Chapter 3
The Application of the Macroeconomics Analysis of Climate Changes Model (MACC-Model) in China: Floods

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Abstract Global climate change has a potentially large impact on economic growth but measuring such economic impact is subject to a great deal of uncertainty. Hence, this chapter examines the possibility of measuring the economic impact of climate change through the macroeconomics analysis of climate change (MACC) model, a new model to evaluate the impact of climate change on GNP growth. To give light to the model, a test run is carried out on China to evaluate the impact of the country's natural disasters on its economy.

Introduction

The issue of climate change and its ravaging impact on the socio-economic, environmental and political wellbeing of people and societies across the world is obviously well acknowledged. In fact, given the importance to avert its deleterious effects to the world we live in today, the debate on climate change is a front burner in the agenda of many world leaders. Apparently, climate change is inextricably linked to economic activities that drive economic growth and development.

Hence, with the economic benefits, comes the unavoidable depredation of the ecosystem that in turn affects the different facets of human livelihood. This is testament to the unprecedented and hostile nature of the climate in many parts of the world particularly over the last decade that witnessed record number of lives lost, destruction of property and a significant strain on the economy, all resulting from environmental disorders most often linked to climate change.

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Literally, climate change can be considered a natural disorder occurrence (cause) that is generated by natural evolutionary elements often linked to the high and competitive demand and extraction of natural resources in the production and consumption of goods and services. This process poses a significant strain on the ecosystem, which reacts with imbalances and irregular climatic conditions (effect) in different ecospheres (Ruiz Estrada 2013). In the same vein, it is without doubt that climate change has a significant impact on economic growth in light of the fact that it imposes both direct and indirect costs on the economy of a country, and those costs change and evolves over time.

Moreover, climate change adversely affects economic activities in the short run through a number of channels. For example, the record occurrence of floods in many parts of China severely curtailed the country's agriculture sector output following the destruction of plantations, forestry, fisheries, livestock, water resources, transportation systems, telecommunication systems, private and social infrastructure, and housing.

Beyond the very short term, however, the negative economic impact of climate change tends to fade when there is massive spending towards human and infrastructural development. The deadly floods and earthquakes that brought about the huge human and material losses in Central South China (Henan, Hubei, Hunan, Guangdong, Guangxi, Hainan) and Southwest China (Chongqing, Sichuan, Guizhou, Yunnan, Tibet) and the recovery efforts that followed between 1992 and 2012 is a good reference point. The government's reconstruction spending spearheaded a robust recovery in private investment and consumption. As a result, macroeconomic indicators recovered slowly and stabilized after its initial plunge.

Apparently, developing countries in particular are more vulnerable to the effects of climate change given their huge quest for economic growth and development, which is often accompanied by huge pollution levels and almost uncontrolled depredation of natural resources. In fact, developing Asia accounted for 55 % of global fatalities and 30 % of all persons affected globally by climate change between 2000 and 2012 (Asian Development Bank 2012). According to Table 3.1 shows the fatalities and estimated damages from various types of climate change in China between 2000 and 2012. The estimated damages imply a sizable negative economic impact on the region.

Given the effects of climate change on economic growth in developing countries, it is important that policymakers have reasonable and accurate estimates of its effects on a country's Gross Domestic Product (GDP) (Kunreuther and Rose 2004). However, measuring such impact to get an acute understanding of the degree of its effects on a country's GDP is subject to a great deal of uncertainty (Loayza et al. 2009). In essence, this chapter aims to examine and shed light on the effect of climate change on the economy of a country. Moreover, the chapter sets out to showcase a novel contribution to the study and economics of climate change by introducing the macroeconomics analysis of climate change (MACC) model, an economic instrument to evaluate the impact of climate change on GNP growth.

