NBER WORKING PAPER SERIES

GLOBAL FINANCIAL STRUCTURE AND CLIMATE CHANGE

John Whalley
Yufei Yuan

Working Paper 14888
http://www.nber.org/papers/w14888

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
April 2009

We thank the Center for International Governance Innovation (CIGI) and the Academic Development Fund, University of Western Ontario for the financial support. The views expressed herein are those of the author(s) and do not necessarily reflect the views of the National Bureau of Economic Research.

Global Financial Structure and Climate Change
John Whalley and Yufei Yuan
NBER Working Paper No. 14888
April 2009
JEL No. G21,Q54

ABSTRACT

This paper analyzes the medium to long-term implications of global warming for the evolution of global financial structures. Stern (2007) and other related scientific literature reports that greenhouse gas emissions generated by human activities will very possibly lead to global temperature increase of 1-5 degrees C by 2050. This will cause a dramatic increase in global risks to human life. The response to this will be the seeking-out of financial innovation by major forms, primarily in the area of insurance, but also in the diversification of asset holdings. We suggest in this paper that, with modest climate changes of 1-2 degrees C, the global insurance market will expand dramatically. However, under more extreme climate change scenarios, the entire global financial structure will undergo major changes, with a re-focusing of major financial activity away from intermediation between borrowers and lenders and the facilitation of the accumulation of assets, and towards a focus on insurance arrangements and the diversification of risks associated with climate change.

John Whalley
Department of Economics
Social Science Centre
University of Western Ontario
London, Ontario N6A 5C2 CANADA
and NBER
jwhalley@uwo.ca

Yufei Yuan
Wang Yanan Institute for Studies in Economics
Economics Building A307
Xiamen University
Xiamen, Fujian, P.R.China, 361005
yyuanwise@gmail.com

1. Introduction

This paper discusses the medium to longer term implications of severe global warming scenarios for the evolution of global financial structure. We agree that growing climate risk both broadly across the world in specific locations of specific forms raises the prospect of a global financial system increasingly dominated by insurance driven rather than more conventional lender-borrower intermediating transaction. The form of the instruments and transactions will likely to be and involve substations financial innovations. This is a topic that has seemingly to have attracted little attention in the existing climate change literature, but is one which seemingly is poised to become of major significance. In the negotiation to be concluded in Copenhagen in December 2009 on a new global climate change regime for a post-Kyoto world, one of the four pillars is in the area of trade and finance. This, however has so far been focused on the financial needs of the global economy for the achievement of a significant mitigation of carbon emissions and not on the implications of climate change for global financial structure. This is our focus here.

In essence, we argue that the prospect of climate change scenarios over the next 20-50 years with temperature change in the region of 1 - 5 ^{o} C, as projected for 90-percent confidence intervals for climate change by Stern (2007), poses challenges for the global economy both in location specific and area specific climate risk. We suggest the response to this will be financial innovation of major form, primarily in the area of insurance, but also in diversification of asset holdings. We suggest that, even with modest climate changes of 1 – 2^{o} C, global insurance markets will expand dramatically; but under more extreme climate change scenarios, the whole global financial structure will undergo major change, we see a re-focusing of major financial activity away from intermediation between borrowers and lenders and the facilitation of the accumulation of assets to one of insurance arrangements and diversification of risks associated with climate change. The latter is likely to lead to major financial innovation and poses large challenges for future global financial structure.

Current insurance arrangements globally are focused on national insurance markets and regardless while climate risk will be of varying form and decentralizing across individual national economies, given both geographical divide and diverging form economies to be. Nationally based insurance markets sometimes can not accommodate disappearance of small islands due to sea level rise or area specific desertification or health risk of regional malarial infection. The contrast is extreme between, say, Russia, which spans 10 time zones and has large land and reserves and, say, Hong Kong, which spans 25 sq. and has a population of 5-6 million people an inability to diversify climate risk and the risk associated with sea level rise.

