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Necessity as the mother of invention: Innovative responses to natural disasters

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ABSTRACT

How do innovators respond to the shock of a natural disaster? Do natural disasters spur technical innovations that can reduce the risk of future hazards? This paper examines the impact of three types of natural disasters—floods, droughts and earthquakes—on the innovation of their respective mitigation technologies. Using patent and disaster data, our study is the first to empirically examine adaptation responses across multiple sectors at the country level. Considering the potential endogeneity of disaster damages, we use meteorological and geophysical data to create hazard intensity measures as instrumental variables. Overall, we show that natural disasters lead to more risk-mitigating innovations, while the degree of influence varies across different types of disasters and technologies.

Introduction

How people cope with natural disasters is of interest to both policy makers and researchers. This issue presently is gaining renewed attention because of the increasingly evident threats of climate change. As climate scientists warn that global warming will likely increase the frequency and intensity of extreme weather events (e.g., floods, droughts, tropical cyclones and heat waves), incorporating strategies for reducing the risk of natural disasters is an important part of climate change adaptation (International Panel on Climate Change, 2012).[2]

In this paper, we ask whether natural disasters lead to innovations of risk-mitigating technologies. Such technologies are analogous to those that may aid adaptation to climate change and associated natural disasters. Specifically, we coin the term "risk-mitigating innovation," referring to the *development of new and more effective technologies that assist people in better*

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[1] Fax: +1 315 443 1075.
[2] A term initially used to explain biological evolution, adaptation is now applied more often to human society and regarded as an important strategy to address climate change (for a review on the concept, see Smit and Wandel, 2006). The IPCC defines adaptation as "*adjustment in natural or human system in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities*" (IPCC, 2001: 72).

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coping with natural disasters and building resilience to future shocks. Such innovation may include both the development of new products and the improvement and commercialization of existing technologies to make them more appealing for consumers to adopt. Technological innovation is an important form of adaptation because it provides the necessary tools for people to utilize in adapting to a changing environment. Although adaptation in some cases can be just behavioral changes (e.g., relocation), people more often have to employ certain technologies, which take either a hard form (e.g., equipment and infrastructure such as building levees) or a soft form (e.g., science, technical know-how and skills such as emergency management) (UNFCC, 2006). Technological innovation enhances their capacity to cope with natural hazards and provides a long-term adaptation strategy.

As an example of how technology can affect adaptation, consider how the advent of air conditioning changed the development of regions in warmer climates. Moving forward, other innovations, such as developing new breeds of crops more resistant to drought, have the potential to adapt agriculture to possible future changes in climate. Smithers and Blay-Palmer (2001) discuss the role of technology research and development in agricultural adaptation, recognizing climate as an inducement for innovation. Increased attention recently has been paid to the implication of science and technology development in the policy world of climate adaptation, both domestically and internationally (e.g., UNISDR, 2009; UNFCC, 2006). In an editorial comment, Smith et al. (2009) suggest technology development and diffusion should be incorporated as a necessary component of the national adaptation architecture, given its role in "*expand(ing) the range of adaptation possibilities by expanding opportunities or reducing costs.*"

In this research, we take a worldwide view in investigating how innovation, as an economic and scientific endeavor, responds to the shock of natural disasters. By using risk-mitigating innovations as an outcome of adaptation, our study presents the first attempt to examine systematically adaptation responses across multiple sectors at the country level. In particular, we focus on three types of natural disasters—floods, droughts and earthquakes—and match each of them with one mitigation technology including flood control, drought-resistant crops and quake-proof buildings.[3] Our empirical analysis, using a panel of up to 28 countries over a period of 25 years, shows all three types of natural disasters have a significant and positive impact on the patent counts of their corresponding technologies. This result implies that the private sector is adapting by innovating, but in a more reactive than proactive manner.[4] It thus suggests government has a particularly important role to play in developing technologies necessary for mitigating risks so they are in place before a disaster occurs. In addition, we also explore whether domestic innovation is spurred by foreign disasters, and find such evidence in the case of floods.

Another contribution of this paper is to explore the motivation and ability for adaptation responses, which is an under-researched issue in the adaptation literature. Notably, a majority of the current adaptation studies focuses on estimating costs or cost-effectiveness of adaptation measures, and many climate models simply treat adaptation as autonomous. For instance, recent examples of climate policy models incorporating adaptation are the AD-DICE model (de Bruin et al., 2009), the WITCH model (Bosello et al., 2009), which assesses the optimal mix of mitigation and adaptation measures, and the FUND model, which has been used to analyze the tradeoff between mitigation and adaptation for protecting coastlines (Tol, 2007). None of these models consider the possibility that the tendency and ability to adapt are endogenous. Our empirical evidence of reactive risk-mitigating innovations can inform the current endeavors in integrated assessment modeling of climate change, and more specifically, suggests the possibility of treating adaptation as a function of previous disaster losses.

Finally, our study also contributes to the empirical literature on the economics of natural disasters by addressing the potential endogeneity of disaster damage. While the severity of disaster damages are a driver of risk-mitigating innovations, we argue that observed human and monetary losses experienced by a country from natural disasters are endogenous. We thus take an instrumental variable approach and use objective meteorological and geophysical data to exploit the exogenous variation in physical disaster intensity. Our measures of hazard magnitude are highly predictive of disaster damages experienced by our sample countries. This approach not only sheds light on research of the economic impacts of natural disasters, but also inform modeling of disaster losses, particularly with respect to controlling for exogenous natural hazards.

Relevant literature

This paper is part of a growing literature on the economics of natural disasters (for a survey of the literature, see Cavallo and Noy, 2010; Kellenberg and Mobarak, 2011). This literature consists of two bodies of research that are highly related but differ regarding the treatment of disaster variables: one concerning the economic effects of natural disasters, and the other assessing the determinants of natural disaster impacts. While this study falls into the former category by considering how natural disasters affect innovation, we also draw on the latter research to address the endogeneity of disaster damages. We

[3] It should be noted that earthquake is normally classified as a geological hazard and regarded with a weak link to climate change. However, given that catastrophic climate impacts have not yet been observed, we consider not only disasters directly relevant for climate change such as drought and floods, but also include responses to other natural disasters like earthquakes. Moreover, as researchers expect the probabilities of earthquakes to rise in certain regions (such as California) because of the crust movement, we believe earthquake fits neatly into the context of adaptation.

[4] The adaptation literature distinguishes between reactive adaptation and proactive adaptation (Fankhauser et al., 1999). The former occurs when people anticipate the risks and take measures to forestall disasters or mitigate their risks, while the latter refers to actions taken only after a disaster happens.