focused on catastrophic loss events, "small" loss events are responsible for 50% of total economic and insured losses from weather-related events globally (Munich Re, 2000). If such events are closely spaced, they also can generate insolvencies or deplete surplus (Swiss Re, 1997; Ryland, 2000). Hybrid events involving multiple sources of insurance losses are of particular concern (White and Etkin, 1997; Francis and Hengeveld, 1998). This concern is exemplified in the case of ENSO events. A series of small events could be worse for insurers, in fact, than a single large event because individual losses per event often are capped (Stipp, 1997). Very little has been published on this subject since the mid-1980s (AIRAC, 1986).

8.3.3.3. Vulnerability of Reinsurers

Reinsurance provides a significant and essential form of risk-spreading capacity for primary insurers. For natural catastrophes, this risk-spreading normally takes the form of an "excess" contract; primary insurers retain the first tier of losses up to a "trigger point" above which they purchase reinsurance, which operates up to a specified "exit point" or upper limit. After the catastrophes of the past 2 decades, reinsurers are leaving more of the risks with primary insurers, by increasing trigger points and lowering exit points (Stipp, 1997).

Many of the vulnerabilities experienced by primary insurers also apply to reinsurers. Several reinsurers became insolvent or were absorbed by larger firms during the crisis period of

1989–1993 (ISO, 1999; Mooney, 2000). The unexpectedly costly European windstorms of 1999 caused further problems (Andrews, 2000). For example, an already weakened Australian reinsurer covering these storms became insolvent despite total assets of US$2.3 billion (Howard, 2000a). According to the Insurance Information Institute (III, 2000a), the world's catastrophe reinsurance industry "…lacks the capacity to insure mega-losses in excess of US$50 billion." Government reinsurance systems also have shown signs of stress—as evidenced in France, where reserves fell by 50% during the 1990s and reinsurance rates rose sharply (CCR, 1999).

8.3.3.4. Regulatory Uncertainties

An additional source of vulnerability arises from regulatory uncertainties, such as the degree of flexibility afforded in withdrawing from markets and risks and in raising insurance prices (Davidson, 1996; Insurance Regulator, 1998; III, 2000a; Ryland, 2000). In some jurisdictions, regulators have restricted policy cancellations and nonrenewals following natural disaster losses such as Hurricane Andrew (ISO, 1994a,b; Lecomte and Gahagan, 1998). Recent requests from Florida insurers to double rates to protect insurers from hurricane risks also have been resisted by regulators (III, 2000b). On the other hand, under some conditions regulators can force insurers to withdraw from markets or otherwise change their business practices so they maintain minimum solvency requirements (GAO, 2000a). Pre-event accumulation and taxation of reserves also is an important issue, and policies vary by country (Eley, 1996; Davidson, 1997).

8.3.3.5. Vulnerability of Local, State, and Federal Governments as Providers of Insurance and Relief Assistance

Under climate change, sustained increases in the frequency and/or intensity of extreme weather events could stress the government sector itself as a provider of insurance, a provider of domestic and international disaster preparedness/recovery services, and an entity that itself manages property and undertakes weather-sensitive activities (e.g., ranging from mail delivery to operation of military facilities near coastlines or waterways). Increasingly, governments seek to cap or reduce existing exposures (ISO 1994b, 1999; Gastel, 1999; Pullen 1999b; FEMA, 2000; III, 2000b). Governments in developing countries participate especially deeply in weather-related risks, given the low level of private insurance availability and often a higher level of government-owned infrastructure.

Disaster relief provided by the U.S. government has totaled $30 billion since 1953 (Changnon and Easterling 2000). Nearly half of these losses have occurred since 1990, and inflation-corrected payments rose six-fold between the late 1960s and the early 1990s (Easterling et *al.*, 2000a). These costs do not include temporary housing, unemployment insurance, and small business loans also provided by government.

Governments are particularly sensitive to changes in flood- and crop-related losses because they often are the primary or sole providers of such insurance, and climate changes are expected to exacerbate these losses (see Chapters 4 and 5; Rosenzweig *et al*., 2000). U.S. government-insured crop/hail losses grew 11-fold between the 1950s and the 1990s (Easterling *et al.*, 2000a). In Japan, the majority of international relief—7–8 billion yen in 1990—is related to floods (Sudo *et al*., 2000). Solvency is a material issue for government programs, as exemplified by the $810 million deficit in the U.S. flood insurance program in the mid-1990s (Anderson, 2000). U.S. crop and flood insurance programs have never been profitable (GAO, 2000a; Heinz Center, 2000). The French catastrophe reinsurance fund (Caisse Centrale de Réassurance) had become depleted as of the late 1990s and could no longer deal with a major catastrophe from accumulated surplus (CCR, 1999).

8.3.4. Adaptation

Insurance losses are paid out of premiums and from surplus (net assets). The ability to generate premiums and rebuild surpluses cannot be increased quickly in response to changes in the incidence of losses. In a developing country context, where insurance markets are nascent, this problem is particularly acute.

Insurers have many tools for reducing their financial vulnerability to losses (Mooney, 1998; Berz, 1999; Bruce *et al.*, 1999; Unnewehr, 1999; III, 2000b). These tools include raising prices, nonrenewal of existing policies, cessation of writing new policies, limiting maximum losses claimable, paying for the depreciated value of damaged property instead of new-replacement value, or raising deductibles. The additional strategies of improved pricing and better claims-handling were reviewed in some detail in the SAR (Dlugolecki *et al.*, 1996). Many adaptation strategies in use or under discussion make good sense for insurers irrespective of potential changes in the climate resulting from human activities (Sarewitz *et al*., 2000) (see Box 8-1).

Insurance prices exhibit sensitivity to disaster events (Paragon Reinsurance Risk Management Services, as cited in Klein, 1997; Edgecliffe-Johnson, 1999). Reinsurance prices rose by approximately 250% following Hurricane Andrew (see Section 15.2.7). Following the upsurge in catastrophe losses in 1999, the trend once again is toward upward pressure on prices (Mooney, 2000).