These challenges of adaptation to both climate change and climate risk through financial innovation, in our opinion, will become a progressively major preoccupation of debate and discussion of future global financial arrangements. In this paper we try to point the way forward to what some of these debates will focus on.

2. Physical Dimensions of Climate Risk

We begin our discussion with an overview of literature on the physical dimensions of climate risk, both in terms of the nature of the risks involved and the potential severity across different geographical location. Much of available work on this derives from the activities of the Intergovernmental Panel on Climate Change (IPCC) and, in turn, much of that activity is summarized in the recent Stern (2007). The dimensions of climate risk involve the risks of temperature change itself, with varying scenarios as to the potential severity of climate change under a Business-as-Usual (BAU) scenario. These risks differ by location. They principally involve risks of reduced crop yields (and modestly increased yields in some locations) in agriculture, risks of more extreme weather events, risks of sea level rise, and risks of health related damages (for example, increased malaria in Africa). These categories of physical impacts are each discussed in Stern (2007).

Based on claimed correlation of carbon dioxide concentrations with global warming, the IPCC compare the predictions of different climate models and made their estimations of ranges of possible the future temperature increase. They suggest that if greenhouse gas levels were to be stabilized at today's levels, global mean temperatures would eventually rise to around 1 - 3 ^{o}C above pre-industrial (up to 2 ^{o}C more than today's temperature). If annual emissions were there to continue at today's levels, greenhouse gas levels would be close to double pre-industrial levels by the middle of the century. And if this concentration were sustained, with the lower and upper 90% confidence bounds temperatures are projected to eventually rise by 2 - 5 ^{o}C or even higher. These estimates of rages of global temperature change are, however, themselves subject to large variation and have been challenged in the literature. There are thus considerable uncertainties associated with the risk, of both size, type and timing of aggregate impacts of climate change, even before one gets to location or type specific risks.

Along with this temperature change, however, also come the physical effects of damage and their geographical location. Stern (2007) analyzes the impacts of global warming from seven perspectives. Among them, five are expected to impose large and direct impacts on human livings: water, food, health and land. Climate change will affect the global distribution of water, increasing regional, seasonal and annual variability. More locations will suffer higher risks of flooding while others will have more serious and more frequent droughts. For warming of 3 - 4 ^{o} C, the potion of land area globally experiencing severe droughts will increase from 10% today to approximately 40%. And, the proportion of land area experiencing extreme droughts will increase from 3% to 30%. This will reduce the water availability for many people. Temperature rises of 2 ^{o} C will result in 1 - 4 billion people experiencing water shortages of various sovereigns predominantly in Africa, the Middle East, Southern Europe, and parts of South and Central America.

Higher temperatures will also reduce crop yields especially in tropical areas where crops are already close to critical temperature thresholds and it is believed that many countries have limited capacity to make the economy-wide adjustments to farming patterns needed. These impacts will be largest across Africa, Western and the Middle East Asia, where yields of the predominant regional crops may fall by 25 - 35% with a 3 - 4 ^{o} C rise by 2050. There is also a large degree of uncertainty associated with the impacts of higher temperatures on global corps yields. The impacts of Carbon fertilization will affect crop yields critically but still lacks good estimates of the magnitude. According to Stern (2007), the latest analysis from crops grown suggests when a weak carbon fertilization effect is used, worldwide cereal production declines by 5% for a 2 ^{o}C rise in temperature and 10% for a 4 ^{o}C rise. Declining crop yields will likely leave hundreds of millions without ability to produce or purchase sufficient food, particularly in the poorest parts of the world. Temperature rises of 2 to3 ^{o}C will thus greatly increase the number of people at risk of hunger, potentially by 30 - 200 million. Once temperatures increase by 3 ^{o}C, 250 – 550 million additional people may be at risk.

