Centre de Recherche en Économie et Statistique
CREST

Série des Documents de Travail

n° 2013-15

Natural Disasters : Exposure and Underinsurance

C. GRISLAIN-LETRÉMY[1]

October 2013

1 INSEE, CREST and Paris Dauphine University. Email : celine.grislain.letremy@ensae.fr

Natural Disasters: Exposure and Underinsurance*

Céline Grislain-Letrémy†

October 29, 2013

Abstract

Insurance coverage for natural disasters remains low in many exposed areas. A limited supply of insurance is commonly identified as a primary causal factor in this low insurance coverage. The French overseas departments provide a rare natural experiment of a well-developed supply of natural disasters insurance in highly exposed regions. The French system of natural disasters insurance is underwritten and regulated by the French government; instituted initially for metropolitan France only, it was extended to overseas departments in the state of emergency following Hurricane Hugo in 1989. This natural experiment makes it possible to analyze the determinants of insurance coverage on the demand side. Based on unique household-level microdata, I estimate an insurance market model which had not yet been empirically tested. Using this structural approach, I show that underinsurance in the French overseas departments is neither due to perception biases nor to unaffordable insurance, but mainly to uninsurable housing and to the anticipation of assistance, which crowds out insurance. Individual insurance decisions are influenced by neighbors' insurance choices through peer effects and neighborhood eligibility for assistance.

Keywords: natural disasters, insurance, disaster aid, public assistance
JEL classification: Q54, G22, H84, D12

*The conclusions and analysis expressed in this paper are those of the author and do not necessarily reflect the views or opinions of the institutions to which she belongs. I thank Pierre-André Chiappori, Pierre-Philippe Combes, Xavier D'Haultfoeuille, Eric Dubois, Christian Gourieroux, Meglena Jeleva, Guy Laroque, Claire Lelarge, David Martimort, Philippe Mongin, Corinne Prost, Bernard Salanié, Sandrine Spaeter, Eric Strobl, Yoshihiko Suzawa and Bertrand Villeneuve for their insightful comments. I thank Stephen Coate for his help on public assistance. This paper has also benefited from comments by Lucie Calvet, Nicolas Grislain, Laurence Rioux, Corentin Trevien, Lionel Wilner and participants at the Applied Micro Theory Colloquium at Columbia University, the 20th Annual Conference of the European Association of Environmental and Resource Economists, the Seminar of the Chair "Regulation and Systemic Risk" of the French Prudential Supervisory Authority, the 40th Seminar of the European Group of Risk and Insurance Economists, the 74th International Atlantic Economic Conference, the CREST internal seminars, the INSEE internal seminar, the Paris-Dauphine University internal seminar and the 2011 Belpasso international summer school on environmental and resource economics. I thank Francis Roux and Christophe Michel for detailed explanations about data. The Chair "Regulation and Systemic Risk" of the French Prudential Supervisory Authority is thanked.

†INSEE, CREST and Paris-Dauphine University. Email: celine.grislain.letremy@ensae.fr

1 Introduction

Natural disasters have had a considerable and growing impact on national economies; over the last few decades, damages associated with such events have frequently reached several percentage points of GDP.[1] Up to now, the increasing cost of natural disasters has been largely due to the growing urbanization of risky areas (Barredo (2009), Bevere et al. (2011)). In the future, climate change could have a major additional impact (IPCC, 2007). Among the different strategies developed to manage natural risks, insurance has taken on a growing importance as a coverage solution over the last thirty years. Risk transfer to insurance markets represents significant macroeconomic value, since this transfer greatly facilitates economic recovery. The drop in national output subsequent to natural disasters is mainly driven by uninsured losses (von Peter et al., 2012). As government is potentially the "insurer of last resort" after natural disasters, insurance coverage of public and private assets would enable countries to partially transfer catastrophic risk to private foreign actors via insurance mechanisms.[2]

However, risk transfer to insurance markets remains limited. Even if insured losses have significantly increased over time, they still represent a small fraction of economic losses (MunichRe, 2012). Indeed, insurance coverage remains low not only for public goods but also for firms' and households' possessions, even in developed countries.[3] In many developing countries and developing small island states, the concurrence of exposure and underinsurance is striking (Cavallo and Noy (2009), Freeman et al. (2003), Pelling and Uitto (2001)). In particular, Latin America and the Caribbean form one of the world's most disaster-prone areas (Borensztein et al. (2009), Heger et al. (2008), Rasmussen (2004)) and have the lowest levels of insurance coverage (Borensztein et al., 2009).

[1] Natural Disasters. Counting the Cost. March 21st, 2011. *The Economist.*

[2] In almost all developing countries, insurers rely heavily on international reinsurance (Outreville, 2000). Local insurance companies can cede a significant part of their risks to reinsurers, which are mainly foreign companies. For example, in the Caribbean, local insurers which cover households' and firms' possessions for natural disasters retain less than 20% of the amount they insure and cede the remaining share to reinsurers (Pollner, 2000).

[3] For example, insurance coverage is low in the United States (Dixon et al. (2006), Kunreuther (1984)) and in many European countries (Maccaferri et al., 2012)).

A limited supply of insurance is commonly identified as a primary causal factor for low insurance coverage in hazard-prone regions of the world, including Latin America and the Caribbean. However the French overseas departments provide a rare natural experiment of a well-developed and regulated supply of natural disasters insurance in Latin America, the Caribbean and other exposed small island countries.[4] The French system of natural disasters insurance is underwritten and regulated by the French government. This system was created in 1982 and at first applied only to metropolitan land. However, following the devastation of Guadeloupe by Hurricane Hugo in 1989, the government decided, in a state of emergency, to extend the natural disasters insurance system to the French overseas departments. This broad and regulated supply of coverage makes it possible to analyze the determinants of insurance coverage on the demand side, some of which are specific to developing countries, and others which also largely apply in developed countries.

The first and main contribution of this paper is to provide demand-side explanations for underinsurance in disaster-prone areas and to measure and compare their magnitude. A structural approach is used to disentangle the various possible causes of underinsurance in the French overseas departments. I show that the main explanations for the low insurance penetration rate are neither perception biases nor unaffordable insurance, but uninsurable housing and charity hazard.[5] Uninsurable housing, namely the fact that dwellings have such poor resilience to natural events that insurers may consider them uninsurable, widely applies in Latin America, the Caribbean and many other developing countries. The impact of uninsurable housing on insurance demand, which is captured by using proxies for low-quality dwellings, is quantified and significant. Charity hazard, that is the fact that assistance is a substitute for formal insurance and decreases demand for insurance, is a typical example of the Samaritan's dilemma and concerns many developed and developing countries. As data on assistance are unavailable, the impact of charity hazard is shown using the structural estimation; it is also of significant magnitude. Further-

[4]The French overseas departments include French Guiana (South America), Guadeloupe (Caribbean Sea), Martinique (Caribbean Sea) and Réunion (Indian Ocean). Mayotte (Indian Ocean) became a French overseas department in March 2011. As the data were collected in 2006 in the French overseas departments, Mayotte is excluded from this empirical analysis.

[5]A companion paper draws initial basic and robust qualitative conclusions (Calvet and Grislain-Letrémy, 2011).

more, I show that neighbors' insurance choices impact individual insurance decisions through peer effects and neighborhood eligibility for assistance, two channels which are of comparable magnitude. These results contribute to the growing literature on charity hazard (Petrolia et al. (2012), Landry and Jahan-Parvar (2011), Raschky and Weck-Hannemann (2007), Raschky et al. (2010)). Finally, I show that the existing insurance obligations (*de facto* for homeowners with outstanding loans, as in most Caribbean countries, and *de jure* for French tenants) are operant but do not guarantee that targeted households are insured, as households may choose not to renew their insurance contracts once they have settled in.

The second contribution of this paper is to measure the impact of regulation on insurers' pricing behavior. The French government provides an unlimited guarantee to one reinsurer and, in return, regulates the scope and the price of natural disaster coverage. Beyond strict regulation, the attractive, non-actuarially-based reinsurance policies offered by this reinsurer provide little incentive for insurers to price natural risks in their insurance policies. Similar pricing distortions have been observed in other markets; in the retail electricity market for example, intermediaries' pricing reflects their limited exposure and not the real price (Joskow and Tirole, 2006). Besides, as reinsurance policies limit insurers' exposure to natural risks, insurers also have little incentive to acquire detailed information on their insured risk exposure (*ex ante* moral hazard) and to assess damages precisely (*ex post* moral hazard).

The third and final contribution consists in specifying and estimating a theoretical model of insurance derived from the work of Abel (1986), Pauly (1974) and Rothschild and Stiglitz (1976), which had not been previously tested. In this model, a supply equation explains the insurance premium; a demand equation explains the probability of purchasing insurance and takes into account the impact of insurance prices on the decision to purchase insurance. Such an estimation of demand and supply has been performed on other markets, such as the French labor market (Laroque and Salanié, 2002), but is new for an insurance market. A unique household-level micro-database combining detailed information on the insured and the uninsured has been built to estimate this model.

The paper is organized as follows. Section 2 illustrates exposure and underinsurance in Latin America and the Caribbean, presents commonly identified reasons for underinsurance on the supply- and demand- sides, and details the supply of natural disasters insurance provided in the French overseas departments. Section 3 presents the theoretical model. Section 4 details the data and the empirical specification, identification and calibration of the model. Estimation results are commented in Section 5. Section 6 discusses their implications in terms of public policy and the extent to which they apply in other developing and developed countries. Section 7 concludes.

2 Exposure and underinsurance in Latin America and the Caribbean

In many developing countries (Cavallo and Noy (2009), Freeman et al. (2003)) and developing small island states (Pelling and Uitto, 2001), the concurrence of exposure and underinsurance is striking. Latin America and the Caribbean especially form one of the world's most disaster-prone areas (Borensztein et al. (2009), Heger et al. (2008), Rasmussen (2004)) and have suffered damages exceeding 50% of GDP (Table 1), Yet they have the lowest levels of insurance coverage (Borensztein et al., 2009): less than 4% of losses were insured between 1985 and 1999, ranking them last among the world's regions along with Asia (4%), and behind Africa (9%) (Charvériat, 2000).[6] The insurance penetration rate, i.e., the percentage of economic agents with insurance, is particularly low among households (Charvériat, 2000). For example, in Mexico in 1998, less than 1% of houses had disaster insurance coverage (Kreimer et al., 1999); in Argentina, Ecuador and Brazil, the flood insurance penetration rate is also very low among individuals (Gaschen et al., 1998).

[6] For example, in 1999, in the cases of the Vargas tragedy in Venezuela and of the Quindio earthquake in Colombia, only 1.4% and 4.4% of total losses were insured, respectively (Charvériat, 2000).

Table 1: Destructive impact of natural disasters in the Caribbean region

Country	Time	Event	Damages (% of GDP)
St Lucia	1988	Hurricane Gilbert	365
Grenada	2004	Hurricane Ivan	203
Dominica	1979	Hurricanes David and Fredrick	101
St Kitts and Nevis	1995	Hurricane Luis	85
St Lucia	1980	Hurricane Allen	66
Antigua and Barbuda	1995	Hurricane Luis	61
Guyana	2005	Floods	59

Notes: Heger et al. (2008).

