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Meta-analysis based predictions of flood insurance and flood vulnerability patterns in Calgary, Alberta

N. Yiannakoulias[a,*], J.C. Darlington[a], A. Elshorbagy[b], B. Raja[b]

[a] School of Geography and Earth Sciences, McMaster University, Hamilton, Ontario Canada
[b] College of Engineering, University of Saskatchewan, Canada

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ABSTRACT

Flood risk management requires an understanding of the role that the private insurance system can play in helping to manage future flood risk, and how insurance uptake may vary for different levels of social and physical vulnerability to floods. The objective of this research is to understand the patterns of flood risk, socio-economic characteristics and flood insurance uptake in the City of Calgary, Alberta, Canada, where a recent flood was followed by the introduction of private overland flood insurance. We use a meta-analysis approach to generate a pooled prediction of flood insurance uptake, and compare uptake across socioeconomic factors and flood hazard levels. Our results suggest that highest hazard areas have higher household income, higher average dwelling values and lower levels of home ownership compared to other areas in the city. Hazard levels vary less across measures of immigration status and identification as a visible minority. Predicted insurance coverage varies across the city, with households in high hazard areas most likely to purchase insurance, particularly for a pricing scheme in which low risk households cross-subsidize premiums for high risk households. Our findings provide an important starting point for understanding the role of private flood insurance on the future impacts of flooding in the study area, and may serve as a useful template for understanding the impact of insurance in other new markets.

1. Introduction and background

1.1. Introduction

Floods are the world's most common weather-related natural disaster (Wahlstrom & Guha-Sapir, 2015), and are a growing concern in many parts of the world as a result of anticipated changes to the global climate. In addition to large-scale engineering projects that can reduce flood risk near flood zones, there is a breadth of small scale mitigation tools available as well. These include landscaping, raising houses, and the installation of sump-pumps and/or sewage valves. However, financial cost, lack of public infrastructure and lack of awareness result in a population that is thought to be largely under-protected from flooding in many parts of the world.

The general objective of this research is to understand geographic and socioeconomic variations in flood hazard and uptake of flood insurance in Calgary, Alberta, Canada. In 2013, the City of Calgary and its surrounding area experienced a flood event that resulted in one of the most costly natural disasters in Canadian history with total losses of approximately 6 billion dollars (Gober & Wheater, 2015). At the time, overland flood insurance was not generally available in Canada, however, a number of insurance companies have since begun to offer insurance products to households. The impacts of this very new insurance marketplace on future government disaster relief and population vulnerability to floods are unknown.

Our analysis has three specific objectives that help address some of this uncertainty. First, we describe the socioeconomic characteristics of the population based on exposure to flood risk. Second, we predict and map the spatial variation in insurance uptake in Calgary. Finally, we describe the relationships between predicted insurance uptake and selected socioeconomic characteristics of the population. Given the lack of data and newness of the overland flood insurance market in Canada, we use a meta-analysis approach to make predictions required for our analysis. As such, we also demonstrate a simple methodological strategy for using previous research to understand the impact of insurance on flood vulnerability in settings with no previous history of flood insurance.

* Corresponding author.
E-mail address: yiannan@mcmaster.ca (N. Yiannakoulias).

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1.2. Flood insurance demand

Flood insurance has three key purposes: 1) it internalizes the costs of living in and otherwise using flood prone areas 2) it helps ration and prioritize public flood prevention investments and 3) it covers losses that cannot be protected against by other means (Chivers & Flores, 2002). The availability and regulation of flood insurance varies internationally. In the United States, the National Flood Insurance Program (NFIP) helps underwrite the cost of insurance in some communities, and requires the purchase of insurance for some homeowners with federally backed mortgages. In the United Kingdom, privately underwritten insurance is widely available and mandatory for mortgage holders (Surminski & Eldridge, 2015). In continental Europe, there is a mix of private optional, mandatory, and public disaster relief programs (Bouwer, Huitema, & Aerts, 2007, p. 33). Flood insurance (and natural disaster insurance in general) is less common in low and middle income countries due to their higher susceptibility and vulnerability to extreme weather events, lack of information, lack of public resources to reduce risk, affordability and a lack of access to international insurance and finance markets (Skees, Barnett, & Murphy, 2008).

Economic models of optimal insurance coverage (Smith, 1968) and models of insurance demand (Ehrlich & Becker, 1972) lay the groundwork for the theoretical understanding of private insurance markets. These models have been used to understand the flood insurance market, and to predict household demand for insurance. Alternatives to insurance include self-insurance—lowering the magnitude of potential losses—and self-protection—lowering the probability that a loss occurs may impact demand for market insurance (Ehrlich & Becker, 1972). In flood risk management, the former might include moving valuables out of a flood prone area of the house, and the latter could include landscaping a yard to reduce risk of overland flow. If upfront costs are low enough, self-protection and self-insurance may satisfactorily mitigate risks, particularly if an insurance provider cannot differentiate insurance premiums to account for households that have adopted self-protection and/or self-insurance measures. On the other hand, insurance can work as a disincentive to take measures of self-protection and self-insurance through the well known moral hazard problem.

