Proactive Risk Management of Climate Change Youth Forum Research Result 6

A Preliminary Study on Quantitative Analysis of Physical Climate Risks

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In recent years, the continuously rising global temperature, coupled with the frequent occurrence of extreme disasters, has led to a growing concern about environmental and climate issues from all walks of life. The assertion that climate-related risks are a source of financial risks has, therefore, become a consensus in the global financial community. With the introduction of the goal to peak carbon emissions before 2030 and achieve carbon neutrality by 2060 (hereinafter referred to as "the dual carbon goal") and the continuous progress of related work in China, environmental and climate issues are drawing more attention across the country, with financial institutions moving to include environmental and climate risks in their comprehensive risk management systems and conduct related risk measurement & analysis. Nevertheless, most of the existing efforts are focused on transition risks, and little research has been conducted on physical risks. In this paper, we will briefly introduce the overview of physical risks, their relationship with transition risks, and existing measurement methods, and then put forward suggestions for the quantitative analysis of physical risks.

I. Overview of physical risks

i. Definition and sources of physical risks

Physical risk is the possibility that a variety of natural disasters and events related to the environment and climate cause adverse consequences. Professor Ma Jun, President of the Institute of Finance and Sustainability (IFS) in Beijing, in his article titled *The Significance, Methodology, and Promotion of Environmental Risk Analysis by Financial Institutions*, divided physical risks into four categories, namely, extreme climatic disasters of all sorts, sea level rise, ecological pollution accidents, and natural resource damage and shortage. Among them, natural disasters represented by floods, typhoons, snowstorms, droughts, and wildfires are a category of physical risks that take place more frequently and have a more direct and significant impact on our production and life than others.

ii. Development and status quo of physical risks

After empirically examining the relationship between natural disasters and the losses they cause, many foreign institutions generally hold that compared with historical patterns, global warming and climate deterioration contribute more to the fact that extreme natural disaster events become more frequent and more devastating. For example, the International Monetary Fund (IMF) analyzed the changing trends of total losses and insured losses from natural disasters worldwide over the period of 1980-2018. The analysis results show that the insured losses from natural disasters tripled in 2018 compared to the 1980s. BlackRock overlaid Rhodium's hurricane modeling onto the approximately 60,000 underlying commercial properties in BlackRock's commercial mortgage-backed securities (CMBS) database, finding that the median risk of any of these properties being hit by a Category 4 or 5 hurricane has risen by 137% since 1980. It is hence concluded that the losses from physical risks take up an upward trend over a long period of time.

The *Global Risks Report 2020* released by the World Economic Forum states that for the first time, environmental and climate concerns dominate the top five risks facing the world in the coming 10 years, of which extreme weather events and natural disasters related to physical risks rank first and third, respectively. According to the latest study released by the World Economic Forum in early 2021, environmental and climate risks remain the top issue facing human society in the next decade by likelihood and impact. Specifically, the extreme weather-related risks top all risk types by likelihood, which should be of great concern.

iii. Relationship between physical risks and transition risks

Transition risks are the risks arising from policy changes, technological innovations, changes in market sentiments and preferences, and transformation of business models in the process of coping with climate change and shifting to a sustainable economy. While physical risks are the cost of passively accepting climate deterioration, transition risks turn out to be the price of proactively addressing climate change.

It is generally believed that if we cannot effectively curb the continuous rise of global temperature, it will lead to a growing number of natural disasters that are more frequent and more serious. In other words, there is a positive correlation between temperature rise and physical risks. In contrast, transition risks are the risks derived from the efforts to control temperature rise, so there is a negative correlation between the two. Therefore, it is theoretically analyzed that there exists a trade-off between physical risks and transition risks. This opinion has been justified by a study of AVIVA. The British insurance company used a climate risk assessment model constructed by Carbon Delta to analyze how the assets held by it could be possibly affected by transaction risks and physical risks. The analysis results suggest that in the scenarios with high temperature rises such as 3℃ and 4℃, more than 95% of the impact would come from physical risks; in the scenarios with low temperature rises such as 1.5℃ and 2℃, transition risks and physical risks would exert a basically equal impact.

iv. Temperature and precipitation changes in China

In August 2021, the Center on Climate Change of China Meteorological Administration released the latest *Blue Book on Climate Change in China*, mentioning that the annual average surface temperature in the country rose by 0.26℃ every decade between 1951 and 2020, a level significantly higher than the global average (0.15℃ per decade) during the same period. China's average annual precipitation from 1961 to 2020 increased by 5.1 mm per decade. Since this year, Henan, Shaanxi, Zhejiang, and other places were prone to heavy rainfall, with daily rainfall exceeding the historical extremes since the meteorological records began.