2.1 Supply of insurance

2.1.1 Limited supply of insurance

A limited supply of insurance is commonly identified as a primary causal factor for low insurance coverage in the world's hazard-prone regions. Insurance supply is particularly limited in developing countries; microinsurance provides increasing but still partial coverage of damages to life, property and crops caused by natural disasters (see Mechler et al. (2006) for a review).[7] The restricted supply is mainly due to unavailable or unaffordable reinsurance and also to limited standardized information on risk exposure (Cavallo and Noy, 2009).

The case of Latin America and the Caribbean is again particularly striking. Supply of coverage for governmental expenditures remains limited despite recent advances such as the creation of the Caribbean Catastrophe Risk Insurance Facility in 2006, or the Mexican government's successful issuance of catastrophe bonds in 2006 (Borensztein et al., 2009) and in 2009 (WB, 2011).[8] Similarly, developments in the supply of insurance for households remain isolated,[9] and this insurance supply can be frag-

[7]See also Barnett et al. (2008) for a review of index-based risk transfer products to cover natural damages to crops.

[8]In the 1980s and the 1990s, Mexico, Colombia, Costa Rica, Nicaragua also set up national natural disaster funds for uninsured regional or local infrastructures (Charvériat, 2000).

[9]In Brazil, the government-owned reinsurance institute is largely responsible for developing the supply of flood reinsurance (Charvériat, 2000); in Puerto Rico, a reserve for catastrophe losses was created in 1994 to improve the availability and the affordability of catastrophe insurance (Charvériat (2000), Evans (1996)); in Manizales (Colombia), the city allows any resident to buy insurance from a private insurer through the municipal tax collection system (Fay and Wellenstein,

ile. Montserrat is a particularly telling example: in 1997, after several volcanic eruptions, insurance companies responsible for most policies withdrew from the island entirely (Analytica, 1997). Even when available, insurance premiums offered to households are high in Latin America and the Caribbean, because of the limited reinsurance supply (Auffret (2003), Charvériat (2000) and Evans (1996)).

2.1.2 The exception of the French overseas departments

The French overseas departments provide a rare natural experiment of a well-developed and regulated supply of natural disasters insurance in Latin America, the Caribbean and other exposed small island countries.

Like many countries located in these areas, the French overseas departments are highly exposed to tsunamis, floods and ground movements.[10] Guadeloupe and Martinique are exposed to intense seismic activity;[11] each of the three islands is composed of an active volcano (Grande Soufrière in Guadeloupe, Mount Pelée in Martinique, Piton de la Fournaise in Réunion) and is exposed to strong hurricanes or cyclones.[12] This is why collective prevention against natural disasters is highly developed in the French overseas departments.[13]

The French overseas departments were integrated into France as overseas departments in 1946 and are now integral parts of France. The French system of natural disasters insurance was created in 1982 to institutionalize and coordinate numerous aid mechanisms that had been functioning for centuries (Favier and Larhra, 2007).

2005).

[10]Ground movements include all soil and subsoil movements (such as mudslides, rock and/or block falls, land collapses or subsidence, landslides, movements due to clay soils).

[11]See the French earthquake map: http://www.planseisme.fr/IMG/jpg/Poster_alea_sismique_avril_2008-2.jpg. Major earthquakes occurred in Guadeloupe in 1843 and in Martinique in 1839. Earthquakes of smaller intensity happen more frequently, such as Les Saintes (Guadeloupe) earthquake on November 21, 2004 and Martinique earthquake on November 29, 2007. According to scientists, a major earthquake can be expected on both of these islands in the very next decades.

[12]Hurricane Dean hit Guadeloupe and Martinique on August 16, 2007; Cyclone Dina occurred in Réunion on January 22 and 23, 2002.

[13]The vast majority of municipalities have already undertaken or set up natural risk prevention plans. In Guadeloupe and Martinique, the government set up additional measures in 2007 to improve resilience to seismic activity, especially for public infrastructure.

It first applied only to metropolitan France; a specific insurance system was initially foreseen for the overseas departments. However, following the devastation of Guadeloupe by Hurricane Hugo in 1989, the government decided, in a state of emergency, to extend the system of natural disasters insurance to the French overseas departments (Bidan, 2000).[14] As such, since August 1, 1990 the French overseas departments have benefited from a well-developed and regulated supply of natural disasters insurance. The government provides an unlimited guarantee to the French system of natural disasters insurance and, in return, regulates the scope and the price of natural disasters coverage. As such, the insurance system corresponds to a tax system: the government ultimately compensates insured damages caused by natural disasters and taxes the insured in return.[15]

Definition of natural disasters. Natural disasters are defined by law as uninsurable natural hazards.[16] They can be earthquakes, volcanic eruptions, hurricanes or cyclones, tsunamis, floods or ground movements. In practice, after a natural event, the French government decides whether this event is a natural disaster and which periods and municipalities are concerned.[17] The decision relies on the conclusions of an interministerial commission, which analyzes the phenomenon on the basis of scientific reports. Storms (which are neither hurricanes nor cyclones) and forest fires are considered insurable risks; their coverage is included *de facto* rather than *de jure* in home insurance and is not regulated.

Insured households. The coverage of dwellings for natural disasters is mandatorily included in comprehensive home insurance,[18] and this coverage is not provided

[14] At that time, the system of natural disasters insurance was also extended to two self-governing territorial overseas collectivities of France - Mayotte, and Saint Pierre and Miquelon. Mayotte became a French overseas department in March 2011 and so was not a department in 2006, when data were collected.

[15] The system of natural disasters insurance also provides coverage to firms and local governments.

[16] Natural disasters are defined by law as "non insurable direct material damage the determining cause of which was the abnormal intensity of a natural agent, when normal measures taken to avoid such damage have been unable to prevent the occurrence thereof or could not be taken" (Insurance Code, section L. 125-1).

[17] An order of the ministries of the Interior, of the Economy and of the Budget establishes whether an event is a natural disaster and determines the periods, municipalities and hazards to be covered by the insurance system. Insured households and firms can benefit from the insurance compensation only if an order is published for the event concerned.

[18] See Insurance Code, section L. 125-1. Home insurance is an accessible product, as households can purchase a policy over the phone in approximately 20 minutes.

by any other insurance policy to my knowledge. Insurers are not allowed to sell home insurance without this coverage, which guarantees that insurers do not select their clients. Similarly, households are not allowed to buy home insurance without this coverage. Recall that this system was first intended to apply only to metropolitan France, where almost all households purchase home insurance. Thus, this mandatory inclusion initially guaranteed the widespread mutualization of natural risks over the country.

In practice, French insurers offer households coverage of their home for several hazards (such as theft, fire, explosion, water damage or natural disasters), without letting them choose the insured value of the building; households can only choose the insured value of contents.

Insurance pricing. The law requires the natural disasters premium to be a fixed share of the home insurance premium: the premium for natural disasters amounts to 12% of the premium charged for other risks.[19] Insurers are allowed to increase the home insurance premium (and therefore the natural disasters premium) with respect to the exposure to natural risks.

Reinsurance policy. However, by using reinsurance policies, the government gives insurers little incentive to price natural risks. Indeed, the government provides an unlimited guarantee to one reinsurer, the *Caisse Centrale de Réassurance* (CCR), which offers insurers an attractive and not-actuarially-based reinsurance policy and captures more than 90% of market share on the natural disasters reinsurance market.[20] Insurers transfer their natural risks to CCR (with the exception of a fixed deductible which equals the sum of their collected premiums); in return, they pay CCR a fixed share of their collected natural disasters premiums. As the potential loss and reinsurance premium paid by the insurer are affected only to a very limited extent by the exposure of its policyholders, insurance premiums only

[19]See Insurance Code, sections L. 125-2 and A. 125-2. The premium for natural disasters equals 12% of the premium charged for other damages, excluding for example the premium for civil liability coverage. For the sake of simplicity, the model ignores this point (Section 3). See http://www.ccr.fr for more details.

[20]Private communication to the author.

partially reflect risk exposure and insurers have little incentive to acquire detailed information on their insured risk exposure (*ex ante* moral hazard) and to assess damages precisely (*ex post* moral hazard).

More specifically, the reinsurance policy offered by CCR is such that the insurer yields 50% of the sum of all the natural disasters premiums it has collected (over all policies) and 50% of its losses caused by natural disasters (over all policies) to CCR (quota-share contract).[21] So, the insurer keeps half of the premiums and covers half of the risks. For its remaining risks, it is exposed up to a deductible, which equals the sum of the initially collected premiums (stop-loss contract) (Figure 1).[22] In 2006, the amount paid by insurers to CCR corresponded to 51.5% of the collected premiums (€670 million over €1.3 billion, Letrémy (2009)), that is 50% as the price of the quota-share policy and 1.5% as the price of the stop-loss policy. In practice, the stop-loss price depends on the composition of the insurer's portfolio in terms of professional risks and not household risks.[23]

Finally, insurers also have to give the French government 12% of the collected premiums to fund prevention measures.[24] Thus, over the initially collected natural disasters premium, the insurer pays 63.5% of the premium, that is 51.5% to CCR and 12% to the government; in return, the insurer is exposed up to a deductible which equals the sum of the collected premiums.

This reinsurance policy is applied to the whole set of natural disasters policies offered by the insurer overall (home, firm and car insurance in metropolitan France, overseas departments and territories). For the sake of simplicity, the theoretical model (Section 3) compares the premium of one home insurance policy with the additional expected coverage that it represents.

[21]Since 2000, insurers are not allowed to select which risks they cede to CCR (Erhard-Cassegrain et al., 2006).

[22]Each year the deductible is reassessed according to the reserve constituted by the insurer.

[23]Private communication to the author.

[24]See Environment Code, section L. 561-3.

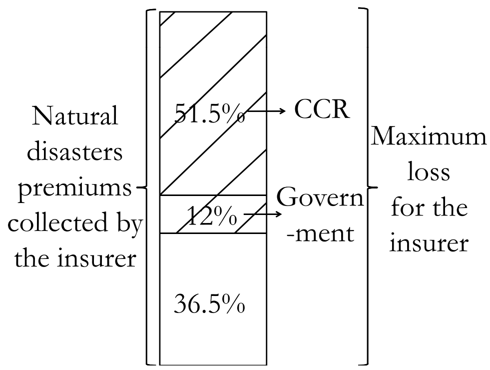

Figure 1: Reinsurance policy

Insurance penetration rate. Despite the supply of broad coverage for natural disasters at a regulated price, in 2006 only half of households living in the French overseas departments had purchased home insurance, which includes natural disasters coverage, for their primary residence (Table 2). This penetration rate is higher than the rate observed in other exposed countries, but remains much lower than the rate observed in metropolitan France, where households are far less exposed to natural risks but almost all insured (Table 2).[25]

2.2 Demand for insurance

Several reasons may explain the low demand for natural disasters insurance: perception biases, unaffordable insurance, uninsurable housing, anticipation of assistance, which crowds out insurance, and a vicious circle of underinsurance.

