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Disaster-mitigating and general innovative responses to climate disasters: Evidence from modern and historical China

Hui Hu[a,*], Ting Lei[b,*], Jie Hu[c], Songlai Zhang[d], Philip Kavan[e]

[a] Economic Development Research Center, Wuhan University, Hubei 430072, China
[b] School of Economics, Fudan University, Shanghai 200433, China
[c] School of Economics and Management, Tsinghua University, Beijing 100084, China
[d] Department of Finance, London School of Economics and Political Science, WC2A 2AE London, UK
[e] Faculty of Education, Science, Technology & Maths, University of Canberra, ACT 2601, Australia

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ABSTRACT

In studies on the effects of climate disasters, positive aspects are often overlooked. However it is important to accurately estimate the long-run impact of these disasters. This study presents the first attempt to investigate the innovative response to climate disasters in modern and historical China. For modern China, using panel data of up to 31 provinces from 2005 to 2013 and the Generalized Methods of Moments (GMM) technique, this study suggests that past climate disasters have led to an increase in the number of disaster-mitigating patents. These patents also boost innovations in other fields, which indicate that there exists a spillover effect in technological progress. The paper further investigates five major province groups in modern China and finds that disaster-mitigating patents not only respond to local disasters but serve as feedback to disasters occurring in neighboring provinces as well. Additionally, this study creatively uses the time-series data from 11 A.D. to 1910 A.D. to analyze the historical case with the Ordinary Least Square (OLS) method. The results show that climate disasters only spurred innovations in disaster mitigation fields and not in others, meaning that innovation spillovers did not exist in historical China. This study provides practical implications for policymakers and governments. They should introduce incentives to encourage and increase investment in research and technological development sectors after climate disasters.

1. Introduction

There is a growing consensus that climate change could worsen some natural disasters [1]. Over the past few decades, global warming had raised the frequency of extreme climatic events. As a result the world has been suffering from more climate disasters than geological disasters [2]. Climate disasters constitute 75–80% of all natural disasters [3]. They principally include floods, droughts, hail, frost and cyclones. Economic losses resulting from climate disasters are tremendous and, with a rise in the frequency of climate disasters, continue to increase [4]. The United Nations claim that in 2014, climate disasters resulted in economic losses totaling over 40 billion US dollars around the world.

Furthermore, climate disasters can lead to either negative or positive impacts on the economy and society. On the negative side, they can cause extensive damage, both in history and modern society. For instance, Vu and Hammes [5] claims that a disaster with a 1% increase in the percentage of population killed is associated with a fall in output of about 47 billion RMB in China. From the perspective of history, Wang et al. [6] and Zhang [7] confirm that floods in ancient China often damaged the agriculture in the Huaihe River district. Chen [8,9] argues that climate shocks played an important role in nomadic conquest and peasant uprisings, indirectly impeding economic development. Overall, climate disasters negatively influence the economy and cause people to alter their risk perceptions [10].

Recently, however, increased attention has been paid to the positive impact of climate disasters. It is possible for people to adapt climate changes, by mitigating disasters' harm, creating business opportunities and adjusting social ecological systems in response to incurred climate impacts [11]. As a matter of fact, Skidmore and Toya [10] argue that climate disasters are positively correlated with human capital accumulation and GDP growth. Cuaresma et al. [12] claim that disasters seem as "creative destruction" to some extent, because they could increase productivity and capital investment. These conclusions are

* Corresponding authors.
E-mail addresses: hui.hu@whu.edu.cn (H. Hu), leit16@fudan.edu.cn (T. Lei), huj.16@sem.tsinghua.edu.cn (J. Hu), s.zhang47@lse.ac.uk (S. Zhang), philip.kavan@canberra.edu.au (P. Kavan).

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confirmed in several recent studies. Kousky [13] finds that areas more prone to disasters invest more in reducing hazards, which serves as a future climate change adaptation. Birkmann et al. [14] indicate that climate disasters can generate large resource inflows for financing and supporting reconstruction as well as rehabilitation of disaster areas. Cunado and Ferreira [15] argue that moderate floods often result in a positive impact on per capita GDP growth in over one hundred developing countries.

According to Callaghan [16], disasters decreasing the amount of the factors of production would spur innovations that reduce the use of them. In other words, technological innovation is also of great importance in mitigating climate disasters. If the innovative response works out well and timely, economic losses will decrease and disaster resilience will increase [17]. On the one hand, innovations equip people with useful tools to cope with climate hazards. Shaw et al. [18] find that hazard reduction in Asia has benefitted from the invention of early warning systems which forecast climate disasters. Moreover, technical innovations in construction enhance the resilience of buildings and infrastructures to various climate disasters. Using panel data of up to 28 countries in Europe over a period of 26 years, Miao and Popp [19] further find that the increase of disaster-mitigating innovations corresponds to the severity of natural disasters in the last five years. On the other hand, innovations resulting from climate disasters are beneficial for post-disaster economic development. As an example, drought-resistant crops are being developed to adapt to possible droughts and the effects of global warming, which would contribute greatly to farming all over the world [20]. Consequently, many patents based on new agricultural technologies are being registered, such as new freeze-resistant crops, as well as new fertilizers. Neumayer et al. [21] also suggest that private investments in disaster prevention and public damage mitigation policies spur innovations. Thus, climate disasters seem to be powerful inducements for technological progress.