As for impacts on health, higher global temperatures will make vector-borne diseases such as malaria and dengue fever more widespread. According to the World Health Organization (WHO), even a 1 ^{o}C increase in global temperature above pre-industrial levels could double annual deaths from climate change to at least 300,000. This will greatly increase health disparities between rich and poor parts of the world. Today, in Africa, 450 million people are exposed to malaria and among these people around 1 million die each year. A rise of 2 ^{o}C in temperature may lead to 40-60 million more people exposed to malaria in Africa, with this estimate increasing to 70 - 80 million at higher temperatures.

According to Stern (2007), global warming even from the last century has already pre committed the world to rising seas for many centuries to come. Further warming this century will increase further these effects. This threatens to impose significant costs on the land resources-especially in coastal areas. A significant portion of major cities globally are ports with major risks for infrastructures in these cites. Also more than 200 million people live in coastal flood plains around the world, with 2 million square Km of land and $1 trillion worth of assets at less than 1-m elevation above current sea levels. According to Warren, Arnell, Nicholls, Levy and Price (2006) who assume that protection from sea level rise will increase in line with GDP per capita, between 7 -70 million and 20 -300 million additional people could be flooded each year by warming of 3 to 4 ^{o}C causing 20 - 80 cm of sea level rise.

Finally, global warming will increase the risk of triggering abrupt and large-scale changes. With higher temperature increase, the world risks crossing a threshold level of warming beyond the point where collapse of Greenland Ice Sheet (GIS) and Western Antarctic Ice Sheets (WAIS) would be irreversible. In Lenton, Held, Kriegler, Hall, Lucht, Rahmstorf and Schellnhuber (2008), the GIS threshold is estimated at 3 ^{o}C local warming, which is clearly accessible this century. As for WAIS, concern has been raised by recent observations that the WAIS are losing more ice than they are gaining. The worst case scenario is that WAIS collapses with 300 years, which then creates further sea rise of 1 m per century.

In addition, according to Lenton et al. (2008), global warming could also induce sudden shifts in regional weather patters such as the Asian and African monsoons. This could lead to the severe drought and a major reduction of crop yields. Challinor, Wheeler, Craufurd, Ferro and Stephenson (2007) predicts up to a 70% reduction in crop yields by the end of this century under these conditions, assuming no adaptation.

Although the earth researches have analyzed these physical risks, the damage associated with then, in economic terms, is another matter depends on both the distribution of population across the world and differences in incomes levels and forms of economic activity across populations. In essence, the physical dimensions of climate change are thought to span a number of critical areas and components by the current literature, especially studied in Stern (2007). The critical elements of discussion have thus far focused on the following. First, not only the impacts of global warming are highly uncertain, but once in place they will continue for a long time and likely worse as time goes on.

Greenhouse gases, as a major source of temperature increase, can remain in the atmosphere for hundreds of years. And, climate change itself could also trigger additional increases in greenhouse gases in the atmosphere, further amplifying warming. Stern (2007) suggests that these "positive feedbacks" could lead to an addition rise in temperatures of 1 - 2 ^{o}C by 2100. This implies that once initial adaptations are in place for the adverse initial impacts of climate change, then it will not fully deal with further long-term changes affecting social and economic life.

Second, IPCC studies suggest that the damages from climate change will be disproportionately concentrated in Africa, Western and The Middle East Asia, South Asia, and coastal areas. The first three areas cover the large population low income level parts of the world, in which effective adaption may be unaffordable from the beginning. For coastal areas, significant fractions, which at present are seemingly unknown, of the global capital stock are potentially affected, and hence losses from even a relatively small elevation from existing sea levels can be large. A large portion of the major cities of the world are ports in coastal zones, and hence a sea level rise implies potential impairment or even destruction of significant portions, not only of physical capital in use by private enterprise, but also infrastructure in the form of roads, rails, airports, telecom systems and buildings as sea level rise accelerates.

These features about the impacts of global warming scenarios suggest the critical importance of insurance as a way of sharing the burden of climate risks. In water, food production and health, larger insurance market will be necessary to respond to risks of more frequent and more serious droughts, floods, pests and infectious deceases. In the cases of more extreme sea level rise such as 1m-5m by 2050, most of the coastal cities will stay below the sea. This will impose large adjustment costs on populations which work in these regions and, in turn, in responding to the implied adjustments, moving large numbers of people across these lands would seemingly be necessary. Also, large redistributions of income would occur across these groups and that much of this would occur across national borders.