Hence, as means to illustrate and illuminate the MACC model, the climate change occurrences in China is dissected using the model to assess and evaluate

Table 3.1 The climate change growth rates (αi) and National climate change vulnerability rate (ΩT)

No.	Country	α1	α2	α3	α4	α5	α6	α7	α8	α9	α10	α11	α12	α13	α14	α15	α16	ΩT
1	China	0.95	0.35	0.99	0.75	0.15	0.99	0.35	0.25	0.3	0	0.25	0.95	0.25	0.1	1	0.95	0.54

$\mathbf{\Omega_i}$ = The climate change growth rates
α1 = Mean temperature
α2 = Temperature extremes
α3 = Mean precipitation
α4 = Precipitation extremes
α5 = Snow and ice
α6 = Carbon cycle
α7 = Ocean acidification
α8 = Sea level
α9 = El Niño
α10 = Monsoons
α11 = Sea level pressure
α12 = Radiative forcing
α13 = Tropical cyclones
α14 = Hailstorms
α15 = Sandstorm
α16 = Hurricanes and typhoons
High level of risk: 1 = Mean temperature, 2 = Mean precipitation, 3 = Carbon cycle
Source: Intergovernmental Panel on Climate Change (IPCC)

the economic impact of climate change on the country to give us a sense of the degree to which the problem affects the country's economic wellbeing. The model is based on five basic indicators viz. (i) the climate change growth rate (α_i); (ii) the national climate change vulnerability rate (Ω_T); (iii) the climate change magnitude rate (Π); (iv) the economic desgrowth rate (δ); and (v) the CC-Surface. In addition, the model is based on elements from an alternative mathematical approach analysis framework from a multidimensional perspective.

Economic Modeling in the Analysis of Climate Change

The economic dimension to understanding and analyzing the effects of climate change on economic growth is obviously not new. In fact, this approach has taken an evolutionary development over the years with significant improvement to the tools and analytical approach to the economic study of climate change. Hence, in this section, we review the classical and modern economic contributions to the study of climate change from where we find a place for the MACC model.

Classic Economic Modeling in the Analysis of Climate Change

The study and origins of the economics of climate change could well be credited to Cline's (1992) publication entitled "The Economic of Global Warning" and Reilly and Thomas's (1993) "Toward Economic Analysis of Climate Change Impacts: A Review and Analysis of Studies of the Impact of Climate Change". In these two publications, we locate the very earliest yet fundamental analyses on the impact of climate change from both microeconomic and macroeconomic perspectives. Subsequently, Harris and Roach (2002) in their book further expanded the discourse and debate by providing comprehensive analyses on the causes and consequences of climate change from a broader economic angle. In fact, Harris and Roach (2002: 25–50) summarized their main economic arguments on climate change as follows.

> Concern has grown in recent years over the issue of global climate change. The problem, frequently called global warming, is more accurately referred to as global climate change. A basic warming effect will produce complex effects on climate patterns—with warming in some areas, cooling in others, and increased climate variability. In terms of economic analysis, greenhouse gas emissions, which cause planetary warming, represent both environmental externalities and overuse of a common property resource. If indeed the effects of climate change are likely to be severe, it is in everyone's interest to lower their emissions for the common good. But where no agreement or rules on emissions exist, no individual firm, city, or nation will choose to bear the economic brunt of being the first to reduce its emissions. In this situation, only a strong international agreement binding nations to act for the common good can prevent serious environmental consequences.

While we are very much in consonance with Harris and Roach's (2002) contributions particularly with regards to policies and implications that usher in some fundamental points about climate change, Cline (1992) and Reilly and Thomas's (1993) contributions, however, remain the cornerstone in the study of economics of climate change. This so given their comprehensive analysis of the short and long term recovery model that made reference to the climate stabilization process involving the community back to the past economic level. Climate stabilization is defined and seen by these three main authors as "this should be the goal, rather than economic optimization of costs and benefits. Stabilizing greenhouse gas emissions is not sufficient, since at the current rate of emissions carbon dioxide and other greenhouse gases will continue to accumulate in the atmosphere.

Hence, stabilizing the accumulations of greenhouse gases will require a significant cut below present emission levels". It is important to mention that the short and long term recovery model formulation is based on the use of the cost benefit by using the equilibrium general circulation model (GCM), which runs at 2xC02 and gives different levels of C° by Manabe and Kirk (1969) to estimate the annual damages to any economy from global climate change. Also worth mentioning and useful to our study are research on "CETA: A Model for Carbon Emissions Trajectory Assessment" by Peck and Teisberg (1992) and "The Economics of Controlling Stock Pollutants: An Efficient Strategy for Greenhouse Gases" by Ita and Mendelsohn (1993). Hence, analyses of the above papers by Reilly and Thomas (1993: 15–35) brought about the following submission deemed critical to the study of economics of climate change.