Another important conclusion of Cunado and Ferreira [15] is that some disasters such as floods have a direct positive effect on agricultural growth rates, as well as an indirect effect on growth rates in other sectors. Why does this indirect effect exist? Our paper finds two main reasons. First, although climate disasters directly spur disaster-mitigating innovations, technology transfer among different fields are becoming more frequent [22,23]. Second, human abnormal behaviors like suicidal tendencies usually arise in the aftermath of natural disasters [24]. To satisfy security needs, people tend to make efforts in innovations that fight against mental issues and save lives [25]. In this case, it is of importance to identify the spillover effect of disaster-mitigating innovations on other patent applications.

China has a long history of recording climate disasters, like floods and droughts, which date back to 200 B.C. Successive dynasties and regimes gave their full attention to preventing disasters [26]. Nowadays, the economic losses due to climate disasters increase by approximately 30% per year on average in China [27]. Although China provides a good case study of the issue, no research empirically studies the relationship between climate disasters and innovations in China with both a modern and historical view.

This research presents the first attempt to reveal the causal link between climate disasters and innovations, both in modern and historical China, based on current knowledge. The study also creatively demonstrates the spillover effect of disaster-mitigating innovations and the impact of climate disasters on local innovations in neighboring provinces. The objective of the study is to provide policymakers and governments with practical implications for technological innovation.

The study selects the Generalized Methods of Moments (GMM) technique, based on Roodman [28], to estimate the panel of modern China. This study investigates modern China with data from 31 provinces from 2005 to 2013 and identifies the causal link between disaster-mitigating innovations and climate disasters. Moreover, disaster-mitigating patents could spur patent applications in all fields. Empirical analysis results show that 1 year lagged climate disasters significantly spur disaster-mitigating patents. A positive correlation can be found between disaster-mitigating patents and the total number of patent applications. It also demonstrates the impact of climate disasters on local disaster-mitigating innovations in neighboring provinces.

This study further models to investigate innovative responses to climate disasters in historical China. According to Chen's [8,9] work, he uses time series data from 11 A.D. to 1910 A.D. and defines each decade as an observation. This study gets 190 observations as time-series data and uses the Ordinary Least Square (OLS) to investigate innovative responses to climate disasters in historical China [8,9]. It finds that climate disasters which occurred in a given decade have had a positive impact on disaster-mitigating innovations in the next decade in historical China. The above findings confirm that the study provides valuable insight onto the economics of climate disasters. The present study contributes to researches by estimating the cost of climate disasters. Innovations are outcomes of the disasters, and should be particularly emphasized when estimating the long-run impact of disasters.

The rest of the paper is organized as follows: Section 2 reviews the literature; Section 3 presents the empirical model; Section 4 introduces the data and provides statistical analysis; Section 5 investigates and discusses empirical analysis results, and the final section concludes.

2. Empirical model

To discover how climate disasters boost innovation in modern China, this study first emphasizes risk perception. Risk is the key factor that spurs innovation, as people are generally reluctant in taking risks. In other words, someone's risk perception ($R_{i,t}$) greatly affects their self-protection decisions [29]. According to Cameron and Shah [30], individuals who had recently suffered from a natural disaster display a high level of risk aversion. Moreover, Miao and Popp [19] suggest that a region's capability to deal with disasters ($C_{i,t}$) as well as its baseline hazard ($B_{i,t}$) influences people's risk perception. Baseline hazard is measured by the frequency of geological disasters. For example, globally, 81 percent of all earthquakes occur in countries located along the "Ring of Fire" in the Pacific Ocean. Therefore, people living in this area perceive a stronger risk of earthquakes. In China, the province of Sichuan suffers more debris flow compared to the Hubei province, and as the result, suffers a higher baseline hazard. The paper models the perceived risk ($R_{i,t}$) as follows:

$$R_{i,t} = f_R\left(\sum_{n=1}^{N} D_{i,t-n},\ B_{i,t},\ C_{i,t}\right) \tag{1}$$

where $D_{i,t-n}$, a pre-determined variable free of endogeneity, denotes the lag of climate disaster damage.

Many researches focus on how the characteristics of an area can reduce disaster damages. Toya and Skidmore [31] and Kousky [13] show that the region with higher incomes ($Y_{i,t}$), higher education levels ($E_{i,t}$), greater openness ($O_{i,t}$), and stronger financial institutions ($I_{i,t}$) suffer fewer losses. In addition to this, the government spending ratio ($G_{i,t}$) correlates to how the region can withstand the disaster shocks [32]. Hence, the model $C_{i,t}$ is detailed as follows:

$$C_{i,t} = \quad f_c(Y_{i,t},\ I_{i,t},\ E_{i,t},\ O_{i,t},\ G_{i,t},\ K_{i,t-1}) \tag{2}$$

where $I_{i,t}$ refers to the financial system and institutions, and $K_{i,t-1}$ denotes existing knowledge stocks in year t. Miao and Popp's [19] study show that regions usually pay significant attention to prior exposure to disasters and can attain technological progress from it.

Disaster-mitigating Innovations ($INN_{i,t}$) in China, in response to climate disasters, principally depend on the perceived risk, income, government action, institutions, knowledge stocks, and human capital [33]. Using the variables mentioned above, we have the following function:

$$INN_{i,t} = f_I(R_{i,t},\ Y_{i,t},\ G_{i,t},\ I_{i,t},\ K_{i,t-1},\ E_{i,t}) \tag{3}$$