Because of the high concentration of risks in these areas, the insurance transaction implied may be far beyond the financial ability of countries in these areas. This, in turn, thus raises issues of insurance across borders to resist climate risk. The number of countries severely affected this is also an issue, particularly so for the 43 countries who comprise the Alliance of Small Island States (AOSIS). An extreme case is Maldives Islands, which may disappear within 30 years under more extreme scenarios. While the populations involved in these small island states are relatively small, the number of these countries is large and this poses major issues clearly for global financial structure in terms of the insurance arrangements which may be undertaken by governments of these entities.

3. Mapping Physical Risk into Risk of Economic Damage

The insurance demands on the global financial structure that could arise under the more extreme climate change scenarios will depend not only on physical risks of damage, but also the economic value of damage at issue. For any, given physical impacts from climate change, the economic damage depends on several factors. Among them, the most important one is how much people can adapt to climate change and how costly it is to adapt. If adaptation is costless then insurance demands will be small and as adaptation costs rise so do insurance demands. We first discuss estimates of adaptation costs to climate change. These include adaption costs for individual sectors and aggregate adaptation costs across the global economy. These are discussion of Agrawala and Fankhauser (2008), but they only account for costs of people in resisting impacts of climate changes and do not include residual (unprotected) economic damages due to climate change.

In water, temperature rise will generate more inequality in distribution and availability. Therefore, for regions where precipitation is expected to increase, problems such as flood management will impose substantial additional costs. On the other hand, in regions where water availability might decline on account of glacier retreat or smaller precipitation, investments in enhanced storage, as well as enhancing the efficiency of water allocation become part of adaption costs. Kirshen (2007) assesses of the adaptation costs in water resources at the global level. The assessment tells that the adaptation costs in water resources will reach USD 531 billion for the period up to 2030. In food and agriculture, as claimed in Agrawala and Fankhauser (2008), a general finding from the global-level studies is that relatively modest and low-cost adaptation measures can significantly offset declines in projected yield as a result of climate change. For example, Tan and Shibasaki (2003) estimate that the global low-cost adaptation can reduce the adverse impacts of global warming on crop yields in the rage of 23-48% of the damage. But for those areas with serious potential impacts like Africa and The Middle East of Asia, adaptation does not generate significant benefits in reducing the impacts of global warming. In health, there are only very limited studies providing estimates of global adaptation costs to climate change in the health sector. Ebi (2007) estimates adaptation cost as USD 4-5 billion by 2030, and they are primarily for developing countries.

For the coastal zones, the studies listed in Agrawala and Fankhauser (2008) estimating adaptation costs tend to focus on sea level rise, and miss elements like coastal protection and property insurance. Also the sea level rise is expected to reach 18-59 cm in this century, which does not include uncertainties associated with more extreme cases like the potential melt of GIS and WAIS, which could raise sea level by 5 meters from 2030 to 2130 according to Nicholls, Tol and Vafeidis (2005). These studies show that the optimal levels of coastal protection are often quite high, which reflects the high income, high population density and the high concentration of capital in costal areas. And the cost estimates for optima levels of protection are typically relatively modest. For example, Tol, Fankhauser, Richels and Smith (2000) estimate with 1m sea level rise, the global adaptation costs take 0.056% of GNP and the optimal protection level is 89%.

Finally, UNFCC provide the estimates of global adaptation costs. Annual global adaptation costs by the year 2030 are calculated to be in the range of USD 49-171 billion which, according to Smith (2007) corresponds to 0.2-0.8% of global investment flows or 0.06-0.21% of projected GDP in 2030.