"These two models developed provide more applicability in representing damages as non-linearly related to a single climate change indicator and they study the implications of damages that are linear, quadratic, and cubic in the climate variable. Peck and Teisberg also evaluate the case where damages are related to the rate of change rather than the level of climate change. If damages are related to the rate of climate change, the economically optimal level of control is less. If climate stops changing at any level, no more damages occur. In contrast, if the level of change matters, then the flow of damages accruing during each period continues to accumulate even if climate change is halted. To stop the flow of damages, climate change must actually be reversed. Viewing damages as related to the rate of change is consistent with a view that damages are due largely to adjustment, where slow climate change may have negligible effects even if the rate persists over many years.

In considering these different possibilities, Peck and Teisberg do not provide evidence for any particular damage function relationship. Their work only illustrates the importance of further research to clarify how damages can best be represented". In our opinion, building a model of this magnitude back in 1992 is obviously a significant effort and one deserving huge commendation indeed particularly in light of the limitation of database confined to simple observations. Without doubts, all the authors mentioned have made remarkable contributions given their futuristic views about climate change and its impacts.

The Macroeconomics Analysis of Climate Change Model

The macroeconomics analysis of climate change (MACC) model assumes that any country is vulnerable to the effects of climate change anytime and anywhere. Additionally, each climate change occurrence has its own level of potential damage and impact on the final GNP of any country. Hence, our world is in a constant dynamic imbalanced state. This means, at anytime and anywhere, there is the possibility of a climate change occurrence, which could generate different magnitudes of climate change effects. Climate change in the context of this model refers to any occurrence beyond human control that can generate massive destruction anytime, anywhere, without any advance warning. The quantification and monitoring of climate change is inherently difficult, and we cannot evaluate and predict them with any degree of accuracy, but we can compute series of climate change within a fixed period of time (per year or decades). In addition, the MACC model is useful for demonstrating how the GNP growth rate is directly connected to the presence of climate change.

Intrinsic to the MACC model are five new key indicators viz. the climate change growth rates ($\boldsymbol{\alpha_i}$), the national climate change vulnerability rate ($\boldsymbol{\Omega_T}$), the climate change magnitude rate ($\boldsymbol{\Pi}$) the economic desgrowth rate ($\boldsymbol{\delta}$) and the CC-Surface. These five indicators aim to simultaneously show the different levels of vulnerability and devastation arising from different climate change occurrence. The five indicators are determined by the collection of historical data of different climate change occurrence that have impacted any country, where climate change is defined according to certain intervals of time and magnitude. Based on our model, the analysis of any climate change from an economic point of view must take into account the production reduction (national output) and human capital mobility (labor) simultaneously. With this, we introduce a new concept called "economic desgrowth (δ)" (Ruiz Estrada 2010).

The economic desgrowth rate (δ) is defined as a leakage of economic growth due to any climate change. The main objective of this concept is to determine the ultimate impact of any climate change on the final GNP growth rate behavior over a certain period of time. The basic data used by the MACC model is based on the use of sixteen different possible climate change events. These include mean temperature; temperature extremes; mean precipitation; precipitation extremes; snow and ice; carbon cycle; ocean acidification; sea level; El Niño; monsoons; sea level pressure; radiative forcing; tropical cyclones; hailstorms; sandstorm; hurricanes and typhoons.

The National Climate Change Vulnerability Rate (Ω_T)

Based on the MACC model, we assume an irregular oscillation into different climate change events all the time. We do so by applying the climate change growth rates (αi), which is equal to the total sum of the same type of climate change event in the present year ($\Sigma\lambda_o$) minus the total sum of the same type of climate change event in the past 10 years ($\Sigma\lambda_{n\text{-}1}$) divided by the total sum of the same type of climate change event in the past 10 years ($\Sigma\lambda_{n\text{-}1}$) (see Expression 3.1).

$$\alpha_i = \Sigma\lambda_o\text{-}\Sigma\lambda_{n\text{-}1}/\Sigma\lambda_{n\text{-}1} \tag{3.1}$$