Insurance obligations. Purchasing home insurance is often a condition for obtaining a mortgage. However, some homeowners with outstanding loans may not renew their insurance contracts once they have settled in. Indeed, as few checks are performed once people have moved in, some households choose to cancel insurance expenditure as soon as possible. This situation prevails in most Caribbean countries

[25] Indeed, we do not observe the adverse selection effect that would typically be expected: insurance subsidization for exposed households by those least exposed (living in metropolitan France) could lead to a higher participation on the insurance market of exposed households (living in overseas departments). This adverse selection would mainly derive, not from insurers' lack of information, but from their limited incentive to use information because of reinsurance policies: as insurers bear a very small share of losses caused by natural disasters, insurance premiums only partially reflect natural risks and this subsidizes exposed households.

Table 2: Population, exposure to major natural risks and insurance penetration rate for primary residences in France in 2006

	French Guiana	Guadeloupe	Martinique	Réunion	Metropolitan France
Population					
	205,954	400,736	397,732	781,962	61,399,733
Percentage of households exposed to natural hazards					
Earthquakes	0	100	100	55(⋆)	59(⋆)
Volcanic eruptions	0	30	100	65	0
Wind effects	0	100	100	100	8(⋆)
Tsunamis and floods	85(†)	84	100	100	21(†)
Ground movements	70	100	100	100	19
Forest fires	0	0	0	100	19
Avalanches	0	0	0	0	1
Percentage of households insured for their primary residence					
	52	43	50	59	99

Notes: (⋆): Réunion and metropolitan France are exposed to low intensity earthquakes; metropolitan France is also exposed to low intensity wind effects. (†): the tsunamis to which French Guiana and metropolitan France are exposed are also of low intensity, but these two areas are exposed to high intensity floods. Population census by the French National Institute of Statistics and Economics Studies (INSEE) in 2006; GASPAR database by the French Ministry of Ecology; French Household Budget survey by INSEE in 2006 (13,374 observations for percentage calculations).

(Auffret, 2003).[26] In the French overseas departments, purchasing home insurance is also compulsory for tenants. According to my data, in 2006 only 67% of tenants and 72% of homeowners with outstanding loans were insured, whereas the overall insurance penetration rate was 48%.

Perceptions biases. Perception biases are often evoked to explain a low demand for coverage against extreme events. A large body of literature deals with cognitive biases in the perception of extreme risks and their impact on demand for natural disasters insurance (see Tallon and Vergnaud (2007) for a review). For example, an accurate perception of low probabilities is hindered by availability bias (Tversky and Kahneman, 1973), the "gambler's fallacy" following from a "belief in the law of small

[26] This is also the case in the United States: banks or financial institutions can require the purchase of flood insurance beofre granting a mortgage (Browne and Hoyt (2000), Office (1983)); there is very little monitoring of insurance renewal and many households do not renew their flood insurance policies (Kunreuther and Pauly, 2005).

numbers" (Tversky and Kahneman, 1981),[27] search costs dissuading people from seeking information unless a minimum threshold of disaster probability is reached (Kunreuther and Pauly, 2004), or the difficulty of comparing with ordinary risks (Kunreuther et al., 2001).

Insurance affordability. Another standard explanation is that insurance may be too expensive for households. When insurance is available, premiums for natural disasters offered to households in Latin America and the Caribbean are high (Auffret (2003), Charvériat (2000) and Evans (1996)). For example, in Mexico, premiums in earthquake-prone areas amount to 0.5% of the value of housing on an annual basis (Charvériat, 2000); in the Caribbean in the 1990s, premiums exceeded 1% of the insured value (Charvériat (2000), WB (1999)).

Although the price of insurance is regulated in the French overseas departments, overseas French households may not be able to afford insurance given that the median standard of living in the French overseas departments is almost 40% lower than in metropolitan France (Michel et al., 2010).

Uninsurable housing. In developing countries, many dwellings have such poor resilience to natural events that insurers may consider them uninsurable. The proportion of uninsurable housing in Latin America and the Caribbean is very high. In Mexico, uninsurable houses built with no solid materials or access to drinking water represent about 50% of total housing stock (Charvériat, 2000). 60% of total housing stock in the Caribbean is built without any technical report (IDB, 2000).

In the French overseas departments, dwellings made of light materials (such as wood or sheet metal) of variable quality represented 13% of dwellings in 2006 (Castéran and Ricroch, 2008), and are especially numerous in French Guiana. According to my data, the number of low-quality dwellings is significant and the insurance penetration rate is lower among their occupants: only 17% for houses still under construction (which represent 3% of the sample), 15% for houses without hot water (23% of the

[27] The belief in the law of small numbers is the belief that once the dwelling has been damaged by a disaster, the probability of being touched again is lower.

sample), 34% for houses without drainage (53% of the sample) and 9% for houses without toilets inside the building (4% of the sample), compared to an overall insurance penetration rate of 48%.

All these low-quality dwellings are legal. Unlike in metropolitan France or other developed countries, a building permit is not required by law to build a house. Indeed, in the French overseas departments, property law allows households to own the walls of their dwelling without owning the ground on which it is built. This is why more than 30% of individual dwellings in the French overseas departments have been built without a permit (DIREN (2005), Garnesson and Hecquet (2007), Olive and Riviere (2010)). Similarly, in the Caribbean region, building standards and location restrictions are either nonexistent or outdated and inadequate (Auffret, 2003). However, insurers may require a building permit be obtained before granting home insurance.

Uninsurable housing can be seen as a rational adaptation to exposure to natural disasters in low-income countries, and as an illustration of the poverty trap. Low-income households use these either nonexistent or outdated and inadequate building rights to build low-quality dwellings that would be destroyed by an eventual natural disaster. In this way, households with few assets can become trapped in chronic low-quality housing. This phenomenon has been studied, especially in the field of small businesses and agriculture (Barnett et al., 2008). However, my data indicate that in the French overseas departments, good quality dwellings are built on average in more exposed areas, probably because risk exposure also provides positive amenities (river view, fertile ground).

Charity hazard. Assistance is a substitute for formal insurance and decreases demand for insurance. This phenomenon, called charity hazard, is a typical example of the Samaritan's dilemma. Although charity hazard has been formalized by several theoretical papers, few empirical findings have been established in the case of natural disasters insurance (see Raschky et al. (2010) for a review).[28]

[28]Charity hazard has been tested for health insurance (Herring (2005), Chernew et al. (2005), Brown and Finkelstein (2008)); initial results point to the existence of charity hazard for crop

Charity hazard has a considerable impact in many developing countries (Gilbert, 2001), including Latin America and the Caribbean. Indeed, the Caribbean region largely depends on international assistance: the World Bank and the Inter-American Development Bank provide a considerable and growing amount of assistance to victims of natural disasters (Auffret, 2003).

Households in the French overseas departments can also rely on substantial financial assistance from the government, local authorities, non-governmental organizations or relatives after natural disasters. Their anticipation of financial assistance is essentially based on their past experience, and is difficult to quantify because of the numerous assistance channels. Official statements following natural disasters confirm that the uninsured can rely on significant compensation from the government (Senate, 2005). One of the main channels of governmental assistance to overseas France is the disaster relief fund for overseas areas. This compensation covers damages caused by natural disasters in the primary residence (including rebuilding); it is funded by budgetary credits.[29]

A vicious circle of uninsurance. Finally, two main reasons may explain a sustained level of underinsurance. The first is similar to a peer effect. Social norms impact the decision to purchase insurance: individuals may decide to purchase insurance because they know others who did so; they may think that their relatives have similar preferences to them or have already contributed the search costs of obtaining information on risk, insurance or relief (Kunreuther and Pauly, 2005).

The second reason relates to the endogenous award of assistance and is therefore linked to charity hazard. The neighbors' decision to remain uninsured increases neighborhood eligibility for assistance and so decreases the individual benefit of purchasing insurance. In other words, the more an individual is surrounded by people without insurance, the less need he or she has to purchase insurance since

insurance in the United States (Deryugina and Kirwan, 2012).

[29]See order of December 8, 2010 relative to the implementation of assistance by the disaster relief fund for overseas areas.

the political power of the uninsured grows. This mechanism is predicted in theory for many types of public aid: Arvan and Nickerson (2006) consider endogenous governmental compensation and show that an individual's purchase of insurance coverage creates negative externalities by diminishing neighborhood eligibility for such aid.[30]

3 Theoretical model

I estimate a model of insurance supply and demand (Abel (1986), Pauly (1974), Rothschild and Stiglitz (1976)) within the French overseas departments. In this section, I detail the theoretical specification of this model.

The supply equation explains the insurance premium offered by insurers. This price conveys that insurers' expected profit is zero, i.e., that collected premiums equal expected losses. Both amounts, which reflect the specific design of the French natural disasters insurance system (Section 2), are precisely modeled here. Insurers are assumed to offer a single, standard policy with full coverage.

The demand equation explains the household's probability of purchasing insurance. The quantity of purchased insurance results from the comparison households make between their expected utilities with and without insurance. The decision whether to purchase insurance or not depends on the insurance price. I supplement this demand equation in order to model the underlying determinants of insurance demand precisely (Section 2).

3.1 Risk structure

A dwelling suffers a loss L_d caused by natural disasters with probability p_d. I assume that uninsured households receive assistance A_d after a disaster. The net loss is thus $L_d - A_d$. Ordinary risks (such as theft, fire, explosion or water damage) cause a loss L_o with probability p_o. No assistance is provided to compensate damages caused by

[30]See Herring (2005) for an illustration of endogenous availability of charity care for health.

these individual risks.

For the sake of simplicity, losses caused by natural disasters and damages caused by ordinary risks are assumed to be independent events. As the product of the two probabilities $p_d p_o$ is negligible with respect to any of the two probabilities, there are indeed three states of nature: a high loss $L_d - A_d$ with a low probability p_d, a low loss L_o with a high probability p_o, and no loss with probability $1 - p_d - p_o$ (Figure 2).

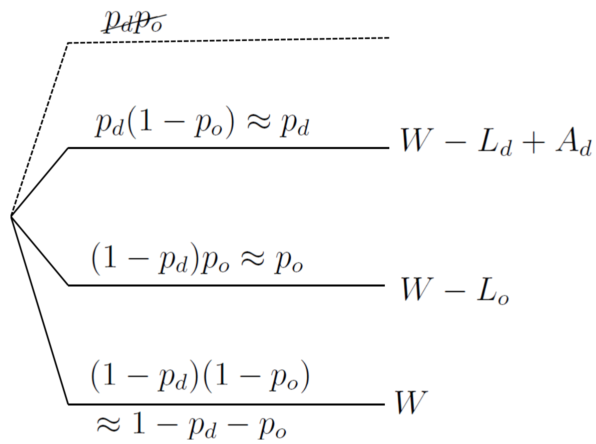

Figure 2: Risk structure

Households' risk perception is potentially biased, and may differ from the accurate risk assessment performed by insurers for the probability of ordinary losses $\tilde{p}_o$, for the probability of natural disasters $\tilde{p}_d$ and for the losses $\tilde{L}_d$ caused by natural disasters. For the sake of simplicity, I assume that households have the same estimation of their ordinary losses L_o as insurers.