Although the adaptation costs reported in the above are not large compared to output, they only include costs that agents incur in resisting the impacts of climate changes. They do not take into account the residual economic costs that people bear even after they have adapted. Hence, we do need to consider economic damages in a broader sense and especially the significant economic costs facing developing countries.

There is large disagreement as to the aggregate economic damage likely due to climate changes summarized in the Stern (2007). The BAU scenario out to 2050 is one where the aggregate loss in gross world product would be in the region of 20% of GDP. But Stern (2007) takes a more extreme position than most other writers in current literature in assessing aggregate damage. In contrast, Mendelsohn (1994) and others have focused primarily on the agricultural yield component of damage due to climate risk, using farm level data in the US and other economies. His recent paper Mendelsohn (2005) offers the conjecture that economic damage between now and 2050 may be indistinguishable from zero and could even be of opposite sign and small on the positive side. Thus, estimates of economic damage in aggregate are highly uncertain in size and form.

However, it is sub-aggregate damage which is critical in measuring and assessing insurance risks. The location-specific damage associated with agricultural yields, the location-specific damage associated with sea level rise, the individual specific components of health and mortality risk, and also the sector and industry concentration of potential risk in terms of increased energy costs all need to be assessed. Aggregate risk can be small, while sub-aggregate risk is large.

Developing countries are especially vulnerable to the impacts of climate change and for three reasons. First, climate change will have a disproportionately damaging impact on developing countries due to their location in low latitudes and tropical areas. Second, developing economies are also sensitive to climate change because of their heavy dependence on agriculture. The rural sector contributes 21% of GDP in India, for example, and 39% in Malawi, 61% and 64% of population in South Asia and sub-Saharan Africa are employed in the rural sector. Third, developing countries also generally have poor adaptive capability. This reflects a lack of infrastructure; inefficient management of adaptation by government; and the low incomes which make adaptation unattractive. For example, under the specific BAU scenarios, major yields in northern India could be reduced by up to 70% by 2100 because of the increased losses of monsoon rainfalls. In Africa and Western Asia, between 250 and 550 million additional people may face additional hunger with a temperature increase of 3 °C. In Latin America, the major crops may fall by around 15% on average by the middle of this century.

4 Financial Responses to Climate Risk and the Future of the Global Financial Structure

Given both the physical dimensions of climate change and the risks of economic damage associated with this both globally and at sub aggregate detail, we now turn to a discussion of the likely response to growing climate risk that may occur through the global financial system.

Our argument in this paper is that, until recently, the global financial system has been one of which a large portion has primarily facilitated intermediation in between borrowers and lenders. In the process, this has provided a vehicle for financing accumulation of physical capital and thus growth and development of the major economies around the world. This has been seen as one of the most important focuses of financial activity as conducted structure through banks, stock markets and other entities. According to Maslakovic (2008), the worldwide assets of the largest 1,000 are equal to $74.2 trillion in 2007. However, insurance activity at the personal level is focused primarily on house, auto and life insurance, and commercial insurance deals with insurance related to property, liability, and trade and other kinds of transactions. Although insurance industry has the annual revenues of $ 3 trillion and consists of world largest industry as suggested by Mills (2005), it is actually very limited in size and scope. Especially for the weather-related natural disasters, according to Mills (2005), insured losses amount to $141 billions which cover only 20% of all the losses from weather-related risks. It covers about 30% of the losses due to weather-related disasters in developed countries. But in developing countries, commercial insurance only covers about 5% of the losses due to weather-related disasters.

This picture is widely accepted in most of the literature on financial structure, even though also significant portions of financial intermediation these days take place across countries and also reflect the different roles and positions that countries find themselves in international transactions.[1] Today, in the Middle-East, for instance, where there has been large accumulation of reserves of perhaps $5 trillion, the prospect of declines in oil deposits and the seeming end of oil revenues motivate financial activity by government which seeks to provide for future activity. In the Chinese case, with the accumulation now of $2 trillion of reserves, government financial activities have been primarily motivated by the desire to maintain stability in the macro policy regime and hence the maintenance of the existing exchange rate regime, along with self-insurance after the events of the Asian financial crisis in 1997.