It means that our world is going to be in a permanent dynamic imbalanced state under high risk of having a climate change event at anytime. The MACC model allows for different magnitudes of climate change. Therefore, we have different climate change events growth rates (α_i) as described in Expression 3.2. Also, we assume that the national climate change vulnerability rate (Ω_T) is directly connected to time (T_j). At the same time, T_j is affected directly by different climate change growth rates (α_i). In our case, "j" is a specific period of time and "i" represents the type of climate change, which according to our classification and usage comprise of 16 different types. Hence, the national climate change vulnerability rate (Ω_T) includes a total of 16 possible climate change events that are as follows: mean temperature (α_1); temperature extremes (α_2); mean precipitation (α_3); precipitation extremes (α_4); snow and ice (α_5); carbon cycle (α_6); ocean acidification (α_7); sea level (α_8); El Niño (α_9); monsoons (α_{10}); sea level pressure (α_{11}); radiative forcing (α_{12}); tropical cyclones (α_{13}); hailstorms (α_{14}); sandstorm (α_{15}); hurricanes and typhoons (α_{16}) respectively. Each global climate change has its magnitude of intensity according to the geographical position and environmental problems.

We assume that if any climate change occurrence was observed to have had a wide interval before a subsequent occurrence, then it is not possible to be predicted with accuracy as in Expression 3.4. Hence, we can calculate the national climate change vulnerability rate (Ω_T), which is equal to the total sum of all α_i divided by the total of climate change in analysis (i_{total}) (see Expression 3.3). In our case, we are making use of sixteen different climate change variables.

$$\Omega_T = (\Sigma\alpha_i)/i_{total} \text{€} \; [0 < \Sigma\alpha_i < 1] i_{total} = 16 \tag{3.2}$$

$$\Omega_T e = \mathrm{Ln}\left[(\alpha_i)_{Tj} - (\alpha_i)_{Tj\text{-}1}\right]/(\alpha_i)_{Tj}] \quad \forall\Omega_T e \neq 0 \tag{3.3}$$

$$\Omega_T p = \mathrm{Ln}\left[(\alpha i_{max})_{Tj}\right] - \left[(\alpha i_{min})_{Tj})\right] \; 0 > \alpha i_{max} \leq 1 \text{ or } 0 \geq \alpha i_{min} < 1 \tag{3.4}$$

$$\Omega_T e \ddagger \Omega_T p \tag{3.5}$$

Expressions 3.3 and 3.4 show the effective national climate change vulnerability rate ($\Omega_T e$) and the potential national climate change vulnerability rate ($\Omega_T p$). The effective national climate change vulnerability rate ($\Omega_T p$) is based on compare the past and present climate change events growth rates. We assume that the present national climate change vulnerability rate Ω_T cannot be equal to zero (see Expression 3.3). However, the potential national climate change vulnerability rate ($\Omega_T p$) is based on the uses of a maximal and minimal climate change events growth rate into a determinate period of time (T_j) (see Expression 3.4).

Additionally, we need to assume that in the potential national climate change vulnerability rate ($\Omega_T p$) exist a random database which makes it possible for the MACC model to analyze unexpected results from different climate change events which cannot be predicted and monitored with the traditional methods of linear and non-liner mathematical modeling. Hence, the effective climate change events growth rate is identified in Expression 3.3.

Finally, our identity about the potential climate change event growth rate cannot be equal to the effective climate change events growth rate in the short run or long run (see Expression 3.5). This is because we assume at the very outset that our world is in a dynamic imbalanced state.

Thus Ω_T calculation in Table 3.2 is possible for observation by different countries by using different α_i and a single Ω_T. The analysis of the national climate change vulnerability rate (Ω_T) is applied to three different levels of vulnerability (see Expression 3.6)

$$\begin{aligned} &\text{Level 1: High vulnerability (red color alert)}: 1 - 0.75 \\ &\text{Level 2: Average vulnerability (yellow color alert)}: 0.74 - 0.34 \\ &\text{Level 3: Low vulnerability (red color green)}: 0.33 - 0 \end{aligned} \tag{3.6}$$

However, in Fig. 3.1, it is possible to observe diminishing returns between the economic desgrowth rate (δ) and the national climate change vulnerability rate (Ω_T). We can have three possible scenarios of analysis in this relationship between the economic desgrowth rate (δ) and the national climate change vulnerability rate (Ω_T).