China's annual average temperature and precipitation from 2000 to 2020 were calculated with the data of various meteorological observation stations nationwide available on the website of Wind. With ten years from 2001 to 2010 taken as one cycle, the average temperature and precipitation in China stood at 11.4℃and 756.49 mm, which jumped to 11.52℃ and 806.54 mm from 2011 to 2020, respectively. It can be seen that from a long period of time, the temperature and precipitation in China indeed show an upward trend. In addition, when annual average temperature is used as an independent variable and annual average precipitation as a dependent variable for correlation analysis, one can find that there is a positive correlation between temperature rise and precipitation change. That is, temperature increase will lead to heavier rainfall, a finding that attests to the negative correlation between transition risks and physical risks to a certain extent.

II. Quantitative analysis of physical risks

Scientific and reasonable quantification of risks is a prerequisite for effective control. In recent years, many research institutions and scholars at home and abroad have studied the transmission mechanisms of physical risks, and come up with relatively similar methods for quantitative analysis. In this paper, we briefly introduce the transmission paths and quantification models of physical risks by comprehensively referring to the studies and cases undertaken by the University of Cambridge, ETH Zurich, and Research Center for Green Finance Development of Tsinghua University (hereinafter referred to as "RCGFD").

i. Risk transmission paths

Natural disaster events that cause physical risks can have impacts on human production and life, which are divided into two categories: direct impacts and indirect impacts. **Direct impact** means a disaster event strikes housing buildings, plants and equipment, transportation facilities, etc., resulting in the impairment or destruction of physical assets, which are direct physical losses. **Indirect impact** means a disaster event leads to the shutdown or production reduction of enterprises, the interruption of production activities, etc., a process accompanied by indirect economic losses such as the deterioration of business conditions, decline in residents' income, and economic development stagnation.

Direct physical losses and indirect economic losses will affect the asset and liability profile, income, and cash flow, among other aspects, of enterprises and individuals, triggering changes in financial indicators. For a financial institution, financial indicators are input variables of risk management models. Changes in financial indicators will lead to changes in output indicators of risk management models, thus reflecting the risk profile of the financial institution. For instance, a flood destroys plants and buildings as well as machinery and equipment located there, which suspends business operations, results in the destruction or impairment of corporate and personal assets, adds to the uncertainty of repayment sources, and reduces the value of collateral. Consequently, loan default rates and expected loss rates may go up.

ii. Quantitative analysis models

It can be seen from the existing research practice that the quantitative analysis models of physical risks can be divided into two major parts: catastrophe risk model and financial risk model.

1. Catastrophe risk model. Also known as "natural disaster loss model", this model is based on the traditional catastrophe risk model of the insurance industry and added the climate change exacerbation effects. It is mainly used to estimate the direct and indirect economic losses from disaster events in different climate scenarios (usually temperature rise ranges). The model consists of the following four modules:

(1) Historical catastrophe events. This module describes the likelihood and impact of a specific catastrophe event in a specific region according to the historical pattern (without considering the influence of climate change factors).

(2) Climate change exacerbation effects. This module describes how much climate change exacerbates a specific catastrophe event in different climate scenarios. For example, it determines how much a 1°C temperature rise will increase the frequency and intensity of a catastrophe event. The climate change exacerbation effects are overlaid onto the module of historical catastrophe events to generate future catastrophe scenarios under the influence of temperature rise.

(3) Asset exposure. This module describes the geographical location and value distribution of an asset to be studied, which spatially corresponds to the geographical distribution of a catastrophe event. The geographical location usually consists of latitude, longitude, altitude, etc., with specific components varying by disaster type. For example, when analyzing the impact of typhoons, longitudes and latitudes are enough to expound the scope and extent of the impact. However, when it comes to floods, altitude information is also required to assess the impact of disasters.