3.2 Modeling the supply side

Insurance policy. As households' coverage choices are restricted to contents in France (Section 2), I assume that insurers offer a single, standard policy with full coverage. Therefore households either purchase home insurance ($\alpha = 1$) or not ($\alpha = 0$).

Zero expected profit. Insurance companies are assumed to be price takers. Insurance market competition and the risk neutrality of insurers imply that insurers' expected profit is zero for each group of identical households (for what is observed by the insurers). Zero expected profit means that collected premiums equal expected losses caused by ordinary risks EL_o and by natural disasters EL_d. I add a multiplicative constant c; this loading factor represents transaction costs (information search, negotiation, policy drafting, controls, claim disputes).

$$\pi = c(EL_o + EL_d). \tag{1}$$

Collected premiums and expected losses both reflect the specific design of the French system of natural disasters insurance; they are precisely modeled here.

Premiums. The home insurance premium π is the sum of the premium for natural disasters π_d and the premium for other risks π_o. The premium for natural disasters π_d amounts to $r = 0.12$ of the premium for other risks π_o (Section 2).

$$\left.\begin{aligned} \pi &= \pi_d + \pi_o, \\ \pi_d &= r\pi_o. \end{aligned}\right\} \Rightarrow \pi = \frac{1+r}{r}\pi_d. \tag{2}$$

Expected losses. Expected ordinary losses equal

$$EL_o = p_o L_o. \tag{3}$$

All insurers are assumed to be reinsured against natural disasters by CCR, since CCR captures more than 90% of market share in the natural disasters reinsurance market (Section 2). Expected losses caused by natural disasters are determined by the non-actuarially-based reinsurance policy offered by CCR (Section 2). Insurers are exposed up to a deductible, which is the natural disaster premium. In return, they have to pay a fixed share $k = 0.635$ of the natural disaster premium. This share corresponds to the sum of the price of reinsurance policy and a tax to fund prevention measures (Section 2).

$$EL_d = p_d \min\left(\pi_d, \frac{L_d}{2}\right) + k\pi_d, \tag{4}$$

$$= (p_d + k)\pi_d. \tag{5}$$

as $\pi_d < \frac{L_d}{2}$.

The supply equation (1) becomes

$$\pi = c(EL_o + EL_d), \tag{6}$$

$$= c(p_o L_o + (p_d + k)\pi_d), \tag{7}$$

$$= cp_o L_o + c(p_d + k)\frac{r}{1+r}\pi. \tag{8}$$

Thus

$$\log(\pi) = \log(cp_o L_o) - \log\left(1 - ck\frac{r}{1+r} - cp_d\frac{r}{1+r}\right). \tag{9}$$

3.3 Modeling the demand side

Comparison of expected utilities. A household is assumed to be risk averse: its utility function $U(\cdot)$ is concave with respect to its wealth. It purchases insurance ($\alpha = 1$) if and only if its expected utility EU is higher when it is insured ($\alpha = 1$) than when it is not ($\alpha = 0$).[31]

$$\alpha = 1 \Leftrightarrow EU|_{\alpha=1} \geq EU|_{\alpha=0}. \tag{10}$$

Given full insurance at price π, the expected utility of the insured is

$$EU|_{\alpha=1} = U(W - \pi). \tag{11}$$

[31] The standard expected utility framework may not be most appropriate for analyzing the economic consequences of fat-tailed events (Weitzman, 2009); however Weitzman's alternatives may be less appropriate for studying the purchase of catastrophe insurance.

The expected utility of the uninsured is

$$\begin{aligned} EU|_{\alpha=0} &= \tilde{p}_o U(W - L_o) + \tilde{p}_d U(W - \tilde{L}_d + \tilde{A}_d) + (1 - \tilde{p}_o - \tilde{p}_d) U(W), \\ &= U(W) - \tilde{p}_o [U(W) - U(W - L_o)] - \tilde{p}_d [U(W) - U(W - \tilde{L}_d + \tilde{A}_d)]. \end{aligned} \tag{12}$$

I supplement the demand equation (10) in order to precisely model the underlying determinants of insurance demand (Section 2).

Insurance obligations. Purchasing home insurance is compulsory for tenants and often a condition for obtaining a mortgage (Section 2). As many tenants and homeowners with outstanding loans remain uninsured (Section 2), proxies $\{O_k\}_k$ for occupancy status are added to control for these insurance obligations and to measure their impact.

Uninsurable housing. A significant number of houses are uninsurable buildings: they do not meet building standards or have been constructed without a building permit (Section 2). I supplement the demand equation (10) by adding proxies $\{H_{k'}\}_{k'}$ for uninsurable housing.

Peer effects. To test whether it holds that the more neighbors are insured, the higher the individual probability of purchasing insurance, I add the expected penetration rate $E(Z_{\text{peer},i})$ of the group J_{peer} of peers to which the household i belongs to the demand equation :

$$E(Z_{\text{peer},i}) = \frac{\sum_{j \in J_{\text{peer}}, j \neq i} \alpha(j)}{\text{card}(J_{\text{peer}}) - 1}. \tag{13}$$

This model corresponds to a special case of Nash equilibrium, where the decision of the group impacts the household's decision but where the reverse impact is negligible because of the size of each group. This strategy is inspired by other papers on peer effects, such as Hernández-Murillo and Sengupta (2012).

Neighborhood eligibility for assistance. An individual household's decision to purchase insurance depends on other households' decision, not only via peer effects but via neighborhood eligibility for assistance. To test for its endogenous nature, anticipation of assistance is assumed to depend on the expected penetration rate $E(Z_{\text{aid}})$ of the group J_{aid} for aid eligibility: $\tilde{A}_d(E(Z_{\text{aid}}))$.[32] This makes it possible to test whether the percentage of insured households around an individual household decreases its likelihood of obtaining assistance after a disaster and so decreases the charity hazard effect.

The demand equation becomes

$$\begin{aligned}\alpha = 1 \Leftrightarrow & [U(W-\pi) - U(W)] + \tilde{p}_o[U(W) - U(W - L_o)] \\ & + \tilde{p}_d[U(W) - U(W - \tilde{L}_d + \tilde{A}_d(E(Z_{\text{aid}})))] + \sum_k o_k O_k \\ & + \sum_{k'} h_{k'} H_{k'} + \delta E(Z_{\text{peer}}) \geq 0. \end{aligned} \quad (14)$$

4 Data and model specification, identification and calibration

In this section I present the unique household-level micro-database that has been built to estimate this theoretical model (Section 3). The empirical specification, which is fully parametric, is detailed. The identification and calibration of the model are discussed; all the robustness tests performed are presented.

4.1 Data

The database combines information about insurance expenditure for the insured, risk exposure and other economic variables for the insured and the uninsured. It was built by matching the 2006 French Household Budget survey with the GASPAR database, which provides information about exposure to natural disasters.

The French Household Budget survey, managed by the French National Institute of Statistics and Economics Studies (INSEE), is a comprehensive national survey of

[32] Again, this model corresponds to a special case of Nash equilibrium.

household expenditure, and in particular insurance expenditure. Regarding home insurance, households declare whether they have purchased home insurance and if so the premium paid. Neither the identity of the different insurers nor the type of company (mutual insurance company or not) is given. Data on assistance are unavailable (Section 4).[33] The French Household Budget survey also provides information about the household itself (such as size, income and standard of living, and, for the reference person,[34] gender, age and place of birth). Detailed information about housing (such as occupancy status, housing quality, and number of rooms) is given. However, no information on dwellings' compliance with building standards and permits is provided. The 2006 French Household Budget survey includes 3,134 households living in the French overseas departments.[35]

The GASPAR database, compiled by the French Ministry of Ecology, is the database to support the computer-aided management of administrative procedures relative to natural and technological risks. It specifies which of five hazards each municipality is exposed to, out of earthquakes, volcanic eruptions, hurricanes or cyclones, tsunamis or floods, and ground movements.[36] It also provides the number of disasters by hazard type in each municipality from 1990 (date of the enforcement of the system of natural disasters insurance in the French overseas departments) until the survey date.

As the decision whether to purchase insurance or not depends on the insurance price, I exclude from the study the households insured by their relatives or their employer and any households which declare themselves insured but do not report their premium amount. Out of the initial 3,134 households, 2,860 observations remain. I then exclude 40 observations for which key variables (annual income, number of

[33]Even detailed data on assistance provided by the disaster relief fund for overseas areas are unavailable. Annual aggregate statistics were only provided at departmental level by the French Ministry of Overseas.

[34]More often than not, the household reference person is either the family reference person when there is one, or the oldest man, with priority to the oldest active person.

[35]In French Guiana, the sampling plan of the 2006 French Household Budget survey over-represents the coastal area, which is more exposed to floods and tsunamis (Forgeot and Celma, 2009).

[36]It also specifies whether each municipality is exposed to forest fires, but this hazard is considered insurable and therefore it is not considered a natural disaster (Section 2). See Table 2 for the exposure of each French overseas department to the different natural hazards.

rooms) are missing and 11 for which the declared annual income is below €500. Finally, 2,809 observations remain.

Table 3 describes my sample. The average municipal exposure to natural risks is high but very varied: according to the GASPAR database, while municipalities are on average exposed to 4 distinct natural hazards, some are exposed to 5 hazards, and others to none. On average, 8 natural disasters have occurred since 1990; this number reaches 18 in some municipalities, whereas others have been spared. 48% of households living in the French overseas departments had purchased home insurance, which includes coverage for natural disasters, for their primary residence in 2006. This insurance rate also varies considerably between municipalities: it reaches 92% in some, whereas in others no one is insured. The average premium paid by insured households is €254, with premiums ranging from €20 to €2,000, reflecting significant disparities among the sample population. Annual income ranges from €600 to €169,637 for an average of €22,694. 36% of households are tenants; 13% are homeowners with outstanding loans, the remainder own their home freehold. While dwellings have an average of 4 rooms, some have only 1, others 12. Many houses lack modern conveniences: 23% are without hot water, 53% without drainage, and 4% without toilets inside the building. 3% of houses are still under construction. Finally, the reference person is born in metropolitan France or abroad in 10% and 8% of cases, respectively; this person is a woman in 46% of households; age varies between 17 and 95.

4.2 Specification, identification and calibration of the supply side

As no information is provided on the insurer, only a zero expected profit for all insurers taken together can be considered.[37]

[37] However, some characteristics of policy-holders could capture their choice of insurance company (and this way indirectly modify the premium, even if insurers may not measure them). For example, some insurance companies (mainly mutual ones) cover civil servants exclusively and are said to increase premiums with respect to risk exposure to a smaller extent than other companies. Here dummies for civil servants and other characteristics such as age or gender appear as non significant in the premium estimation.