Following the period of (upward) price adjustments in response to a major natural disaster, however, insurers often enter or re-enter a battered market that offers substantial nonactuarially based discounts, resulting in inadequate prices for all players in the market (Matthews *et al.*, 1999). Similar behavior has been observed among reinsurers (Stipp, 1997). Insurers also may reduce risk management efforts and incentives in the face of competitive pressures on prices. Competitive pressures can cause some insurers to assume greater risk to offer more attractive

Box 8-1. Co-Benefits that Are Relevant for the Insurance and Other Financial Services Sectors

Co-benefits are discussed elsewhere in the Third Assessment Report (TAR WGIII Chapters 3 and 8). Several adaptation mechanisms that are relevant to public and private disaster risk management possess important co-benefits, but these mechanisms are rarely accounted for in cost-effectiveness analyses. Though they normally are associated with mitigation (e.g., emissions reductions or enhanced carbon sinks), some also stand to enhance adaptive capacity or otherwise benefit insurers and other parties in the financial services sector (Sarewitz *et al.*, 2000). Further research on this topic is merited.

- *Energy End-Use Efficiency.* Various co-benefits pertaining to energy-efficient technologies have been documented (Mills and Rosenfeld, 1996; Vine *et al.*, 1999, 2000; Changnon and Easterling, 2000; Zwirner, 2000; TAR WGIII Chapter 5). Improved insulation and equipment efficiency can reduce the vulnerability of structures to extreme temperature episodes and contribute to reduced greenhouse gas emissions. Other examples include linkages between public transit and reduced speed limits and improved highway safety (Unnewehr, 1999; TAR WGIII Chapter 9); energy-efficient ultraviolet water disinfection to conserve fuelwood and reduce deforestation (Gadgil *et al*., 1997); and emission reductions resulting in improved air quality and reduced respiratory disease (see Chapter 9).
- *Renewable Energy and Distributed Energy Systems.* Certain renewable and distributed energy supply technologies have attributes that are relevant to risk management and disaster recovery (Mills, 1996, 1999; Mills and Knoepfel, 1997). For example, low-power/energy-efficient technologies can reduce business interruption risks by extending the reliability and operating range of backup power systems (Stauffer, 1995; Kats, 1998; Lecomte and Gahagan, 1998; Vine *et al.*, 1999; Deering and Thornton, 2000). Substitution of biofuels for fossil fuels can yield improved air quality and reduced flood risk (IPCC, 2000; TAR WGIII Chapter 9).
- *Sustainable Forestry, Agriculture, and Wetlands Management.* Enhancing organic soil content benefits crop insurance as well as contributing to improved water quality and food security. Sustainable forestry practices yield benefits of watershed management and flood/mudflow control, which are necessary foundations for establishing a modern economy (Scott, 1996; IFRC-RCS, 1999b; IPCC, 2000; Hamilton, 2000; see also Chapter 5). Wetlands restoration helps to protect against flooding and coastal erosion, although methane release from wetlands also must be considered (IPCC, 2000).
- *"Green" Financial Products.* Initiatives such as innovative financing of energy-efficiency improvements, insurance products that promote better environmental management, or insurance for adaptation/mitigation projects under the U.N. Framework Convention on Climate Change (UNFCCC) can simultaneously support adaptation and mitigation objectives (Hugenschmidt and Janssen, 1999; Mills, 1999; UNEP, 1999; Zwirner, 2000). However, considerable business risk and liability may be associated with UNFCCC projects if measurement and verification are poor or issues of buyer/seller liability are not addressed by insurers in the drafting of insurance contracts.

prices and products to consumers, through acquisitions of weakened companies and destabilizing growth rates (Matthews *et al.*, 1999).

Favorable underwriting or investment experience may generate surpluses, but many legislatures do not permit insurers explicitly to fund pre-event catastrophe reserves to account for anticipated changes in climate and weather. Alternatively, insurers may try to raise more capital or reduce dividends paid to shareholders, but such actions will not be acceptable to financial markets if the risk-to-reward ratio is not competitive with that of other companies or sectors. The trend toward consolidation within the insurance sector is sometimes regarded as a factor that reduces insurer vulnerability to catastrophic losses.

8.3.4.1. Adaptation Mechanisms: Risk-Spreading

Public and private insurance is inherently a risk-spreading mechanism. Insurers also can spread risks through reinsurance, depending on its availability and price. Losses associated with uninsurable risks, or unpaid claims in the event of insurer insolvencies, often are partly spread to the community through disaster relief or guaranty ("solvency") funds. State-managed guaranty funds—to which insurers must contribute—are used for specified catastrophe losses in France, Germany, Japan, The Netherlands, the UK, and the United States (III, 2000a; Swiss Re, 2000a). Of the 25 largest U.S. P/C insolvencies (amounting to US$5 billion in claims), 29% of the losses were recoverable through guaranty funds; national capacity was only US$3.4 billion as of 1998 (NCIGF, 1999). In the United States, the property insurance residual markets known as Fair Access to Insurance Requirements (FAIR Plans), Beach or Windstorm Plans, and joint underwriting associations (JUAs) represented insured property value (exposure) of US$24 billion in 1970 and US$285 billion in 1998 (III, 1999; Gastel, 2000).

Although risks also can be spread between public and private insurers, governments have elected to cap their exposures by formally limiting government-paid losses for weather-related events in the United States (GAO, 1994; Pullen, 1999b; III, 2000b) and earthquake losses in Japan (Gastel, 1999).

Governments also are trying to reduce their insurance and disaster recovery spending (ISO, 1994b, 1999; FEMA, 2000).

Nonconventional "alternative risk transfer" (ART) mechanisms have begun to emerge and are regarded by some banks and insurers as playing a role in the continued viability of insurance (see Section 8.4). On the other hand, some insurers, consumers, and members of the financial community question the efficacy and attractiveness of these new risk-spreading mechanisms (Tol, 1998; Peara, 1999; Swiss Re, 1999b; Bantwal and Kunreuther, 2000; Freeman, 2000; GAO, 2000a; Jamison, 2000; Nutter, 2000).