(4) Vulnerability. This module describes the correspondence between the intensity of a catastrophe and the impairment of asset value, e.g., the percentage of impaired value of a house due to the typhoon of a certain magnitude or wind speed. The relationship between a specific catastrophe and economic losses from it is usually derived from empirical studies and expert estimations combined. By inputting information items such as a future disaster scenario and location/value of an asset to be studied into the vulnerability module, we can figure out the impaired value of the asset if hit by a specific disaster in the scenario of a certain temperature rise.

2. Financial risk model. The financial risk model could be a loan default rate model, an enterprise value assessment model, or an insurance actuarial model, depending on different measurement purposes. The loss results output from the catastrophe risk model are converted into relevant indicators and input into the financial risk model to calculate the risk quantification results. In the case where the RCGFD analyzed the impact of typhoons on the default rate of home mortgage loans in coastal regions of China, the loan-to-value ratio (LTV) is calculated using the impaired housing value output from the catastrophe risk model, and then put into the home mortgage loan default rate model to calculate the probability of default (PD) and expected loss (EL), two prerequisites for obtaining to what extent typhoons exacerbate credit risk associated with home mortgage loans under the influence of temperature rise.

III. Recommendations for future work

Given the long-term existence and widespread impact of physical risks, financial institutions should pay more attention to and intensify the management of credit risk, collateral risk, and operational risk, and other risk types that may be caused by extreme disaster events, with an aim to do better in preventing and controlling physical risks.

i. Strengthen the building of data systems to consolidate the foundation for data measurement and analysis

The data required for quantitative analysis of physical risks can be divided into internal data and external data. Of internal data, data on asset value and geographic location are essential to identify the impact of disasters. Specifically, geographic locations are usually expressed as latitudes, longitudes, and altitudes, which can be obtained by converting address information. Data related to asset characteristics and quality, such as materials, structure, and service life, can reflect how vulnerable assets are to disasters. The availability of such data will improve the accuracy of measurement. External data mainly consist of meteorological data (like historical intensity, frequency of occurrence, and coordinate path of disasters) and loss data. They can be used to simulate the occurrence of disasters under historical patterns, construct models of climate risk exacerbation effects, and create quantitative relationship curves between specific disaster scenarios and losses. To carry out relevant calculations, we will firstly figure out the data types required in light of actual operation/management needs and characteristics of disaster events, and then obtain more adequate, accurate, and systematic data through internal business channels or by intensifying cooperation with meteorological departments, disaster management departments, universities & research institutions, and consulting agencies. The process will not only benefit the quantitative analysis of physical risks, but also enable related departments to manage their businesses and assets in a more meticulous manner.

ii. Hold themed seminars and exchanges to improve the level of professionalism and expertise

The quantitative analysis of the impact exerted by natural disasters involves a number of non-financial disciplines such as meteorology, oceanography, and environmental science. Furthermore, different types of disasters have distinctive influencing factors and complex transmission mechanisms. Therefore, it is very challenging for financial institutions to quantitatively analyze physical risks. To address this challenge, we propose a two-pronged approach. First, it is important to increase the ability to learn and the initiative in learning. Starting from the basic knowledge of underlying disciplines, we can hold special training programs, research sharing sessions, and other activities to raise related awareness, expand the knowledge reserve, and enhance the systematic understanding of environmental and climate risks. Second, it is advised to actively communicate with and learn from others. We will conduct seminars on environmental and climate issues with peers, research institutions, and consulting firms, seek help from external data, models, and experts, and pool together and internalize professional expertise and practical experience from all parties, with a view to continuously improving the level of physical risk measurement and control.

iii. Conduct case study practice to strengthen risk management capabilities

At present, the research of physical risks in China is still in the exploratory stage, where most financial institutions have not yet carried out relevant quantitative analysis. It is hence recommended to start with collateral risk management. Specifically, we will match the geographical locations of our collateral assets with the geographical distributions of common natural disasters in China, focus on analyzing the extent to which high-value collateral assets are affected by natural disasters in the scenario of temperature rise, and then figure out the potential increase in risks that we may face as a result. For example, it is floods that are analyzed to identify the impact on home mortgage loans in the Yangtze and Yellow River basins. When it comes to the coastal regions, the objects of analysis will become typhoons. Focal analysis in the form of case study could help us accumulate some practical experience. After that, we will engage in more detailed and in-depth calculations until a quantitative analysis framework is established to support more effective physical risk management and business development.