Table 3: Descriptive statistics

	Percentage / mean	Minimum	Maximum
Number of natural hazards	4	0	5
Number of past natural disasters	8	0	18
Households insured for their primary residence	48%		
Insured households living in the same municipality	47%	0%	0.92%
Premium paid by the insured	€254	€20	€2,000
Annual income	€22,694	€600	€169,637
Standard of living	€13,359	€407	€87,266
Number of rooms	4	1	12
Tenants	36%		
Homeowners with outstanding loans	13%		
Houses still under construction	3%		
Houses without hot water	23%		
Houses without drainage	53%		
Houses without toilets inside the building	4%		
Reference person born in metropolitan France	10%		
Reference person born abroad	8%		
Age of the reference person	49	17	95
Gender of the reference person (female)	46%		

Notes: Are considered in the sum of natural hazards earthquakes, volcanic eruptions, wind effects, floods (including tsunamis), and ground movements. 2006 French Household Budget survey and GASPAR database. 2,809 observations.

Ordinary losses. Ordinary losses L_o depend on dwelling characteristics. More precisely, they depend on the value of contents and of the building. One proxy for the value of contents (mainly jewels and furniture) is the standard of living Y, i.e., income divided by household size.[38] One proxy for the value of the building is the number of rooms N. Losses also depend on occupancy status, since tenants, denoted by $O_t = 1$, do not bear all losses, a part of them being borne by their landlord.[39]

These effects are assumed to be multiplicative: the value of contents in each room increases with respect to the standard of living Y, and the number of pieces of furniture increases with respect to the number of rooms N; last, tenants insure only

[38] The standard of living is measured by the income per consumption unit. The first adult is worth one consumption unit; the second adult and each child older than 14 are worth 0.5; younger children are worth 0.3.

[39] Landlord is responsible for potential damages to contents in furnished dwellings, to the structure (walls, foundations) and for damages implying his liability (structural defects).

a fraction $(1-\tau)$, $\tau \geq 0$ of the total value of the dwelling. l is a multiplicative constant. Thus, the ordinary loss L_{oi} for household i is

$$L_{oi} = lY_i^y N_i^n (1-\tau O_{ti}),\ \tau \geq 0. \tag{15}$$

y and n are the elasticities of the loss with respect to the standard of living and the number of rooms, respectively.[40]

Loss probabilities. I have no specific information on p_o, since I do not observe past ordinary losses nor other proxies for the probability of suffering these losses.

Insurers estimate the probability of natural disasters using information about physical hazards. Business practices indicate that French insurers use very basic information about natural risk exposure, probably because their financial exposure to natural risk is limited due to the reinsurance contract offered by CCR (Section 2); this is a typical case of *ex ante* moral hazard. I assume that the probability of natural disaster estimated by insurers for each household i increases linearly with respect to the sum of hazards R_i to which its municipality is exposed.[41]

$$\text{Insurers: } p_{di} = pR_i,\ p \geq 0. \tag{16}$$

Error. An error ϵ is attached to the supply equation. This error term is due to a potential assessment error made by the insurer. It is assumed to be normally distributed.

Using (9), (15) and (16), I get

$$\begin{aligned} \log(\pi_i) &= \log(cp_o l) + y\log(Y_i) + n\log(N_i) + \log(1-\tau O_{ti}) - \log\left(1 - \frac{ckr}{1+r} - \frac{cpr}{1+r}R_i\right) + \sigma\epsilon, \\ &= c_\pi + y\log(Y_i) + n\log(N_i) + \log(1-\tau O_{ti}) - \log(1-\kappa-\rho R_i) + \sigma\epsilon, \end{aligned} \tag{17}$$

where $c_\pi = \log(cp_o l)$, $\kappa = ckr/(1+r)$, and $\rho = cpr/(1+r)$.

[40] Losses caused by natural disasters are not estimated in the supply equation, as the potential loss and reinsurance premium paid by the insurer are not determined by these losses (Section 2).

[41] R is public information.

Identification and calibration of risk parameters. c_π, $1-\kappa$ and ρ cannot be simultaneously identified. I estimate c_π and ρ and I calibrate $\kappa = ckr/(1+r)$. $r = 0.12$ and $k = 0.635$ are imposed by the government and CCR (Section 2). I calibrate loading factor c using values provided by the literature: $c \approx 1.3$ (Gollier, 2003). Thus, I take $\kappa = ckr/(1+r) \approx 0.088$. Estimations are performed for $c \in \{1, 1.5\}$, that is for $\kappa \in \{0.068, 0.10\}$.

Estimation of $c_\pi = \log(cp_o l)$ does not make it possible to simultaneously identify p_o and l (and c), even when considering that c is already calibrated. I calibrate p_o using statistics provided for metropolitan France: $p_o \approx 0.075$ (FFSA, 2006);[42] estimations are performed for $p_o \in (0.05, 0.5)$. Risk parameter l is deduced from the estimated value of c_π.

Similarly, the risk parameter p will derive from the estimated value of $\rho = cpr/(1+r)$, given that c is calibrated and r is known.

Given that α_i states whether the household i purchases insurance or not, the supply equation becomes

$$\begin{cases} \text{if } \alpha_i = 1, \ \log(\pi_i) = c_\pi + y\log(Y_i) + n\log(N_i) + \log(1-\tau O_{ti}) \\ \qquad\qquad\qquad\qquad - \log(1-\boldsymbol{\kappa}-\rho R_i) + \sigma\epsilon_i, \\ \text{if } \alpha_i = 0, \ \pi_i = 0, \end{cases}$$

where $c_\pi = \log(cp_o l)$ and $\rho = cpr/(1+r)$ are estimated parameters and $\boldsymbol{\kappa} = ckr/(1+r)$ is calibrated.

[42] In metropolitan France, between 2000 and 2004, home insurance statistics complied by the French Federation of Insurance Companies show that the frequency of ordinary risks is around $p_o \approx 0.075$ (FFSA, 2006). Abroad, the probabilities of some of the ordinary risks are of the same order of magnitude. In Taiwan, the probability of fire occurrences in residential buildings per m^2 of floor space is around 0.01 (Lin, 2005). In Long Beach (CA), the probability of burglary is around 1.9% for a house which has never been burglarized and reaches 59% after a first burglary (Short et al., 2009).

4.3 Specification, identification and calibration of the demand side

Utility function and risk aversion. In an expected utility setting, constant relative risk aversion is a reasonably good approximation of individual attitude toward risk (Chiappori and Salanié, 2008). A constant relative risk aversion λ with respect to income corresponds to the following utility function: $U(W) = W^{1-\lambda}/(1-\lambda)$. The literature has estimated different values for λ (Chiappori and Salanié, 2008). Estimations are performed here under the assumption that utility is the log function, which is the limit case of $U(W) = W^{1-\lambda}/(1-\lambda)$ as λ tends to 1. Results are robust when using $\lambda = 2$ or $\lambda = 3$.[43]

Losses and loss probabilities. As households are assumed to have the same estimation as insurers of their ordinary losses L_o (Section 3), losses L_o are simultaneously estimated in the supply equation - but for the insured households only - and in the demand equation. On the contrary, losses $\tilde{L}_d$ intervene in the demand equation only.[44] Losses $\tilde{L}_d$ caused by natural disasters fundamentally depend on the same dwelling characteristics as ordinary losses L_o. For the sake of simplicity, I assume that, for every household i,

$$\tilde{L}_{di} = \beta L_{oi}, \beta \geq 1. \tag{18}$$

Because of this intrinsic link between ordinary losses and losses caused by natural disasters (that remains even in a nonproportional specification), the utility decrease caused by ordinary losses, weighted by their occurrence probability, $\tilde{p}_o[U(W) - U(W - L_o)]$, and the utility decrease caused by natural disasters, weighted by their

[43]Estimation of risk aversion raises numerical problems. Indeed, risk aversion determines the orders of magnitude of the terms expressing the expected utility losses; and if the orders of magnitude of the variables in the demand equation strongly differ, the model may be wrongly estimated (coefficients corresponding to the negligible terms may appear as non significant). For example, in the case of the log function, I use $U(W) = c_U \log(W)$, with $c_U = 10$. Indeed, with $c_U = 1$ the terms expressing the expected utility losses would be too small by comparison to the other terms (Equation 14) and the corresponding coefficients would be poorly estimated. The adequate value of c_U would be different when using another value of risk aversion λ. Note that c_U and λ cannot be simultaneously identified.

[44]Losses caused by natural disasters are not estimated in the supply equation, as the potential loss and reinsurance premium paid by the insurer are not determined by these losses (Section 2).

occurrence probability, $\tilde{p}_d[U(W) - U(W - L_d + \tilde{A}_d)]$, are fundamentally linked and $(\tilde{p}_o, \tilde{p}_d, \beta)$ cannot be simultaneously identified. I favor the estimation of the natural disasters parameters, which makes it possible to capture charity hazard, and I calibrate β and $\tilde{p}_o$.[45]

In metropolitan France, the ratio of mean natural disaster losses over mean ordinary losses $\bar{L}_d/\bar{L}_o$ ranges from 6.25 to 12.5.[46] Given that natural disasters are more intense events in the French overseas departments, I take $\beta = 15$. As a sensitivity test, I have performed estimations for $\beta \in (10, 20)$ and the significance and sign of all estimated coefficients are robust to the choice of this parameter.[47]

The probability of ordinary losses $\tilde{p}_o$, for which no proxies is observed, is calibrated. Section 5 presents the results under the assumption that $\tilde{p}_o = 0.075$. Estimations are performed for $\tilde{p}_o \in (0.05, 0.5)$, while allowing $\tilde{p}_o$ to be different from p_o. Significance and sign of all estimated coefficients are robust to the choice of these parameters.

Learning from past disasters. The number S of past disasters that have occurred in each municipality from the enforcement of the insurance system (1990) to the sampling date (2006) is public information. Past disasters have a dual impact on households' estimation of their exposure to natural disasters. First, the number of past disasters increases households' estimation of their probability $\tilde{p}_d$ of suffering another disaster. Second, this number modifies households' expectation of receiving assistance, since their expectation is based on compensation provided to them after past events. Thus, households' expected assistance $\tilde{A}_d$ depends on number S of past disasters and on penetration rate $E(Z_{\text{aid}})$ of the group J_a of joint eligibility for assistance (Section 3): $\tilde{A}_d(S, E(Z_{\text{aid}}))$. Given that no proxy for expected assistance is

[45]Even once β is calibrated, $\tilde{p}_o$ and a fixed part a in an affine function $\tilde{p}_d(S) = a + bS$ are not simultaneously identified.

[46]In metropolitan France, between 2000 and 2004, home insurance statistics complied by the French Federation of Insurers Companies show that the average damages caused by ordinary risks are around €1,200 (FFSA, 2006). Average damages caused by floods and ground movements for metropolitan households are around €7,500 and €15,000, respectively (Grislain-Letrémy and Peinturier, 2010).

[47]Indeed, as the potential losses cannot exceed the wealth of the household, wealth determines the upper limit of the range of values for β. For $\beta = 20$, the potential losses already exceed the wealth of 17 households. Estimations provide consistent orders of magnitudes: losses L_o are between €300 and €2,700 (for $\beta = 15$).

observed (Section 4), the two impacts of the number S of past disasters on insurance demand must be disentangled in order to capture charity hazard.