First scenario, if the national climate change vulnerability rate (Ω_T) is very high then the economic desgrowth rate (δ) will be high. Second scenario, if the national climate change vulnerability rate (Ω_T) is very low then the economic desgrowth rate (δ) will be low (see Figure 3.1). Finally, we assume that the national climate change

Table 3.2 Climate change magnitude rate of China floods in the year 1931 and 2010

Climate change magnitude rate of China floods in the year 1931 (Π_{1931})			(Π)
Φk 20b	80b	0.25	
ΨL 4 M	60 M	0.067	**–5**
Climate change magnitude rate of China floods in the year 2010 (Π_{2010})			
Φk 51b	375b	0.14	
ΨL 5000	30 M	0.000067	**–11**

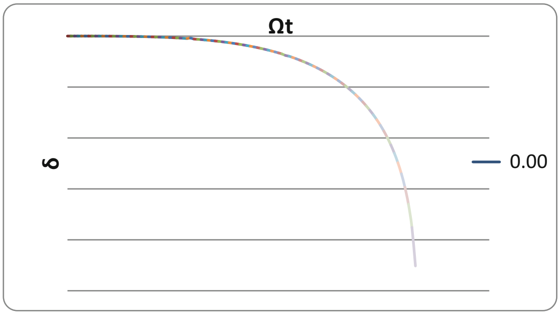

Fig. 3.1 The relationship between the national climate change vulnerability rate (Ωt) and the economic desgrowth (δ). *Source*: See Table 3.2

vulnerability rate (Ω_T) can never intercept the economic desgrowth rate (δ), because we use "The Dynamic Imbalanced State (DIS)". The DIS never keeps static but constantly keeps changing. Hence, we suggest the application of the Omnia Mobilis assumption to keep the DIS in the long run. It changes according to change in the national climate change vulnerability rate ($\boldsymbol{\Omega_T}$).

The Climate Change Magnitude Rate (Π)

Basically, we use two main variables to calculate the climate change magnitude rate (Π). The first main variable, which is capital devastation (Φk) is computed by dividing the area of infrastructure destroyed by the climate change (km^2) by total infrastructure area (km^2) in the same geographical space. The second main variable is human capital devastation (ΨL). We compute human capital devastation (ΨL) by dividing the number of people killed by or missing due to climate change by the total population in the same geographical space.

After calculating both main variables, we can then multiply the results to get our natural disaster magnitude rate (Π). In short, the climate change magnitude rate (Π) is equal to the product of the capital devastation (Φk) and the human capital devastation (ΨL). Finally, we generate the natural logarithm to calculate the final climate change magnitude rate (Π) that is expressed in the Expression 3.7.

$$\Pi = f(\Phi \mathrm{k}, \Psi \mathrm{L}) = \mathrm{Ln}\,[(\Phi \mathrm{k}) \times (\Psi \mathrm{L})] \tag{3.7}$$

We decide to apply the product rule of differentiation in Expression 3.7 to obtain the first derivative test to find the relative maximum and minimum in the capital devastation (Φk) and capital devastation (Φk) (see Expressions 3.8, 3.9, and 3.10).

$$\partial f / \partial (\Phi \mathrm{k}) = \Phi^{'}(\mathrm{k}) \Psi \mathrm{L} / \Phi(\mathrm{k}) \Psi \mathrm{L} \tag{3.8}$$

$$\partial f / \partial (\Psi \mathrm{L}) = \Psi^{'}(\mathrm{L}) \Phi(\mathrm{k}) / \Psi(\mathrm{L}) \Phi(\mathrm{k}) \tag{3.9}$$

$$\partial\Pi = \Phi^{'}(k)\ \Psi(L) + \Phi(k)\ \Psi^{'}(L) \tag{3.10}$$

Moreover, we can also observe that the climate change magnitude rate (Π) is directly proportional to the national climate change vulnerability rate (Ω_T).