"Moral hazard"—a pervasive issue in the industry—results when, by virtue of adaptation efforts or the very availability of insurance (or reinsurance or government aid), the insured feels less compelled to prevent losses (White and Etkin, 1997; Ryland, 2000). Government programs have been faulted for unintentionally encouraging such maladaptation and risky behavior (Anderson, 2000; Changnon and Easterling, 2000). For example, it is estimated that one-quarter of the development over the past 20 years in at-risk areas along the U.S. coastline is a result of the presence of the National Flood Insurance Program (Heinz Center, 2000). Moral hazard also has been ascribed to primary insurers or reinsurers who rely excessively on state-maintained guaranty funds (Kunreuther and Roth, 1998; Swiss Re, 2000a).

8.3.4.2. Adaptation Mechanisms: Risk Reduction

Although risk-spreading is largely an economic and distributional process, risk reduction focuses more on technology, environmental management, land-use planning, engineered disaster preparedness/recovery, and predictive modeling. Hooke (2000) provides a good overview of the challenges facing risk-reduction initiatives. The UN's International Decade for Natural Disaster Reduction (IDNDR) is a leading example of international cooperation in this area.

The insurance industry is an important participant in partnership with other public and private entities (Ryland, 2000). Examples include the use of geographic information systems to better understand and pinpoint risks, land-use planning, flood control programs, early warning systems, sustainable forest management, coastal defense, and wind-resistant construction techniques supported by building codes (Bourrelier *et al.*, 2000; Davenport, 2000; Hamilton, 2000; Hooke, 2000; Sudo *et al.*, 2000). However, the scale of effort has been much smaller than that anticipated for global climatic changes, and loss prevention generally has focused on fortifying the individual against perils, rather than reducing the peril itself (Kunreuther and Roth, 1998) and on post-disaster actions (Ryland, 2000).

Any discussion of vulnerability, impacts, and adaptation also should include insurance brokers, agents, risk managers, and trade associations. In 1998, there were more than 750,000 such workers in the United States alone (III, 1999).

A key but often untapped opportunity is to rebuild damaged structures in a more disaster-resistant fashion following loss events, as in the U.S. National Flood Insurance Program. Pervasive problems with building code enforcement and compliance have emerged following natural disasters. For example, 70% of the losses from Hurricane Alicia were traced to lax code enforcement (III, 2000a). Building industry stakeholders often resist new codes. Reinvigorating businesses and other forms of economic activity also is central to disaster recovery (Carrido, 2000).

Energy systems can have important implications for economic and insured losses through the vulnerability (reliability and/or physical damage) of energy generation, transmission, and distribution technologies (Epps, 1997; Keener, 1997; Deering and Thornton, 2000). Hydroelectric power resources, for example, are weather sensitive (see Chapter 15). Climate change may confound the actuarial basis for weather-related insurance provided to energy producers and for utility interruption insurance provided to energy users. Energy-related business interruption (via lightning damages, interrupted operations, inventory spoilage, event cancellation, disrupted tourism, etc.) is a significant weather-related exposure faced by the insurance sector (as evidenced by the extended power failure faced by Auckland, New Zealand, following a major heat wave in 1998). The North American ice storm of 1998 offers another dramatic example of the role of power disruption in disaster-related insurance losses (Lecomte and Gahagan, 1998; Table 15-5). Improved appraisal of the physical vulnerability of existing energy systems and of new technologies deployed for emission-reduction projects (e.g., as part of Clean Development Mechanism or Joint Implementation) would help to reduce vulnerability to extreme weather events and other losses (World Bank, 1999; Zwirner, 2000). The aftermath of Hurricane Andrew illustrated the complex nature of losses caused by natural disasters. About 20% of insured economic losses were related to business interruption (40% in the case of Hurricane Hugo) (Mills, 1996).

Effective risk reduction requires foresight. The insurance sector participates in a limited way in weather- and climate-related research and modeling (Kelly and Zeng, 1999). The Risk Prediction Initiative and the World Institute for Disaster Risk Management are two examples of insurer-funded research centers. Insurers' catastrophe models are not presently used in association with climate-prediction tools such as general circulation models (Peara and Mills, 1999). Their predictive power is poorly validated (Pielke, 1998; Pielke *et al.*, 1999) and often exhibits significant unexplained model-to-model variation (Matthews *et al.*, 1999; GAO, 2000a). Insurance regulators in the United States have resisted efforts to include them in ratemaking proceedings (III, 2000b). Thus, the insurance community may stand to benefit from analytical collaboration with the natural sciences community (Nutter 1996; Changnon *et al.*, 1997; Zeng, 2000; Mills *et al.*, 2001). Formal solvency analyses conducted by insurance regulators also could benefit from more explicit treatment of future climate scenarios.

Box 8-2. Equity Issues that are Relevant for the Insurance and Other Financial Services Sectors

Equity is a material issue facing the financial services sector systems, within and among countries. For example, inequities can be created when the premiums paid by insureds become severely decoupled from the risks they face. On the other hand, strictly equalized insurance payments can result in a problem known as "adverse selection," wherein only those with higher-than-average risk will actively purchase insurance, causing the system to become ineffective.

The burden of natural disasters tends to fall disproportionately on economically disadvantaged people, especially in developing countries (Hooke, 2000; Kreimer and Arnold, 2000). However, access to the benefits of insurance is correlated with income level. Lower income consumers in poor and wealthy countries alike have difficulty affording insurance or financing even at current rates (Miller *et al*., 2000) and often live and work in more vulnerable locations. Immigrant cultural groups, as well as aboriginal peoples, may have less access to pre-disaster information and be more vulnerable to natural disasters themselves (Solis *et al.*, 1997).