More formally, in the theoretical model,

$$\alpha = 1 \Leftrightarrow [\log(W-\pi) - \log(W)] + \tilde{p}_o[\log(W) - \log(W-L_o)] + q_d(S, E(Z_{\text{aid}}))[\log(W) - \log(W-\beta L_o)] + \sum_k o_k O_k + \sum_{k'} h_{k'} H_{k'} + \delta E(Z_{\text{peer}}) + \nu\epsilon + \eta \geq 0, \quad (19)$$

where $q_d(S, E(Z_{\text{aid}}))$ "summarizes" the two impacts of past disasters: estimation of the probability $\tilde{p}_d$ of natural disasters and of expected assistance $\tilde{A}_d$.[48] Indeed, as the number S of past disasters increases, insurance demand is modified by a premium increase and a utility loss. The premium increase effect (PIE) refers to the fact that an increase in insurance price (as risk exposure and number of past disasters are correlated) may reduce insurance demand. The utility loss effect (ULE) denotes the fact that the anticipated loss of utility may also increase, which should on the contrary increase insurance demand. If the anticipation of assistance also increases with respect to the number of past disasters, the utility loss effect is reduced: this is the charity hazard effect (CHE). The sign of $\partial\alpha/\partial S$ is determined by the sign of

$$\underbrace{-\frac{\partial \pi}{\partial p_d}\frac{\partial p_d}{\partial S}\frac{dU}{dW}}_{\text{PIE}\leq 0} \underbrace{\underbrace{-\frac{\partial \tilde{p}_d}{\partial S}(U(W-\tilde{L}_d+\tilde{A}_d(S)) - U(W))}_{\text{ULE}\geq 0} \underbrace{-\underbrace{\tilde{p}_d(S)}_{\geq 0}\underbrace{\frac{\partial \tilde{A}_d}{\partial S}}_{\geq 0}\underbrace{U'(W-\tilde{L}_d+\tilde{A}_d(S))}_{\geq 0}}_{\text{CHE}\leq 0}}_{\text{ULE+CHE}=-\frac{\partial q_d}{\partial S}\text{UL}}. \quad (20)$$

As data on assistance are unavailable, only the sum of ULE and CHE can be identified. Thus, estimation reveals the existence of a charity hazard effect only if it exceeds the utility loss effect, i.e., only if $|\text{CHE}| \geq \text{ULE}$ that is only if $\frac{\partial q_d}{\partial S} \leq 0$. If on the contrary $\frac{\partial q_d}{\partial S} > 0$, $|\text{CHE}| < \text{ULE}$ and this would be consistent with a small

[48] Simultaneous estimation of functional forms of $\tilde{p}_d$ and A_d with respect to S obtains non robust results, as it can lead either to positive values, as expected, or to a huge amount of assistance (beyond loss, i.e., $A_d > L_d$) that would make the utility decrease positive: households would gain in the case of natural disasters and then $\tilde{p}_d$ becomes negative to balance this effect.

or null value of the charity hazard effect, CHE.

$$\frac{\partial q_d}{\partial S} \leq 0 \Leftrightarrow |\text{CHE}| \geq \text{ULE} \Rightarrow \frac{\partial \tilde{A}_d}{\partial S} \geq 0. \tag{21}$$

Indeed, a negative sign of $\partial q_d/\partial S$ would indicate that households' anticipation of assistance increases with respect to the number S of past disasters that have occurred in the municipality (Equation 20). This would correspond to a cumulative effect in the anticipation of assistance: households living in municipalities where numerous disasters have occurred are probably more aware than other households of the scope of assistance; therefore they anticipate higher amounts of *ex post* aid.

Besides, to test for the endogenous nature of anticipated assistance (Section 3), the expected penetration rate $E(Z_{\text{aid}})$ of the group J_{aid} of joint eligibility for assistance is crossed with the charity hazard effect. Thus, for each household i,

$$q_{di} = (q + \theta E(Z_{\text{aid},i}))S_i. \tag{22}$$

A negative sign of q would indicate a charity hazard effect and a positive sign of θ would mean that the percentage of insured neighbors decreases this charity hazard effect, as it decreases the individual likelihood of obtaining assistance after a disaster.

Let us check that no other phenomenon could imply a negative sign of q. First, perception bias could decrease $\partial \tilde{p}_d/\partial S$ and therefore the demand for insurance (Section 2) but it would not imply a negative sign for the estimated coefficient $\partial q_d/\partial S$: in the presence of perception bias, the perceived utility loss would still increase with respect to the number S of past disasters, even if the belief in the law of small numbers is considered. This belief is the tendency to think that once a dwelling has been damaged by a disaster, the probability of being struck again is lower (Tversky and Kahneman, 1981). Households may hold this belief after one disaster, but are unlikely to after having been struck several times, as is the case here - they have suffered 8 disasters on average since 1990 (Table 3). Second, a negative sign of q could derive from uncontrolled differences in risk aversion. In other words, one cannot exclude for now that more exposed households do not purchase insurance because they have a lower risk aversion.[49] However, data show that households living in more exposed areas are presumed to be actually more risk averse (Table 4): they are older, the proportion of women among them is higher.[50] Besides, among households living in more exposed areas, the proportions of people either born in metropolitan France (who could be used to managing risk differently), or who purchase automobile insurance - with limited or extended coverage -[51] are not significantly higher.[52]

Table 4: Self-selection on housing market: correlation between proxies for risk aversion and the number of past disasters in the municipality

	Correlation value	Pr > |r|
Age of the reference person	0.060	0.0015
Gender (female) of the reference person	0.068	0.0003
Place of birth (metropolitan France) of the reference person	-0.0032	0.86
Insured automobile	-0.0053	0.78
Comprehensive automobile coverage	0.029	0.13

Notes: 2006 French Household Budget survey and GASPAR database. 2,809 observations.

Adverse selection because of insurance pricing? On the contrary, if $q \geq 0$, I can test whether there is adverse selection, that is whether

$$\text{ULE} + \text{CHE} \geq |\text{PIE}|, \tag{23}$$

i.e., whether $\partial\alpha/\partial S \geq 0$. Insurance subsidization for exposed households by less exposed households could lead to an extensive adverse selection, that is to a higher

[49] Heterogeneities in wealth or in dwelling quality are already taken into account in the demand equation. The location choice of wealthy households is not significantly correlated with risk exposure; good quality dwellings are on average built in more exposed areas (Section 2).

[50] Levin et al. (1988), Powell and Ansic (1997), Halek and Eisenhauer (2001) and Jianakoplos and Bernasek (1998) show that women are more risk averse than men. Morin and Suarez (1983), Palsson (1996) show that the risk aversion increases with respect to age; however, cohort effects may complicate the impact of age on risk aversion (Brown (1990), Jianakoplos and Bernasek (1998)). Besides, risk aversion depends on the contextual framework (Schubert et al. (1999)).

[51] Only third-party insurance is mandatory for automobiles. Only 1.5% of households own a car without this coverage.

[52] These statistics also confirm that supply accessibility is not lower for exposed households. Indeed, difficulties in terms of supply accessibility are especially limited for home insurance, as households can purchase a home insurance policy over the phone in approximately 20 minutes.

participation of exposed households in the insurance market. Here, adverse selection would mainly derive, not from insurers' lack of information, but from their limited incentive to use information because of reinsurance policies (Section 2): as insurers bear a very small share of losses caused by natural disasters, insurance premiums only partially reflect natural risks and this subsidizes exposed households.

Insurance obligations. Dummies for tenants O_t and for homeowners with outstanding loans O_l are added to control for these insurance obligations and to measure their impact.[53] Results are robust when tenants and homeowners with outstanding loans are excluded from the sample and also when the model is estimated either for tenants only.[54]

Uninsurable housing. Data provide information about dwelling quality, but not about dwelling compliance with building standards or permits (Section 4). The Inter-American Development Bank defines the insurable housing market as housing built in solid materials and with drinking water and drainage (IDB, 2000). Here I control for uninsurability by adding dummies for low quality housing: a dummy H_c for houses still under construction and three dummies for houses without modern conveniences (without hot water H_w, without drainage H_d, and without toilets inside the house H_t).

Groups of peers and of joint eligibility for assistance. Different definitions for the group J_{peer} of peers and for the group J_{aid} for joint eligibility have been tested by crossing the municipal level (which is the smallest geographical level that I observe) with any other observed household characteristic (such as age, gender, occupational groups, place of birth).[55]

The place of birth can also explain the probability of purchasing insurance via an

[53] Monitoring of insurance renewal may be partly performed in public housing. Unfortunately, information about public housing is unavailable.

[54] An estimation for homeowners with outstanding loans only is not possible, as they are only 336 of them.

[55] When the geographical level is the municipality, the geographical impact is implicitly assumed to be uniform across municipalities, as there are too many municipalities to allow for different coefficients between municipalities.

"initial peer effect". Indeed, as the insurance penetration rate of metropolitan France is exceptionally high (Grislain-Letrémy and Peinturier, 2010), growing up in a place where the vast majority of people are insured can increase the probability of purchasing insurance. Hence the addition of dummies B_m and B_a for households born in metropolitan France and abroad, respectively, to the demand equation.

Wealth. The wealth measure used to perform estimations corresponds to households' holdings. Indeed, households can lose almost all their possessions in the case of a natural disaster. For the sake of simplicity, I assume that the household's observed annual income w is constant over time until the death of the household's reference person. I denote by A the age of the household's reference person and E his/her life expectancy, which is calculated by linear interpolation using registry office statistics (Niel and Beaumel, 2010). Here I use the discount rates recommended by Gollier (2007), that is $r_1 = 4\%$ until 30 years and $r_2 = 2\%$ beyond. Thus, I get

$$W = \sum_{0 \leq t \leq E-A} \frac{w}{(1+r_1)^t} \quad \text{if } E - A \leq 30, \tag{24}$$

$$= \sum_{0 \leq t \leq 30} \frac{w}{(1+r_1)^t} + \sum_{31 \leq t \leq E-A} \frac{w}{(1+r_1)^{31}(1+r_2)^{t-31}} \quad \text{otherwise.} \tag{25}$$

This corresponds to a multiplication of the annual income by a factor that depends on the age of the reference person: it varies from 6 for the 95-year-olds to 24 for the 17-year-olds, with an average of 18. Significance and sign of all coefficients are robust to this modification: they are similar when using the holdings as defined here or the annual income. They are even robust when uniformly multiplying annual income up to 100.[56]

Selection bias. I add the term $\nu\epsilon$, where ϵ is the error attached to the insurance premium. This term allows for a selection bias, i.e., for correlation between unobserved heterogeneity factors that affect the insurance premium and the decision to purchase insurance.

[56]Indeed, at the first order, the constant by which income is multiplied can be factorized in the terms implying income (Equation 26). Thus, its presence mainly modifies the order of magnitude of the coefficients of these terms.

Error. Another error η is also attached to the decision to purchase insurance. It can be interpreted as an assessment error made by households. It is also assumed to be normally distributed. ϵ and η are assumed to be independent, since possible correlation is taken into account by the selection bias term.