Our conjecture is that progressively over the next 30-50 years, the growing significance of climate change and associated climate risk as an element in day to day economic life will mean that insurance concerns will need to progressively dominate intermediation concerns in the evolution of global financial structure. This, in turn, will pose many challenges for the arrangements of these insurance related activities and will likely generate new kinds of insurance related instruments as financial innovation occurs. The recent literature starts to study the adaptation that people can achieve through insurance market against climate changes. To adapt to more modest risks related with climate changes, the literature such as Pollard, Oldfeld, Randalls and Thornes, eds (2008) puts forward the financial innovation of weather derivatives. The background for weather derivatives is there will be more and more frequent abnormal weathers, which generate small risks but with high possibility to happen,

[1] Please refer to Allen and Gale (2000) for the details about the literature on financial structure.

such like wetter (or hotter) than average summer which might affect businesses like restaurants. The potential market related to these kinds of risks is large in magnitude. According to Pollard et al., eds (2008), 70% of UK firms may be affected by the weather; in the USA, estimates suggest that between 25% and 42% of the US gross domestic product (more than $ 2.7 trillion) is weather sensitive. One distinctive feature of weather derivatives is that to make claims on weather derivatives, firms do not need to specify any insurable interest or demonstrate that the weather has affected their business for them to be compensated in order to claim for payment on weather derivatives. As for the high climate related risks, as suggested in section 2 and section 3, climate changes will lead to more frequent weather-related disasters and more progressive adverse impacts on more people. Under the BAU scenario, it is quite reasonable to expect the losses of the weather related natural disasters 5-10 times the current losses in 2050, which will generate insurance covered losses of 1 trillion given the similar ratio of coverage as present. If we add the weather derivatives, the future insurance market related to climate change will expand even more than 10 times.

One central issue concerns the viability of climate related insurance arrangements. If financial activity involving insurance related activity is engaged in by countries or governments which may disappear as with the Maldives, the sustainability of long term debt issuance to finance insurance engagements becomes a major issue. There has been discussion, for instance, of the Maldives buying land outside their own national territory at lands and progressively moving individuals to that land as the country begins to disappear under the ocean. There have been legal debates as to whether or not sovereignty of nation states can continue to hold when the territory of sovereign state is under water. These legal debates are largely beside the issue for the purposes of this paper. In terms of economic activity, the issues are whether or not nation states and their residents will be able to engage in insurance related activities of the catastrophes, whether entities on their territory can issue financial instruments, and engage in financial intermediation.

Related to this is also the current global regulation of insurance markets, which is largely nationally based. Many countries have insurance regulations which require that any insurance policy being written in a country covered by assets located in that country which exceed it liabilities in terms of the value of policies that they write.[2] In countries which are rapidly disappearing, either physically under the ocean or in economic terms because of the severity of damage, such as may be the case with Bangladesh for sea level rise, the viability and feasibility of such insurance-related arrangements is thus crucial. Equally, from the point of view of global financial arrangements, current regulation of insurance markets on a national basis would seem to be unsustainable, also because of the sharply differing nature both of climate risk and the economic damage due to climate risk by country. In the case of small geographically concentrated countries, such as Singapore or Hong Kong, there would seem to be almost no diversification of climate risk insurable and in the country, the risks will affect all residents of the country equally so that diversification of risk within the country is unfeasible. On the other hand, for geographically large countries with diverse physical geography, such as Russia or China, diversification within the country would be possible. Hence insurance companies focusing on a within-country basis can potentially diversify within country risk. In general, however, across the whole of the global economy, it would seem that nationally based insurance markets would provide only a poor basis for

[2] Please refer to Finsinger and Pauly (1986) for details of such regulations.

diversification of social risk from climate change and hence globally integrated insurance markets may be needed. How that integration is to be achieved is still a major challenge.