As an illustration of price-related stresses, projected increases in coastal erosion in the United States would require a doubling of current insurance rates—probably requiring cross-subsidies among insureds (Heinz Center, 2000).

In developing nations, the availability of insurance and financing has considerably lower penetration than in wealthy nations. At the global scale, one form of inequity arises in which a greater share of the costs of extreme weather events are borne by governments and consumers in the "south" than in the "north." Rising uncertainties could reduce the availability of insurance in some areas and impede the expansion of adaptive capacity offered by insurance markets in developing countries. Governments'ability to compensate by providing more insurance and disaster relief would be similarly strained.

Although much progress has been made in risk-reduction technology *per se*, attention is increasingly focused on problems of implementation. Key issues identified by IDNDR include public awareness of risks, training of practitioners, commitment by public officials, and justification and financing of risk-reduction strategies (Hamilton, 2000; Hooke, 2000)—all areas where the financial services sector can play a part.

8.4. Impacts and the Role of the Banking Industry

In the private sector, the insurance and banking industries play leading roles as investors, although they focus on different aspects of this business. The role of banks is to cover the credit part (by providing loans), whereas insurance companies act as investors on the capital markets, as well as in the property/casualty branches; they also insure projects financed by banks. This section focuses on the banking industry.

8.4.1. Climate Change Impacts

Environmental issues such as climate change may have substantive impacts on the global economy. From a financial point of view, such problems are regarded as environmentally induced economic risks (Figge, 1998). In general, the size of the players, their diversification, and increasingly sophisticated techniques of risk reduction make it unlikely that banks and asset managers will perceive climate change as presenting any material threat to their economic viability.

On the positive side, banks could provide services and develop financing techniques that accommodate and facilitate adaptation to weather extremes (e.g., private insurance, catastrophe bonds, weather-related trading). Assessment of expected benefits of an investment decision—whether it is a direct investment, through financing of an infrastructure project, or an indirect investment that involves investing in shares—is core to financial institutions. Economic assessment of an investment is based on three different factors: expected revenues, operating costs, and risks. Climate change can have an impact on all three aspects but is probably more important for the risk side of an investment decision (Figge, 1998; Mag, 1990).

Lending and Climate Change

Most private and corporate loans are secured by property. If a region becomes more exposed to climate-related natural disasters such as floods or windstorms, the prices for property could go down—which could result in a loss of confidence in the local economy and may even trigger a credit crunch (Grabbe, 1998; Heinz Center, 2000). As an indirect effect, other types of business such as management of private assets and granting of private loans that are not backed by property also will be affected (Bender, 1991; Thompson, 1996).

In terms of the impacts of climate change on the banking industry, there is no clear scientific evidence on how this sector will be affected. One view is that the banking sector is likely to be largely unaffected by climate change because the sector increasingly transfers loans directly to the capital market through asset-backed securities and similar instruments. The major commercial banks are large and diversified and are getting more so as the industry concentrates in the face of global competition. They prefer not to keep any substantial portion of the loans they make on a long-term basis. Instead, driven by capital constraints and return requirements, they actively syndicate and/or securitize their loan commitments (i.e., sell down the loans or shift the loan exposure to other banks and institutions). Even the portion they retain is increasingly likely to be held for a shorter period of time (a maturity under 1 year is better from a capital requirement standpoint) than other institutional lenders such as insurance companies and pension funds. The question still remains: At the end of the day, who will bear the risk of climate change on investments? It is particularly the insurance and asset management sectors that invest in asset-backed securities. So the insurance industry may even get hit twice, first through direct losses in property-related claims but also through impacts on their investments (Salt, 2000). Detailed information on what this increased vulnerability means for insurers and asset managers must be further explored.

On the other hand, it is obvious that banks could be affected indirectly as climate change affects their customers' operations, consumption, and financial circumstances. Any investment activity could be affected if property insurers withdraw coverage or drastically increase premiums, as happened in Florida and the Caribbean. Sectors that are likely to be affected by a drastic change in the local climate are agriculture and tourism. Warm winters in Europe already have negatively impacted the performance of skiing resorts in the Alps and have led some banks to review their credit applications in view of possible impacts of climate change (Credit Suisse Group, 1999).

8.4.2. Adaptation Issues

To date, the literature does not explicitly address financial services firms outside the insurance sector. There is emerging evidence that some investors or businesses as a group are modifying their risk perception to incorporate the potential for climate change. Partly this is driven by pension funds that are filing shareholder resolutions against polluting companies or banks that finance such practices (Behn, 2000). Similarly, there also is emerging evidence that financial services firms are including consideration of potential climate change as a risk factor in evaluating investments or developing new products (World Bank, 1999; Jeucken and Bouma, 2000). However, history has shown that the ability of banks and asset management firms to respond and adapt to external shocks is strongly tied to the ability of those institutions to diversify risk, both for themselves and for their customers. Over the past 25 years or so, financial services firms have changed significantly in response to a variety of circumstances, including macroeconomic disturbances of local and global proportions, advances in communications and information technologies, and changing regulatory regimes (Kaufman, 1992; Downing *et al.*, 1999). Several types of tools can be identified for managing risk: improved information and research, diversification, building up reserves, and new product development.

The Role of New Product Development

Over the years, banks as a whole have demonstrated their ability to continuously develop new products and services to respond to changes in their own business environment as well as the changing needs of their customers (Folkerts-Landau and Mathieson, 1988; Haraf and Kushmeider, 1988; Jeucken and Bouma, 2000). The ability of those firms to respond and adapt to any impacts of potential climate change will be determined largely by their ability to identify any changes in their customers' views of asset risk and to develop new products to hedge and diversify that risk. Again, the literature does not discuss explicitly which specific existing products might be useful in responding to changes in risk stemming from potential climate change or what types of new products might be developed to respond to such potential changes in risk. However, the industry continues to apply basic concepts—including options, swaps, and futures contracts—in new and different ways to create new products that provide investors and businesses with useful tools for reducing well-known and understood risks (Mills, 1999, Vine *et al.*, 1999). These products can range from environmentally and socially screened investment funds to very sophisticated derivatives that hedge against weather risks.