Finally, the estimated model is

$$\begin{cases} \alpha_i = 1 \Leftrightarrow [\log(W_i - \pi_i) - \log(W_i)] + \tilde{\boldsymbol{p}}_{\boldsymbol{o}}[\log(W_i) - \log(W_i - L_{oi})] \\ \qquad +[qS_i + \theta E(Z_{\text{aid},i})S_i][\log(W_i) - \log(W_i - \boldsymbol{\beta} L_{oi})] + o_t O_{ti} + o_l O_{li} \\ \qquad +h_c H_{ci} + h_w H_{wi} + h_d H_{di} + h_t H_{ti} + \delta E(Z_{\text{peer},i}) + b_m B_{cli} + b_a B_{ai} + \nu\epsilon_i + \eta_i \geq 0, & (26) \\ \text{if } \alpha_i = 1, \log(\pi_i) = c_\pi + y\log(Y_i) + n\log(N_i) + \log(1 - \tau O_{ti}) \\ \qquad\qquad - \log(1 - \boldsymbol{\kappa} - \rho R_i) + \sigma\epsilon_i, & (27) \\ \text{if } \alpha_i = 0, \pi_i = 0. \end{cases}$$

where errors ϵ and η follow independent centered normal distributions with unit variance, $c_\pi = \log(cp_o l)$ and $\rho = cpr/(1+r)$ are estimated parameters and $\boldsymbol{\kappa} = ckr/(1+r)$, $\tilde{\boldsymbol{p}}_{\boldsymbol{o}}$ and $\boldsymbol{\beta}$ are calibrated parameters.

Identifying variables. Identification requires the presence of variables that explain the probability of purchasing insurance but not the insurance premium. These identifying variables are the dummies for houses still under construction (H_c) and without drainage (H_d).[57] Economically, this means that houses still under construction and without drainage have a lower probability of being insured (because they are probably uninsurable) but, once a house is covered, the price of its coverage does not depend on these characteristics.

The model is overidentified, as identification requires one variable only to be excluded from the demand equation. Here, the two identifying variables are compatible: when only one of them is excluded from the premium, the remaining one is not significant in the premium equation and both variables are significant in the

[57] Houses still under construction and houses without drainage correspond to 3% and 53% of dwellings, respectively (Table 3). These dummies (like the dummies for houses without hot water or toilets inside the dwelling) do not significantly explain the losses, even when considering that losses can be estimated differently by households and by insurers.

demand equation.

5 Results

Estimation is based on maximum likelihood and is detailed in Appendix A.

5.1 Supply

Insurance pricing. Table 5 presents the results of the estimation of the insurance premium (Equation 27). As expected, the insurance premium increases with respect to the standard of living ($y > 0$) and the number of rooms of the dwelling ($n > 0$), which are proxies for the insured value (contents and building values). Besides, as tenants insure only a fraction of the total value of the dwelling, the insurance premium is lower for tenants ($\tau > 0$). The premium increases with respect to exposure to natural disasters ($\rho > 0$), confirming that insurers' potential loss depends on the exposure of their policyholders, even if only to a very limited extent (Section 2).

Table 5: Estimation results: supply equation

Coefficient	Estimate	Standard error	Pr > |t value|
c_π	2.4	0.16	<0.0001
y	0.22	0.016	<0.0001
n	0.32	0.047	<0.0001
τ	0.29	0.027	<0.0001
ρ	0.056	0.0068	<0.0001
σ	0.61	0.015	<0.0001
$\boldsymbol{\kappa}$	0.088	0	

Notes: $\boldsymbol{\kappa} = ckr/(1+r)$ is calibrated at 0.088 (using $c = 1.3$, $k = 0.635$ and $r = 0.12$). 2006 French Household Budget survey and GASPAR database. 2,809 observations.

Insurance affordability. Some overseas households may not be able to afford insurance, as the median standard of living in the French overseas departments is almost 40% lower than in metropolitan France (Michel et al., 2010). To determine whether insurance is affordable for overseas households, the premiums offered to the uninsured are estimated using these coefficients.[58]

The premiums offered to the uninsured are on average 9% lower than the premiums paid by the insured, mainly because the uninsured are poorer on average (Table 6).[59] As the premium increases less than proportionally with respect to income ($y < 1$, Table 5), the budget weight (ratio of the premium over annual income) decreases with respect to income: the budget weight of the premium is therefore higher for the uninsured (the mean being 2.1%) than for the insured (1.4%), though it remains low (Table 6). The low budget weight of insurance premiums for the uninsured suggests that insurance premiums should not prevent them from purchasing insurance. To answering that question properly, an estimation of insurance demand, and in particular of the elasticity of insurance demand with respect to the premium, is required.

Table 6: Home insurance: premium and budget weight

	Mean	Lower quartile	Median	Upper quartile
Uninsured households				
Premium (2006 €)	231	187	236	274
Annual income (2006 €)	15,735	7,756	13,032	20,236
Budget weight	2.1%	1.2%	1.7%	2.6%
Insured households				
Premium (2006 €)	254	118	180	300
Annual income (2006 €)	30,217	13,974	25,056	40,222
Budget weight	1.4%	0.5%	0.8%	1.4%

Notes: 2006 French Household Budget survey and GASPAR database. 2,809 observations.

[58]These estimated coefficients (Table 5) correct the presence of a significant selection bias in Equation 26 (Table 7). In other words, this estimation takes into account the presence of unobserved heterogeneities that increase the probability of purchasing insurance and the insurance premium. These unobserved heterogeneities may be relative to risk aversion: households with higher risk aversion have a higher probability of purchasing insurance; their higher risk aversion may be partially measured by insurers and therefore reflected in their premium. Regarding residuals, using their estimated variance implies that residuals for the uninsured are assumed to have the same variance as those for the insured.

[59]The elasticity of demand with respect to income is estimated in Section 5.2.

5.2 Demand

Table 7 presents the estimation results for the demand equation (Equation 26). These results are now precisely commented and derived to quantify and compare the magnitude of demand determinants.

Table 7: Estimation results: demand equation

Coefficient	Estimate	Standard error	Pr > |t value|
o_t	0.34	0.070	<0.0001
o_l	0.83	0.094	<0.0001
h_c	-0.71	0.23	0.0020
h_w	-0.85	0.076	<0.0001
h_d	-0.50	0.061	<0.0001
h_t	-0.70	0.20	0.00050
q	-0.065	0.011	<0.0001
θ	0.095	0.020	<0.0001
δ	0.67	0.13	<0.0001
b_m	0.77	0.11	<0.0001
b_a	-0.53	0.099	<0.0001
ν	0.41	0.095	<0.0001
$\boldsymbol{\tilde{p}_o}$	0.075	0	
$\boldsymbol{\beta}$	15	0	

Notes: $\boldsymbol{\tilde{p}_o}$ and $\boldsymbol{\beta}$ are calibrated at 0.075 and 15, respectively. 2006 French Household Budget survey and GASPAR database. 2,809 observations.

Low elasticity of insurance demand with respect to the premium. The elasticity of insurance demand with respect to the premium can be calculated from these results. The elasticity of insurance demand with respect to the premium is $-5 \cdot 10^{-4}$, which is far lower than results found by other studies for home and flood insurance (Table 8).[60] When the premium increases by 50%, the number of households that are willing to purchase insurance decreases by only 0.2%. This small price elasticity is due to the subsidized natural disasters coverage provided by home insurance. This result confirms that overseas households are not deterred from purchasing insurance by its price.

[60]This is not due to the fact that the premium is negligible with respect to households' holdings. Indeed, even when the model is estimated using annual income as wealth, the price elasticity of insurance demand remains low ($-5 \cdot 10^{-2}$).

Income elasticity of insurance demand. The elasticity of insurance demand with respect to income can also be calculated and its order of magnitude is consistent with other studies (Table 8).[61] The income elasticity of insurance demand equals 0.10. Its positive sign confirms that the insured are wealthier on average than the uninsured (Table 6). Income elasticity of insurance demand may be positive or negative. Indeed, two opposite effects come into play. On the one hand, theory predicts that while absolute risk aversion decreases with respect to income, demand for insurance also decreases with respect to income (Schlesinger, 2000). On the other hand, wealthier households may buy more expensive houses, thereby exposing themselves to higher potential losses and increasing their need for coverage (Cleeton and Zellner, 1993).[62] Here a third effect is probably also involved. Low-income households are likely to benefit from more assistance after natural disasters,[63] which decreases insurance demand from low-income households. The positive sign of income elasticity means that the two latter effects outstrip the former.

Table 8: Price and income elasticities of demand for home and flood insurance

Line of insurance and place	Definition of demand	Price elasticity	Income elasticity	Citation
Home insurance				
French overseas departments	(PP)	$-5 \cdot 10^{-4}$	0.10	Current study
Florida	(FA)	-1.08	0.06	Grace et al.
New York	(FA)	-0.86	-0.03	(2004)
National flood insurance				
Unites States	(PP)	-0.11	1.40	Browne and
Unites States	(FA)	-1.00	1.51	Hoyt (2000)

Notes: insurance demand is defined either by the percentage of the population that has purchased policies (PP) or by the face amount of coverage (FA).

Insurance obligations. Tenants, and homeowners with outstanding loans even more so, have a higher probability of purchasing insurance than homeowners ($o_l > o_t > 0$). This result shows that the existing constraints relative to insurance purchase

[61] Given that wealth is proportional to income (Section 4), elasticities with respect to wealth or to income are identical.

[62] Cleeton and Zellner (1993) show that the income elasticity of insurance demand is positive if $\phi_a + \eta > 1$, where ϕ_a is the elasticity of relative risk aversion to initial income and η is the elasticity of the amount of risk with respect to initial income.

[63] For example financial assistance by the disaster relief fund for overseas areas decreases with respect to income.

are operant. Moreover, they have a significant impact: if all households were tenants, the percentage of insured households would go from 48% (Table 3) to 60% (Table 9); if all households were homeowners with outstanding loans, the percentage of insured households would reach 72% (Table 9).[64]

Uninsurable housing. As expected, households living in a house under construction or without modern conveniences have a lower probability of purchasing insurance ($h_c, h_w, h_d, h_t < 0$). In practice, insurers can check building quality and permit, either before selling the policy or before paying compensation once a loss has occurred. In any case, this check can easily be anticipated by households. The impact of uninsurable housing is significant: if all households were living in a house still under construction, the percentage of insured households would drop from 48% to 19%; if all dwellings were houses without hot water, the insurance penetration rate would drop to 13%; if they were living in a house without drainage, this rate would drop to 36%; if all dwellings were houses without toilets inside the building, this rate would drop to 19% (Table 9).

Table 9: Impact of uninsurable housing and insurance obligations on insurance demand

Assumption	Percentage of insured households
$O_t = 1$	60
$O_l = 1$	72
$H_c = 1$	19
$H_w = 1$	13
$H_d = 1$	36
$H_t = 1$	19

Notes: the initial percentage of insured households is 48%. 2006 French Household Budget survey and GASPAR database. 2,809 observations.