The Economic Desgrowth (δ)

We define economic desgrowth (δ) as a macroeconomic indicator that shows the final impact of any climate change on the GNP (Ruiz Estrada 2010). We could say that the final GNP post-climate change effect is a function of the climate change magnitude rate (Π) (see Expression 3.11). At the same time, the climate change magnitude rate (Π) is directly dependent on the national climate change vulnerability rate (Ω_T) (see Expression 3.11) according to Figs. 3.1 and 3.2. In Expression 3.12, we calculate the preliminary GNP post-climate change effect ($Q^{'}$). Hence, the $Q^{'}$ is in function of Π.

$$\Pi = f(\Omega_T) \tag{3.11}$$

$$Q^{'} = f(\Pi) \tag{3.12}$$

The Climate Change Surface (CC Surface)

The construction of the CC-Surface is based on the climate change growth rates (Ωi) results and the mega-surface coordinate space (see Expression 3.13 and Fig. 3.2). The climate change vulnerability surface is a four by four matrix that contains the individual results of all 16 variables (taken from Table 3.1). However, the 16 variables are plotted in a four by four array with the vertical value on the CC-Surface.

The idea is to produce a surface for a quick pictorial representation of the overall propensities for any one country. The underlying idea here is to use the results of 16 variables in the climate change growth rates (Ωi) to build a symmetric surface.

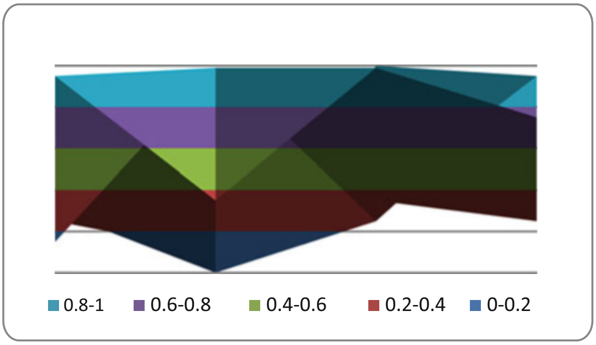

Fig. 3.2 CC-Surface. *Source*: Intergovernmental Panel on Climate Change–IPCC- data and MECC Model results

When the MD-coordinate system (η) has strictly the same number of rows as the number of columns, then the climate change growth rates (αi) can always be perfectly symmetric.

$$\eta = \begin{pmatrix} \alpha_1 & \alpha_5 & \alpha_9 & \alpha_{13} \\ \alpha_2 & \alpha_6 & \alpha_{10} & \alpha_{14} \\ \alpha_3 & \alpha_7 & \alpha_{11} & \alpha_{15} \\ \alpha_4 & \alpha_8 & \alpha_{12} & \alpha_{16} \end{pmatrix} \tag{3.13}$$

The final analysis of the CC-surface depends on any change that this surface can experience in a fixed period of time.

The Macroeconomics Analysis of Climate Change Model: The Case of China

Applying the MACC-Model to China's economy will give us a much better idea of how the model works. Before we do so, it is useful to have a closer look at the general local economic data about China. Such data includes the contribution of each of the country's region to the final GNP of the country as well as its geographical distribution of agricultural production. In terms of the geographical distribution of contribution to the country's GNP, we find that North China contributes around 12 % and East China with the highest share of 34 %, while Northeast China has the least contribution of 15 %. Therefore, the major contributors to the country's GNP are the Central South China and Southwest China regions that collectively account for 39 % of the country's overall output. While the Northeast region contributes 15 %, Central South China and East China account for about 57 % of the country's overall output. Similar trend could be observed with the country's agriculture output by regions where North China accounts for 12 % and Northeast China 10 %, East China 13 %, Central South China 30 %, and Southwest China 35 % respectively (see Fig. 3.3).

The Climate Change Growth Rates (α_i)

In this section, we first examine the natural disaster vulnerability propensity rate for me some countries around the world and then we take a closer look at China's natural disaster vulnerability propensity rate.

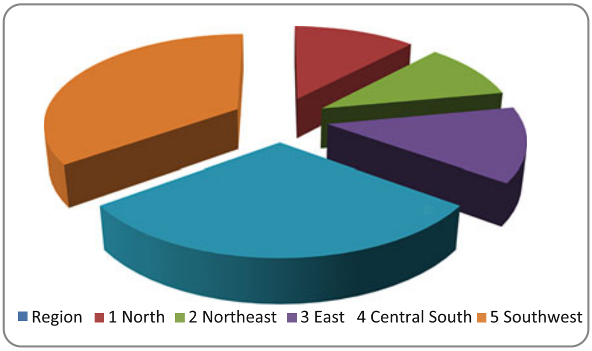

Fig. 3.3 The agriculture production concentration of China. *Source*: FAO and Ministry of Land and Natural Resources of China