In the past few years, such weather derivatives have seen rapidly growing use to hedge the risks of businesses whose sales and revenues are strongly affected by the weather. Securitization is becoming more and more widely used as a means of spreading risk and obtaining resources for investment banking with a secure flow of income in the future. Financial institutions other than insurance companies have been developing and offering such instruments in the form of catastrophe bonds, for example (see Box 8-3).

In summary, the banking industry is more likely to see climate change and the possible response more as an opportunity than as a threat. In the new global competition, banks and asset managers are likely to be less concerned about any possible threat posed to their existing portfolios by weather extremes induced by climate change and more preoccupied with adjusting to a rapidly changing and increasingly competitive global market in which failure to adjust leads rapidly to loss of market share and net revenue and a decline in share price and shareholder value. They have little incentive to try to change the rules, but they are highly motivated to respond once changes are imminent or implemented.

8.4.3. The Role of UNEP Financial Services Initiatives in the Climate Change Debate

The United Nations Environment Programme (UNEP) has brokered statements of environmental commitment by banks and insurance companies that have been endorsed by many of the major players in these industries. These statements have

Box 8-3. Capital Market Alternatives for Risk Financing

Alternative catastrophe risk financing mechanisms through weather derivatives have begun to emerge and are regarded by some observers as playing a role in the continued viability of the insurance sector. Other authors suggest that these instruments will continue to be a niche product because of inability to come up with adequate pricing for these mechanisms as offered through the capital markets. Such products also raise the awareness and visibility of natural disasters and climate change issues within the financial markets (Swiss Re, 1996; Credit Suisse Group, 1998; Lester, 1999; Mahoney, 1999; Punter, 1999).

Contingent Capital Securities. The two types of capital contingency securities available to investors are contingent surplus notes and catastrophe equity puts. Investors in these securities become—at the insurer's option—creditors of or equity investors in the insurer. The exercised "notes" and "puts" are shown as surplus on an insurer's balances sheet and thus increase assets without an offsetting increase in the liability portion of the balance sheet. The insurer can draw from surplus to pay unreserved catastrophe losses and have the funds (surplus) necessary to take on new exposures.

Catastrophe Risk Securities. Two forms of "cat risk securities" are available that transfer underwriting risk to investors: catastrophe bonds and catastrophe insurance options. Primary insurers and reinsurers can make use of these securities. Both benefit insurers by making monies available to offset catastrophe losses. In contrast to contingent capital securities, these instruments do not bolster an insurer's surplus; they provide funds for the payment of losses. They are reflected as both an asset and as a liability on the insurer's financial statements.

These approaches are relatively new, and their efficacy and robustness must be evaluated (see Tol, 1998; Peara, 1999; Swiss Re, 1999b; Bantwal and Kunreuther, 2000; GAO, 2000a; Nutter, 2000; Jamison, 2000; Mills *et al.,* 2001). Among the questions to address include:

- In a more competitive environment, would insurers and reinsurers be inclined to participate in or encourage (subsidize) risk-reduction measures?
- Do derivatives signal a potential means by which self-insurers can expand their capacity, thereby providing greater competition for primary insurers and reinsurers?
- Will the occurrence(s) of catastrophic weather-related events turn away investors after an event?
- Do existing catastrophe and climate modeling techniques yield information necessary to adequately evaluate financial risks and thus the prices of these derivatives?

Of 11 major trends in investing, catastrophe bonds were rated by members of the International Securities Market Association as least likely to have significant impacts on securities markets in the future (Freeman, 2000).

Despite doubts about these new instruments, banks and insurance companies consider this a growing business. In 1999, the cumulative volume of weather-related bonds/derivatives reached US$3 billion. It can be assumed that an increasing number of such instruments will be available to hedge against climate risks. This, in turn, will allow banks to get the "insurance" coverage they need for their lending activities (Nicholls, 2000).

now been signed by almost 300 banks and insurance companies from all parts of the world (most from Europe and Asia) (UNEP, 2000). By signing the statement, companies undertake to make every effort to incorporate environmental considerations into their internal and external processes (UNEP, 1995; Schanzenbächer, 1997). Measures implemented by signatories range from reduction of energy consumption of buildings under their management to incorporation of environmental issues in credit business and risk management considerations. One might think that financial services is a clean industry with very little direct impact on climate change, but insurance companies in particular own huge physical assets (e.g., ~500 million ft^2 of building space in the United States alone, which corresponds to an energy bill of US$750 million a year) (Mills and Knoepfel, 1997).

8.5. Special Issues in Developing Countries

8.5.1. Statistics on Disasters

Although the vast majority of weather-related insurance losses occur in wealthy countries, most of the human suffering occurs in poor countries (Figure 8-6). Whereas 45% of the natural disaster losses between 1985 and 1999 took place in wealthy countries (those with per capita income of more than US$9,360), these countries represent 57% of the US$984 billion in total economic losses and 92% of the US$178 billion in insured losses (Munich Re, 1999b). In contrast, 25% of the economic losses and 65% of the 587,000 deaths took place in the poorest countries (those with per capita income below US$760).

Other literature sources, using slightly different definitions and different time periods, conclude that about 90% of deaths from natural disasters from 1973 to 1997 occurred in Africa and Asia (IFRC-RCS, 1999a). Figures from the World Disasters Report 1999 (IFRC-RCS, 1999a) indicate that, in the period from 1973 to 1997, on average nearly 85,000 persons were killed each year by natural disasters; the number of otherwise affected (impoverished, homeless, injured) was more than 140 million annually. The record of disasters (see Figure 8-6) is a further illustration of the geographic distribution of weather-related disasters.