In addition, we see many challenges arising in the evolution of financial instruments. Although the number of natural disasters has increased about ten times since 1950 as shown by Mills (2005), according to Michel-Kerjan and Morlaye (2008), the insurance market for catastrophes only has very limited expansion. Charpentier (2008) claims that natural catastrophes related to climate changes are hardly insurable because: first, losses can be huge and the premium might be two high; second, diversification through the central limit theorem is not possible because of geographical correlation. Because the weather-related disasters will be more frequent and more serious under the impacts of climate change, the insurers can not refer to past experiences to price the premiums. Therefore, catastrophe insurance market will face larger uncertainty. This will further hinder the development of insurance market. No doubt, new form of innovations is necessary to increase the viability of insurance market to climate change. We may even see the possible issuance of global flooding bonds, global warming bonds and other financial instruments which would involve contingent payouts to either national governments or groups of residents in particular locations, conditional upon certain climate related event occurring. This could be sea level rise of a certain size on a certain date and in a certain location, measured by an agreed agency with mechanisms in place to arbitrate any disputes between the issuers and purchasers of the bonds. The potential exists for financial institutions globally, including merged either across merchant and commercial banks, to be involved in these financial transactions in a major and large way as the whole global financial system's structure tilts rapidly towards global risk diversification as the dominant global financial activity.

We should also pay much attention to the role played by the government provided insurance against extreme weather conditions, which is largely due to the absence of private provided insurance covering these risks. The private insurance does not provide enough coverage for climate related catastrophes such as floods caused by water rise. The reasons for such absence of private insurance in this area stem from both supply side and demand side. For supply side, more financial innovations on insurance businesses are needed such that the private insurance companies are willing to sell such polices. For example, according to Botzen and Van Den Bergh (2008), in Netherland, insurance companies do not cover flood damages because the risks associated with them are regarded as uninsurable by the insurance sector since the catastrophic North Sea flood in 1953. For demand side, people tend to not buy such policies covering the risks brought by weather related catastrophes even if the policies are available. As suggested by Kunreuther (2006), in the United States, many homeowners suffering rising water damage did not have flood insurance even though they were eligible to purchase such a policy through the National Flood Insurance Program (NFIP), a public program administrated by the Federal Emergency Management Agency (FEMA) that was established in 1968. Kunreuther (2006) argue that the reasons for this result are that people tend to underestimate the risks brought by weather extremes and also that some people can not afford the costs of such insurance. The absence of private insurance leads to the necessary intervention of the governments. Just within the few days after Katrina hit landfall, the federal aid voted by the US Senate had reached $60 billion, which surpassed the total claims of 40-55 billion for insurance industry. Therefore, as suggested by Kunreuther (2006), to reduce future losses generated by climate changes, there is a need for creative private-public partnerships. However, it is widely argued in literature that such government provided insurance is inefficient in that it causes serious moral hazard problems.[3] For example, if the government commits to vide compensation as the last resort, people in those areas which are more likely to suffer weather related disasters do not move out of the places even though it is more efficient and much less costly to do so. Therefore, in the long run, in order to achieve more efficient insurance, we must have more innovations in insurance industry.

3 Please refer to Kunreuther (2006) for such arguments.

5 Conclusion

In this paper, we discuss some of the potential dimensions of climate change as they may affect global financial structure. We suggest that there are large degrees of uncertain involved with climate change, but over the next 30-50 years, if the global economy evolves with increasing severity of climate change, as some believe likely, then we may witness n emerging global financial structure which progressively shifts from intermediation to insurance, and the insurance needs will be location and topic specific and will generate major changes in existing global financial structure. How all this endues remains to be seen and this is a first contribution to a wider discussion we expect to follow.

References

Agrawala, Shardul and Samuel Fankhauser, *Economic Aspects of Adaptation toClimate Change: Cost, Benefits, and Policy Instruments*, OECD Publications, May 2008.

Allen, Franklin and Douglas Gale, *Comparing Financial system*, 5th ed., Cambridge: The MIT Press, 2000.