China's Climate Change Vulnerability Rate (Ω_T): Max and Min

In the case of China, we find large differences between maximum and minimum climate change vulnerability rate (Ω_T). According to historical data of climate change, North has the lowest vulnerability, with a Ω_{Tmin} of only 0.15 and Ω_{Tmax} of 0.25. In the rest of China, the climate change vulnerability propensity rates are higher. More specifically, vulnerability rate ranges from 0.45 to 0.95 in East, from 0.35 to 0.95 in Southwest region, and from 0.25 to 0.85 in Northeast and Central regions (see Fig. 3.4).

The Climate Change Magnitude Rate (Π)

Here we would compare the climate change magnitude rate (Π) of floods in China between 1931 and 2010. Hence, the paper estimates and compares the magnitude of the impact of that climate change variable on China. According to our results, the devastation resulting from the China floods in the year 2010 was quite limited at −11. However, according to our computations below, the devastation caused by floods in 1931 were much larger at −5. Similarly, from a clear graphical perspective, we could observe in Table 3.2 and Fig. 3.5 that the China floods in 1931 caused much devastation several times larger than the floods in 2010.

The Economic Desgrowth (δ)

Finally, to measure the impact of the floods and temperature change on economic growth, we use the new concept of "economic desgrowth (δ)" introduced by Ruiz Estrada (2010). According to this concept, we try to discover possible leakages that can adversely affect GNP performance. Basically, this new concept assumes that in

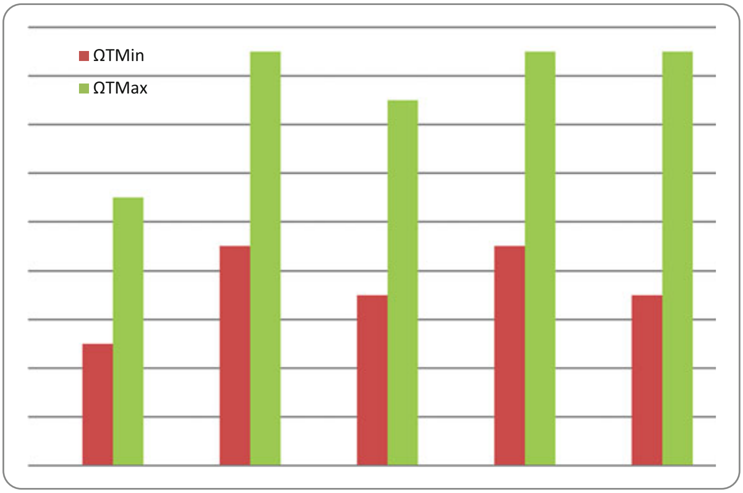

Fig. 3.4 The climate change vulnerability rate by region (China) (Ω_T). *Source*: MACC Model

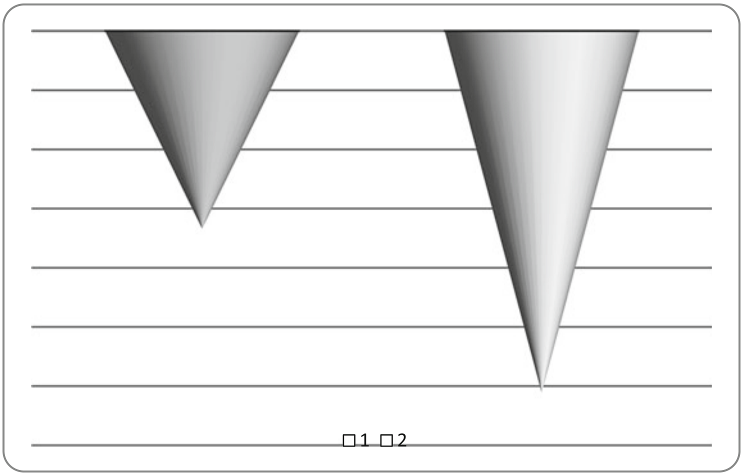

Fig. 3.5 Climate change magnitude rate (Π) between China floods 1931 and 2010. *Source*: See Table 3.2. Note: Final results from MACC Model

the process of the GNP formation, leakages may arise due to different factors, in our case, climate change. According to our estimates, the economic desgrowth caused by the Central South China floods in year 1931 has an impact of −1.51 on China's economic desgrowth (δ). Our estimates indicate that the economic desgrowth caused by the Central South China floods of 2010 has been much larger, at −2.8 in 2010 (see Table 3.3).