As indicated in Chapter 3, climate change comes with changing frequencies and intensities of extreme weather events. The most vulnerable regions and communities are those that are both highly exposed to hazardous climate change effects and have limited adaptive capacity. Countries with limited economic resources, low levels of technology, poor information and skills, poor infrastructure, unstable or weak institutions, and inequitable empowerment and access to resources have little capacity to adapt and are highly vulnerable (see Chapter 18). The regional chapters in this volume (Chapters 10–17) indicate that developing countries, because of their limited or nonexistent financial buffers, are particularly vulnerable to the effects of climate change. Human-induced climate change is expected to result in a further upward trend of disaster losses.

Developing countries—especially those that are reliant on primary production as a major source of income—are particularly vulnerable because these countries and their communities hardly have any financial buffer and there is very little penetration of insurance (see also Figure 8-6). The conditions facing private insurance markets and government disaster relief differ considerably in developing countries. The penetration of private insurance is extremely low in most cases, although it is growing quickly. The degree of preparedness also is low. The government sector is far less able to operate as a surrogate insurer, even in areas such as crop and flood insurance where governments traditionally are essential in the developed world. In developing countries, the economic and social impacts of catastrophic weather events can pose a material impediment to development. Increased frequency or intensity of such events as a result of climate change could render these markets less attractive than they are at present for private insurers, in turn compounding the adverse impact on development. Thus, developing countries tend to have greater vulnerability and less adaptive capacity than developed countries.

8.5.2. Disaster Relief

Because of the lack of insurance, disaster relief is the major input for disaster recovery in many developing countries. After a disaster, the first relief usually is provided by the national government in the form of assistance by the military, the police, and other government services. Often, governments also act as the insurer for uninsured damages in these cases. When the capacity of local disaster relief institutions is exceeded, countries tend to call for help from international institutions. In the period 1992–2000, a yearly average of US$330 million was transferred from country to country for disaster aid (United Nations, 2000).

The institutional setting of international disaster relief is complicated. Presently, 16 UN agencies have a mandate that allows them to work in emergency situations. The UN Office for the Coordination of Humanitarian Affairs (UN-OCHA) is supposed to coordinate efforts in disaster relief. The International Committee of the Red Cross and the International Federation of Red Cross and Red Crescent Societies (IFRC-RCS) have a basis in international law. Médecins sans Frontières (MSF) and OXFAM are examples of internationally operating nongovernmental organizations (NGOs), of which there are hundreds. In addition, all types of local NGOs may be involved in the relief work, along with the national government and local authorities. In a typical disaster situation, one has to cope with a multitude of different agencies (Frerks *et al.*, 1999). Donor governments and agencies as well as international organizations provide the funds; substantial amounts may be raised directly from the public at large.

The large amount of relief amount for cyclones in 1998 was largely a result of Hurricane Mitch, which struck Central America in that year. In the same year, Bangladesh and China were struck by very large flood disasters. The foregoing numbers show that on an annual basis, international relief is in hundreds of millions of dollars. This is a small number compared with total global damage from natural disasters (tens of billions of dollars).

8.5.3. Natural Disasters and Development

Disasters may have a significant impact on the national economy of the country concerned. Some countries lose annually up to 1% or more of their annual GDPas a consequence of recurring natural disaster; in individual cases, damages have been as high as 50% of GDP. The typical Chinese loss experience in bad years is in the range of 5–7% of annual GDP. In 1974, losses in Honduras from Hurricane Fifi were equivalent to 50% of the country's 1973 GDP (Hooke, 2000). Setbacks in development may have been up to 1 decade or more. The majority of these damages usually are covered by the affected population itself or from other domestic sources (United Nations, 1994). In some cases, the relation between GDPand disasters is ambiguous because post-disaster investments may increase GDP. Long-term problems arise when the return period of a disaster is the same order of magnitude or smaller than the time needed for reconstruction. In such cases, the economy of a country or a specific region is likely to spiral downward (Downing *et al.*, 1999). In fact, GDP is a very limited way of describing the impact of weather-related disasters. For example, the UN has defined a disaster as *large* when the ability of the region to cope with the effects of the disaster on its own is exceeded.

Urban and rural infrastructure loss in the developing world as a result of natural disasters has impacted the activity of the world's international lending institutions. The World Bank has estimated that it has loaned US$14 billion to developing countries in the past 20 years for damages from natural disasters. This amount is nearly 2.5 times the amount loaned by the Bank for relief from civil disturbance worldwide (Kreimer *et al.*, 1998). The Asian Development Bank (ADB) has estimated that between 1988 and 1998, 5.6% of ADB loans were for disaster rehabilitation. In 1992, nearly 20% of ADB loans were for rehabilitative assistance to natural disaster recovery (Arriens and Benson, 1999). The World Bank has estimated that during the past decade in Mexico, as much as 35% of its lending earmarked for infrastructure has been diverted to pay for the costs of (Mexican) natural catastrophes (Freeman, 1999). In recent years, the World Bank has recognized the importance of disaster prevention and mitigation for development and poverty reduction (Kreimer and Arnold, 2000).

8.5.4. Vulnerability and Financial Adaptation in Developing Countries

Spreading the risks of catastrophes presents special difficulties in developing countries, particularly rural areas. In general, there is very limited use of commercial insurance because of long histories of economic instability, fluctuating and prohibitive insurance costs as related to agricultural prices, lack of enforcement of building codes and land-use regulations, subjective evaluation of risk by consumers ("it won't happen to me"), and non-monitored economies. In some developing countries, government-organized crop and disaster insurance exists on paper, but with large debt loads and weak economies, many such programs are inactive. In many cases, governments are unable to respond to public expectations.

AWorld Bank/UN Development Programme (UNDP) workshop reports that disaster mitigation is evolving from the phases of relief and contingency planning, technical preparedness, and structural solutions to a phase in which there is a greater emphasis on reducing social and economic vulnerabilities and investing in long-term mitigation activities. However, formal sector mechanisms may completely bypass the poorest households. Therefore, the need to develop informal and flexible financial instruments such as microfinance for disaster mitigation has become extremely important (World Bank, 2000).