In many settings where market insurance has been available (and even subsidized), uptake is typically lower than what might be expected based on traditional economic models. One explanation for this is that people tend to underestimate the probability of floods and other natural hazards, and then reason that insurance costs are too high (Browne, Knoller, & Richter, 2015; Kunreuther, 1984). There is also evidence that home buyers do not have access to sufficient information about risks at the time of home purchase (Chivers & Flores, 2002). Other explanations are found in risk perception literature, as well as evidence that government aid following a flood event may create an expectation of post flood recovery assistance that disincentivizes the purchase of insurance (Kousky, Michel-Kerjan, & Raschky, 2018; Raschky & Weck-Hannemann, 2007).

Specific socio-economic factors may be associated with flood insurance uptake. While it is unclear if these factors have a direct influence on insurance uptake, or are merely associated with a more direct causal mechanism, understanding how geographic variations in factors like income, age, ethnic status and housing tenure are associated with flood insurance is important for flood risk management. This information can help predict the variation in flood insurance uptake in response to new policy instruments—such as the construction of flood prevention infrastructure or the introduction of new insurance options or subsidies. Furthermore, understanding the role of socio-economic factors on insurance uptake may reveal underlying vulnerabilities to flood risk, and help plan geographical risk mitigation strategies targeted to vulnerable groups.

1.3. Social factors that influence flood insurance uptake

Most current research is based on stated preference through willingness to pay/willingness to buy insurance and other risk mitigation strategies, but there is some revealed preference literature on insurance uptake levels, as well as some research that uses insurance purchase data directly. We consider all in the review below. We stratify the following review by distinguishing household-level and individual-level characteristics.

1.3.1. Household-level characteristics

Household level characteristics have been examined in flood literature for their effect on willingness-to-pay for flood insurance and/or flood mitigation measures. When compared to non-homeowners, homeowners have more incentive to buy protection against flood loss; however, results are mixed, showing both positive (Clark, Griffin, & Novoty, 2005; Hung, 2009; Shao et al., 2017; Zhai & Ikeda, 2006) and negative associations (Atreya, Ferreira, & Michel-Kerjan, 2015; Jones, Clark, & Malesios, 2015; Kousky, 2010). The home is one of the most important assets in an individual's financial portfolio, and risk-averse homeowners may be more incentivized to protect their wealth through flood insurance purchases (Kousky, 2010) while renters may be less likely (Atreya et al., 2015; Shao et al., 2017). In addition, the number of members living in a households has been shown to have a negative effect on flood insurance purchases, possibly as a proxy for income (Clark et al., 2005; Petrolia, Landry, & Coble, 2013; Ren & Wang, 2016; Zhai & Ikeda, 2006). Other research has found a positive association between the number of persons in a household and willingness-to-pay for insurance (Lo, 2013a; Raschky, Schwarze, Schwindt, & Zahn, 2013).

Most research suggests that households with mortgages are more likely to purchase flood insurance (Kousky, 2010; Kriesel & Landry, 2004; Petrolia et al., 2013), however some evidence shows a negative relationship between mortgage and the flood insurance policies-in-force (Browne & Hoyt, 2000). In areas of the United States where federally backed mortgages require flood insurance purchase, this likely increases insurance uptake (Kriesel & Landry, 2004). Rural areas are more likely to purchase flood insurance (Botzen & van den Bergh, 2012; Botzen, Aerts, & van den Bergh, 2009) possibly due to a difference in attitude about risk mitigation in sparsely populated areas compared to urban areas (Botzen et al., 2009).

Years of residence in a home has been shown to have both a positive effect on voluntary flood insurance purchase outside of 100-year flood-zone (Brody, Highfield, Wilson, Lindell, & Blessing, 2017), as well as a weak negative effect on willingness-to-pay to reduce the inconvenience of flood (Zhai & Ikeda, 2006). The longer one has lived in a home the more information they are likely to have received from peers, news outlets and local officials on flood risk while also observing nearby adverse impacts from flooding over time (Brody et al., 2017). Additionally, more time lived in a home may reduce the amount people are willing-to-pay to be accommodated elsewhere in order to reduce inconvenience when a flood event actually occurs (Zhai & Ikeda, 2006).

Household and property value have been shown to have both a positive (Brody et al., 2017) and negative (Lo., 2013a) association with willingness-to-pay for flood insurance. Higher housing values represent a more valuable asset to protect from potential peril, while also serving as a proxy for income, however it may also be associated with self-insurance and self-protection since covering losses is easier for wealthy people who can afford to purchase more expensive homes (Lo., 2013a).

1.3.2. Individual characteristics

The most commonly studied driver of insurance uptake found in the literature is income, with a consistently positive effect on willingness-to-pay for flood mitigation and/or insurance (Atreya et al., 2015; Botzen & van den Bergh, 2012; Botzen et al., 2009; Botzen, Aerts, & van den Bergh, 2013; Browne & Hoyt, 2000; Clark et al., 2002; Clark et al., 2005; Hung, 2009; Jones et al., 2015; Kriesel & Landry, 2004; Lo,