Challinor, A.J., T.R. Wheeler, P.Q. Craufurd, C.A.T. Ferro, and D.B. Stephenson, "Adaptation of crops to climate change through genotypic responses to mean an extreme temperatures, Agriculture, Ecosystems and Environment," *Agriculture, Ecosystems and Environment*, February 2007, 119, 190-204.

Charpentier, Arthur, "Insurability of Climate Risks," *The Geneva Papers on Risk and Insurance - Issues and Practice*, January 2008, 33 (1), 91-109.

Ebi, Kristie L., "Health Impact of Climate Change," Technical Report, the UNFCCC Secretariat Financial and Technical Support Division 2007.

Finsinger, Jorg and Mark V. Pauly, *The Economics of insurance regulation : a cross-national study*, 1st ed., Basingstoke: Macmillan, 1986.

Kunreuther, Howard, "Has the Time Come for Comprehensive Natural Disaster Insurance?," in Ronald J. Daniels, Donald F. Kettl, and Howard C. Kunreuther, eds., *On Risk and Disaster: Lessons from Hurricane Katrina*, Philadelphia: University of Pennsylvania Press, 2006, pp. 175-202.

Lenton, Timothy M., Hermann Held, Elmar Kriegler, Jim W. Hall, Wolf-gang Lucht, Stefan Rahmstorf, and Hans Joachim Schellnhuber, "Tipping elements in the Earths climate system," *Proceedings of the National Academy of Sciences of the United States of America*, December 2008, 105 (6), 1786-1793.

Maslakovic, Marko, "BANKING 2008," Technical Report, International Financial Services London Research February 2008.

Mendelsohn, Robert, "The Impact of global Warming on Agriculture: A Ricardian Analysis," *American Economic Review*, September 1994, 84 (4), 753-771.

Mendelsohn, Robert, "Measuring Climate Impacts With Cross-Sectional Analysis," *Climatic Change*, December 2005, 81 (1), 1-7.

Michel-Kerjan, Erwann and Frederic Morlaye, "Extreme Events, Global Warming, and Insurance-Linked Securities: How to Trigger the 'Tipping Point'," *The Geneva Papers on Risk and Insurance - Issues and Practice*, January 2008, 33 (1), 153-176.

Mills, Evan, "Presentation to the 2005 Meeting of the American Association for the Advancement of Science," February 2005.

Nicholls, Robert J., Richard S.J. Tol, and Athanasios T. Vafeidis, "Global Estimates Of The Impact Of A Collapse Of The West Antarctic Ice Sheet: An Application Of Fund," Working Papers FNU-78, Research unit Sustainability and Global Change, Hamburg University July 2005.

Pollard, Jane S., Jonathan Oldfeld, Samuel Randalls, and John E. Thornes, "Firm Finances, weather derivatives and geography," *Geoforum*, March 2008, 38, 616-624.

Smith, Joel B., "Preliminary Estimates of Additional Investment and Financial Flows Needed for Adaptation in 2030," August 2007.

Stern, Nicholas, *The Economics of Climate Change: The Stern Review*, New York: Cambridge University Press, 2007.

Tan, Guoxin and Ryosuke Shibasaki, "Global Estimation of Crop Productivity and the Impacts of Global Warming by GIS and EPIC Integration," *Ecological Modelling*, October 2003, 163, 357-370.

Tol, Richard S.J., Samuel Fankhauser, Richard G. Richels, and Joel B. Smith, "How Much Damage Will Climate Change Do?," *World Economics*, October 2000, 1 (4), 179-206.

Botzen W. J. and Van Den Bergh J. C. J. M., "Insurance Against Climate Change and Flooding in the Netherlands : Present, Future, and Comparison with Other Countries," *Risk analysis*, April 2008, 28 (2), 417-426.

Warren, Rachel, Nigel Arnell, Robert Nicholls, Peter Levy, and Jeff Price, "Understanding the regional impacts of climate change," Technical Report 90, Tyndall Centre for Climate Change Research September 2006.