Although targeted microfinance programs have been able to meet the financial needs of individual households, the same attributes of microfinance also could be applied to deal with natural disaster reduction. There is a potential for microfinance to provide explicit and implicit insurance to households (World Bank, 2000). However, limitations of microfinance as a risk-reduction mechanism arise from issues of moral hazard (see Section 8.3.4), inadequate monitoring of credit programs after large spatial shocks, and reduction in informal insurance arrangements provided by social networks. There also is the possibility of governments committing much less to relief programs in the wake of a disaster if affected communities are served by microfinance institutions. Small microfinance programs without access to reinsurance may collapse in a natural disaster. For nationwide disasters, even the largest microfinance programs may require international arrangements (World Bank, 2000).

Several microfinance organizations in Bangladesh have been seriously affected by the floods in 1998 in terms of maintaining savings mobilization, credit repayment, and cash availability. Larger microfinance organizations with greater capitalization and preparedness cope better with disasters than small microfinance organizations, many of which get completely wiped out. There is now a recognition of the need for providing a financial cushion for the unexpected. It could be provided through a Central Reserve Fund/Emergency Fund and bigger microfinance organizations such as Grameen Bank setting aside part of their funds to meet the contingencies of natural disasters (World Bank, 2000).

8.6. Issues that are Related to Funding forAdaptation

Although some discussion of adaptation appears in virtually all chapters of the WGII report, Chapter 18 addresses core concepts and considerations. It states that key factors affecting the adaptive capacity of a region or country include economic resources, technology, information and skills, infrastructure, and institutions; it notes that there is considerable variability among countries with regard to their ability to adapt to climate change. However, Chapter 18 does not address specifics of how adaptation is likely to be funded in developed and developing countries or how the need to fund adaptation will affect the financial services sector.

Chapter 18 also states that adaptive actions are most likely to be implemented when they are components of or changes to existing resource management or development programs (see World Bank, 1999). Klein (1998) has suggested that investments for adaptation should essentially be incremental to projects justified for other reasons, where a project has value even if climate change were not to occur. When the impact of climate change is uncertain, this is probably the best way to proceed. The financial sector would then play its traditional role, and financial institutional arrangements would be the same as for present-day investments in infrastructure. However, when projections of climate are more certain and/or when the assets exposed are of high value or when many people are at risk, dedicated additional climate change adaptation investments may be required and special funding arrangements may be developed. In these situations, new climate change-related financing schemes may emerge whereby funds are generated through fees on emissions of greenhouse gases or fees on trading of greenhouse gases. The Clean Development Mechanism developed in the framework of the Kyoto Protocol is an example of the development of such a financing arrangement. Such arrangements could generate new roles for the financial sector.

An example of early cost estimates of measures meant to protect people and properties against the risk of increasing rainfall,

Box 8-4. Case Study: Bangladesh Flooding 1998

Bangladesh witnessed 35 cyclones from 1960 to 1991 (Haider *et al.*, 1991) and seven major floods from 1974 to 1998 (Matin, 1998). The flood of 1998 is considered to be one of the worst natural disasters experienced by the country in the 20th century. It occurred from July 12 to September 14, a duration of 65 days (Choudhury, 1998). The flood affected about 100,000 km^2 (68% of the country's geographical area). The numbers of affected families and population were more than 5,700,000 and 30,900,000, respectively (Choudhury, 1998). The flood caused 918 fatalities and disease among 242,500 people. Approximately 1.3 Mha of standing crops were fully or partially damaged. Total economic losses amounted to US$3.3 billion (8% of GDP, 1998 value), according to a study by Choudhury *et al.* (1999). The study also shows that there is a wide discrepancy between its estimates and estimates by other agencies, which is mainly a result of coverage error.

Generally, victims have to depend on their own resources to rehabilitate themselves. During the emergency period, however, the government and NGOs mobilized considerable financial resources to provide relief in the form of food, clothing, and building materials.

To reduce the damage from natural catastrophes, planned activities by the government and NGOs (national and international) include construction of an adequate number of cyclone shelters, embankments, and other shelters in coastal areas, especially in the offshore islands.

With regard to insurance against such calamities, there is not much available except for the large industries and the commercial sector. Flood victims were paid US$27.7 million as compensation by the insurance companies, of which about 70% went to large industrial units. There was virtually no insurance coverage for losses in the agricultural sector. Losses incurred by shrimp farms and water transports, however, received sizeable compensation by the insurance systems, according to government sources (Choudhury *et al.*, 1999).

increasing river run-off, and sea-level rise, using an integral approach, is the white paper of The Netherlands National Committee on Water Management. This white paper projects the additional cost of water management in The Netherlands, taking into account climate change and long-term land subsidence and land-use changes. The paper concludes that a budget of approximately US$2.5 billion is required for investments until 2015 and an additional US$8 billion for the 2015–2050 period to maintain adequate safety levels for people and property (Netherlands National Committee on Water Management, 2000).

Developing countries seeking to adapt in a timely manner face major needs, including availability of capital and access to technology. Given the present state of knowledge, many actions for adaptation are likely to be integrated with and incremental to projects that already are occurring for other reasons. The World Bank (1999) states that "there is no case to be made for 'stand-alone' projects on adaptation to climate change." It also has noted that projects for adaptation should be designed as incremental to projects that are justified for economic development purposes. However, providing financing for projects in developing countries is a complex matter. Even for projects for which the risks and expected returns are commensurate with the requirements of the financial markets, matching investors that have available funds with projects seeking funding is by no means easy. Most simplistically, this process involves linking investors with projects via appropriate sets of institutional and financial intermediaries. The ability to do this successfully depends, in part, on the level of development of financial markets and the financial services sector in the country where the project will be implemented (World Bank, 1997b).