Table 3.3 GNP growth rates from China (1931 and 2010)

1	1931	3 % $\boxed{1.49\%}$	$\delta = -1.51$	$\Omega_T = 0.95$	$\Pi = -5$
2	2010	13.1 $\boxed{10.3\%}$	$\delta = -2.80$	$\Omega_T = 0.99$	$\Pi = -11$
	Variables:				
δ = GNP desgrowth rate					
ΩT = The national climate change vulnerability rate					
Π = The climate change magnitude rate					

Source: International Monetary Fund (IMF) and National Bureau of Statistics of China

Conclusions and Policy Implications

Climate change obviously has a significant negative impact on economic performance but measuring such impact with any degree of certainty is a herculean task. In this chapter, we propose a new model for evaluating the impact of climate change on economic performance. The macroeconomics analysis of climate change (MACC) model, which is based on five key five indicators viz. (i) the climate change growth rates (α_i); (ii) the national climate changes vulnerability rate (Ω_T); (iii) the natural disaster magnitude rate (Π); (iv) the economic desgrowth rate (δ); (v) and the CC-Surface.

The underlying intuition is that the economic impact of climate change depends on a country's vulnerability to temperature change and the floods devastation caused by climate change, which jointly determines the leakage from economic growth and hence, the impact on growth. We are of the belief that our model will contribute to a better and deeper understanding of measuring the economic impact of climate change.

A more useful measurement of the impact from climate change is conducive for appropriate policies, both for dealing with the effects of climate change and also for anticipatory policy measures, which seek to lessen the impact of climate change before they occur. For example, on the one hand, underestimating the impact may lead to the government allocating too few resources for addressing the impact of climate change—e.g. public investment in physical infrastructure and income support for households most affected by the climate change.

On the other hand, overestimating the impact may cause the allocation of too many resources, raising the risk of inefficiency and waste. By the same token, determining the appropriate level of anticipatory investments to limit the impact of future climate change would benefit from an accurate ex-ante assessment of their impact. The MACC Model can also help in determining the appropriate mix of climate change management and policies. For

(continued)

example, the model may allow policymakers to better estimate and compare the impact of different types of climate change occurrences.

The application of our model to two climate change occurrences in China – the floods of 1931 in Central South China and the Zhangshu and Jiangxi floods in year 2010 indicate that the Zhangshu and Jiangxi floods in 2010 will have a bigger impact than the Central South China floods of 1931. Nevertheless, the immediate implication for Chinese policymakers is that they need to support growth with stronger measures than as implemented in 2010.

In particular, they need to provide more fiscal resources for reconstruction efforts to re-build the region's devastated physical infrastructure, which in turn, will lay the foundation for the recovery of the region's productive activities, particularly manufacturing. In addition to rebuilding the infrastructure, the government should provide income support for the residents whose homes and livelihoods have been destroyed by natural disasters emanating from climate change. While China's high public debt level constrains the government's fiscal space, concerted fiscal support is nevertheless vital for China's floods recovery. At a broader level, our results confirm that climate change can have a significant economic impact even in advanced countries with good infrastructure and high level of preparedness.

Anticipatory measures can reduce the extent of climate change damage, loss of life and disruption to economic activity. Such measures include: (1) Good design and adherence to rigorous building codes; earthquake and storm proofing of buildings; floodplain and drainage designs; hillside stabilization, and other measures related to the natural and manmade environments, (2) Early warning system for floods, storms, epidemics, typhoons, tsunamis, and others. (3) Emergency response plans: evacuation systems; emergency response drills; equipment readiness; supplies storage - e.g. medicine and water. Given the high opportunity costs of using fiscal resources to mitigate the effects of climate change in developing countries, the MACC model's more accurate measurement of the economic impact of climate change is all the more valuable.

The failure of authorities to quickly and reliably inform the public led to widespread concerns and fear, which further dented consumer and business confidence. Therefore, more and better information is likely to reduce the impact of climate change, and looking at the role of information would contribute to a more accurate measurement of its impact.

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