However, returns that can be expected from many prospective projects are not sufficient for investors to assume the risks that they believe are inherent in any individual project. This complicates the process further. If such projects are going to be funded, some creative modification must be made to bring each project's risk/return profile in line with the requirements of the financial markets. Unfortunately, there is no straightforward, standardized means for identifying and implementing needed changes. The process is guided in part by the principle that risks should be assumed by the party best able to manage them (IFC, 1996).

This need for financial resources for adaptation in developing countries is addressed in the UNFCCC (or "Convention") and the Kyoto Protocol. The Convention explicitly states that:

- All Parties have responsibilities to make and implement plans for adapting to any human-induced climate change.
- The developed countries shall assist developing countries in meeting the costs of adapting to any adverse effects of such climate change.[3]

Both accords also address this notion more generally in identifying potential actions to aid developing countries, including provision

[3] See Articles 4.1(b), 4.1(e), 4.1(f), 4.3, 4.4, and 4.5 of the Convention.

of "environmentally sound" technology.[4] In addition, the Protocol indicates that a portion of the proceeds from Clean Development Mechanism (CDM) projects is to be used to meet the needs of "particularly vulnerable" Parties for Adaptation[5] (UNFCCC, 1992, 1997). Taken together, provisions in these two accords provide new sources of public sector funding for developing countries to implement adaptation measures.

The Global Environment Facility (GEF), as the main focus of financial commitments under the Convention thus far, has been the institutional mechanism for this funding. GEF projects provide financial models for promoting technology diffusion in developing countries, with some projects designed to mobilize private-sector financing (UNFCCC, 1999). However, GEF activity generally has not addressed the adaptation elements of the Convention. This lack of activity is driven by internal requirements that GEF projects have global benefits, as well as directives that such funding should cover only planning activities that are associated with adaptation (Yamin, 1998). Caribbean Planning for Adaptation to Climate Change is one example of a GEF project that is addressing adaptation. This US$6.3 million project is focusing largely on planning and capacity-building needs for addressing adaptation in the Caribbean (GEF, 1998).

However, there are still many issues to be addressed in connection with both the Convention and the Protocol (Werksman, 1998; Yamin, 1998). Differing interpretations of various provisions of the accords remain.

For example, detailed provisions of the CDM have yet to be worked out, including those related to adaptation funding. One key issue is the size of the "set-aside" from CDM projects that is dedicated to funding adaptation. If this set-aside is too large, it will make otherwise viable mitigation projects uneconomic and serve as a disincentive to undertake projects. This would be counterproductive to the creation of a viable source of funding for adaptation. There also have been no decisions on how these "set-aside" funds would be allocated to adaptation projects. They could be used to fully fund projects or leveraged to simply supplement other sources of funding. Any resulting allocation will be driven by more technical and financial elements of the merits of alternative projects, as well as political considerations of equity and fairness. As a result, it may be some time before any of these provisions can produce a viable source of funding for adaptation. An overview and analysis of the literature on climate change policies and equity appears in Banuri *et al.* (1996). Linnerooth-Bayer and Amendola (2000) propose that subsidized risk transfer can be an efficient and equitable way for industrialized countries to assume partial responsibility for increasing disaster losses in developing countries. Review of the literature indicates that understanding of adaptation and the financial resources involved is still in its early stages. As knowledge grows, the potential role(s) for the financial sector will become clearer.

[4] See Articles 4.8 and 4.9 of the Convention and Article 3.14 of the Protocol.

[5] See Article 12 of the Protocol.

8.7. Future Challenges and Research Needs

This assessment reviews our improved knowledge since the SAR. However, it also identifies many areas in which greater understanding is still needed and suggests several challenges for the research community. These challenges can be summarized as follows.

Improve the transfer of knowledge from the scientific community studying climate change and weather forecasting to the financial services community. There clearly is a need for better understanding of how extreme weather events that are important to financial service firms could be affected by climate change. New knowledge should be communicated to the financial community and society for practical use. There is a specific need to:

- Develop ways for the insurance sector to blend information from the scientific community's climate models, as they evolve, with its own loss estimation models
- Improve daily, seasonal, and annual forecasting of extreme weather, and adapt it for use in disaster prevention.

Advance the understanding of the relative global and regional vulnerability and adaptability of insurance and other financial services to climate change. The trend in losses from extreme weather events has raised questions about the insurance sector's vulnerability to climate change in some respects, although as a whole the industry could be quite resilient. Even less is known about the relative vulnerability or resiliency of other segments of the financial services sector. A more definitive assessment of the industry's strengths and weaknesses in the face of climate change is necessary, with specific needs to:

- Continue analysis to disaggregate climate change, socioeconomic, and any other non-climate drivers of observed trends in historic economic (insured and uninsured) losses
- Explore specific aspects of the industry's vulnerability and resiliency, including maximum probable insurance losses; insurer surplus available for paying claims; insolvency risk in local insurance markets; and ability to raise rates, reduce coverage, or otherwise decrease losses by shifting risk to others
- Assess how climate change could affect the actual and perceived risk of existing loan and investment portfolios
- Understand if or how investors are changing their perceptions of investment risk in light of potential climate change and explore actions that investors are taking in light of any changes in the perception of risk.

Explore the role of the financial services sector in dealing with risks to society from climate change. As intermediaries and risk experts, the financial services sector could play a positive role in efforts to deal with the risks of climate change. The sector also could play an important role in identifying potential synergies and conflicts regarding funding for adaptation and mitigation measures. Work is needed to:

- Assess and develop financial instruments that can spread and hedge against the risks of climate change for developing and developed countries
- Quantify the need for financial resources for investment in adaptation
- Determine how the availability of funds for adaptation could be affected by the use of funds for mitigation activities and vice versa
- Identify any synergies between options for adaptation and for mitigation.

Explore the range of possible financing arrangements to cover the cost of adapting to climate change:

- Investigate potential financial resources needed over the next few decades to cover the cost of damage from climate change and adaptation to climate change
- Evaluate alternative methods of covering such costs
- Develop innovative finance schemes for issues of risk and security regarding long-term investments
- Investigate the potential role of and effects on private and public financial services providers.

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