Charity hazard. The probability of purchasing insurance decreases with respect to the number of past disasters that have occurred in the municipality. As ex-

[64]Purchasing home insurance is also a condition for obtaining a mortgage in the United States (Browne and Hoyt (2000), Kunreuther and Pauly (2006)) (Section 2). Browne and Hoyt (2000) show that the number of mortgages per capita in the United States is negatively related to the number of policies purchased per capita, probably because the level of mortgages captures wealth and income effects.

plained in Section 4, the negative sign of q reveals the presence of charity hazard that outweighs the utility loss effect, and means that households' anticipation of assistance increases with respect to the number of past disasters that have occurred in the municipality. There is indeed a cumulative effect in the anticipation of assistance: households living in municipalities where numerous disasters have occurred are more aware than other households of the scope of assistance; therefore they anticipate higher amounts of *ex post* aid.

A vicious circle of uninsurance. The penetration rate in the neighborhood increases the individual probability of purchasing insurance ($\delta > 0$), which reveals peer effects: the more neighbors are insured, the higher the individual probability of purchasing insurance. This peer effect is significant at the municipal level, but not when defining the group of peers as households that share the same observed characteristics within a municipality.

The penetration rate in the group for aid eligibility decreases the charity hazard effect ($\theta > 0$): the percentage of insured households around one individual decreases his/her likelihood of obtaining assistance after a disaster. The relevant group for aid eligibility is also the municipality ($J_{\text{aid}} = J_{\text{peer}}$). This suggests that there is no favoritism towards households sharing one of the observed characteristics.[65]

Assuming that 3 out of 4 households living in the municipality were insured, if there were peer effects only, the individual probability of purchasing insurance would reach 0.65; if the endogenous nature of assistance only was at stake, this probability would reach 0.49 (Table 10).

The place of birth explains the probability of purchasing insurance when this characteristic is simply added to the demand equation. Indeed, all things being equal, households whose reference person is born in metropolitan France have a higher probability of purchasing insurance ($b_m > 0$), whereas households born abroad have a lower probability of purchasing insurance ($b_a < 0$). This result suggests that hav-

[65] Both external effects of neighbors' decision to purchase insurance (based on peer effect or aid eligibility) remain significant when considering one without the other.

Table 10: Impact of the municipal insurance rate

Assumption	Individual probability of purchasing insurance
Municipal insurance rate = 75%	
via peer effects only	0.65
via aid eligibility only	0.49

Notes: the initial probability of purchasing insurance is 0.48. 2006 French Household Budget survey and GASPAR database. 2,809 observations.

ing grown up in a place where the vast majority of people are insured increases the probability of being insured. This "initial peer effect" is also of considerable magnitude. If all households were born in metropolitan France, the percentage of insured households would go from 48% to 71%. On the contrary, if all households were born abroad, the percentage of insured households would drop from 48% to 29% (Table 11).

Table 11: Impact of the place of birth on insurance demand

Assumption	Percentage of insured households
$B_m = 1$	71
$B_a = 1$	29

Notes: the initial percentage of insured households is 48%. 2006 French Household Budget survey and GASPAR database. 2,809 observations.

Therefore households are not deterred from purchasing insurance by relatively high insurance premiums but by assistance provided after disasters; uninsurable housing also decreases the probability of being insured. My findings also suggest that neighbors' insurance choices impact individual's decision to purchase insurance via peer effects and via neighborhood eligibility for assistance.

6 Discussion

The French overseas departments provide a rare natural experiment of a well-developed supply of natural disasters insurance in Latin America, the Caribbean and other exposed small island countries. The determinants of insurance coverage on the demand side are uninsurable housing, which mainly applies in developing countries, and charity hazard, which also applies widely in developed countries. Implications of these insurance demand factors in terms of public policy will now be discussed in detail.

6.1 Uninsurable housing

Uninsurable housing applies widely in developing countries (Gilbert, 2001) and is well documented in Latin America and the Caribbean (Section 2). Many developing countries (located in Africa, the Asia and Pacific region, Europe or the Middle East) benefit from World Bank aid specifically dedicated to housing repair or rebuilding (Gilbert, 2001). These reconstruction projects often include the improvement of housing quality (introduction or use of earthquake resistant materials and designs, training of local masons, carpenters and tradesmen) (Gilbert, 2001). In the French overseas departments, a system of building aid is already in place (Tjibaou, 2004).[66] This housing policy has been instrumental in lowering the proportion of uninsurable housing (Table 12). This probably partly explains why the penetration rate has been progressively increasing (except in French Guiana, where uninsurable housing remains particularly widespread) since 1995 (Table 13), given that the impact of uninsurable housing on insurance demand is important (Section 5, Table 9).

Table 12: Evolution of housing quality in the French overseas departments

Share of (%) in 1999 / in 2007	Permanent structures	Wooden dwellings	Traditional huts	Makeshift dwellings
French Guiana	68.0 / 73.0	16.8 / 16.4	10.3 / 6.5	4.8 / 4.2
Guadeloupe	74.8 / 89.6	10.1 / 5.5	12.6 / 3.6	2.5 / 1.2
Martinique	88.5 / 93.7	5.3 / 3.6	4.4 / 1.1	1.8 / 1.7
Réunion	73.7 / 86.2	10.3 / 4.2	14.0 / 8.5	2.1 / 1.1

Notes: Only primary residences are considered. Dwellings can be houses or apartments. Population census by INSEE in 1999 and 2007.

[66] Furthermore, recent legal developments allow the owners of squalid dwellings with neither right nor title to be compensated if public operations require their dwelling to be demolished. See law n^{0}2011-725 of June 23, 2011 relative to informal housing districts and poor housing in overseas departments and regions.

Table 13: Evolution of home insurance penetration rate in the French overseas departments

(%)	1995	2001	2006
French Guiana	47	38	52
Guadeloupe	29	32	44
Martinique	39	41	50
Réunion	29	45	59

Notes: French Household Budget survey by INSEE in 1995, 2001 and 2006. 2,922 observations in 1995, 3,302 in 2001, 3,134 in 2006.

6.2 Charity hazard

Charity hazard is significant in many developing countries (Gilbert, 2001), including in the Caribbean region (Section 2); some aid programs, for example from the World Bank, are specifically dedicated to housing repair or rebuilding in developing countries (Gilbert, 2001). Charity hazard is also present in developed countries (see Raschky and Weck-Hannemann (2007) for a review).

Many European countries (Austria, Czech Republic, Germany, Italy, Poland, Slovakia) combine public assistance and private insurance with a low penetration rate (Maccaferri et al., 2012).[67] For example, in Canada, public assistance is also developed (through the Disaster Financial Assistance Arrangements and local funds created by some provinces) and Canadian households do not distinguish between public aid and compensation provided by insurers (Dumas et al., 2005). In Germany and Italy, insurance is private and governmental assistance to flood victims is provided on an ad hoc basis; less than 10% of German households and about 5% of Italian buildings are insured against floods (Bouwer et al. (2007), Schwarze and Wagner (2007)). These few examples illustrate differences in the institutional design of governmental relief programs between countries. This design - more its transparency than the magnitude of coverage - significantly determines the demand for private natural hazard insurance (Raschky et al., 2010).

[67] In all these countries that combine public assistance and private insurance, it is difficult to determine the causality between the development of public assistance and the low penetration rate of private insurance: was demand for private insurance reduced because of public aid? Or was assistance initially developed to make up for a limited supply of private insurance?

Charity hazard may also occur in developed countries where public assistance co-exists with public insurance. In the United States, flood insurance is offered by the Federal State and is purchased by a minority of households (Dixon et al. (2006), Kunreuther (1984)).[68] Before Hurricane Katrina, Browne and Hoyt (2000) and Kunreuther and Pauly (2006) showed that a key explanation for American households' low demand for natural disasters insurance was their biased risk perception rather than charity hazard.[69] After Hurricane Katrina, the Bush administration committed to providing billions of dollars in disaster relief to victims; this may have induced an expectation of Federal assistance (Kunreuther and Pauly, 2005). Petrolia et al. (2012) show that the decision to purchase a flood policy is positively correlated with the eligibility for disaster assistance.

To what extent is charity hazard an issue? After all, as recalled by Raschky and Weck-Hannemann (2007), a catastrophe fund is *de facto* "mandatory insurance". Indeed, one can argue that public assistance is not that different from insurance subsidy: public assistance is a cross-subsidization from less exposed taxpayers to more exposed ones; similarly, insurance subsidy is a cross-subsidization from less exposed insured households to more exposed ones. This comparison is especially relevant for countries where insurance pricing implies insurance subsidy, such as France or the United States. Indeed, in France, the natural disasters premium is a fixed share of the home insurance premium (Section 2). In the United States, flood insurance is actuarial with subsidies for specific risks and 22% of flood insurance policies are subsidized (Hayes and Neal, 2009).

Coate (1995) answers with this very precise objection: compensation provided by insurance is defined *ex ante*, whereas compensation provided by aid is often defined *ex post*. This main difference has two important consequences, both underlined by

[68]In the United States, flood insurance, which is offered by the Federal State to households, is purchased by around half of the single-family homes living in special flood hazard areas - i.e, zones with a 100-year recurrence interval for floods - and by only 1% of single-family homes outside these zones (Dixon et al., 2006).

[69]For example, Browne and Hoyt (2000) test the presence of charity hazard and find a positive correlation between governmental aid and flood insurance purchase - and not a negative one. Their interpretation is that flood exposure may increase both governmental aid and insurance purchase.

Coate (1995).

First, *ex post* assistance is likely to be inefficient. There are two main reasons to expect that people who provide assistance will not choose the optimal level of assistance. The first reason is that assistance may rely on approximate loss assessment or even on discretionary decisions. In the United States, half of disaster payments by the Federal Emergency Management Agency are politically motivated (Garrett and Sobel, 2003).[70] The second reason is that the uninsured can free-ride, since natural disasters assistance is provided via different channels. In that respect, the assistance providers themselves can consider that the level of assistance is not optimal.

Second, providing *ex post* assistance reduces self-responsibility and gives no incentive for prevention. It does not make households refrain from living in exposed areas or from building vulnerable houses, whereas these choices increase future losses and therefore future assistance provided by society as a whole. Certainly, insurance subsidy also reduces self-responsibility, but this subsidy can be made temporary or combined with other incentives for prevention. For example, in the United States, this subsidy is temporary: flood insurance is provided at subsidized rates until the completion of the community's flood rate map. In France, this subsidy is combined with incentives for prevention: the natural disasters insurance deductible increases with respect to the number of past disasters that have occurred in the municipality;[71] increasing the premium with respect to risk exposure could also be considered.[72] For such insurance policies to be efficient it is clearly necessary that the most exposed households purchase insurance.

[70] Similarly, in Pakistan, after the 2001 flood in Islamabad and Rawalpindi, public support checks were mainly distributed to family members and political supporters of local councilors who coordinate governmental assistance (Mustafa, 2003).

[71] The natural disasters insurance deductible paid by individuals is fixed by the government and is higher in municipalities which have suffered several natural disasters and yet have not implemented a risk prevention plan (Insurance Code, section L. 125-1, annex I). As the vast majority of municipalities in the French overseas departments have already undertaken or set up such plans (Section 2), this rule has a negligible impact in these departments.

[72] At present, increasing the premium with respect to risk exposure is considered only for the insurance of firms' or local authorities' buildings, not for home insurance. See `http://www.senat.fr/leg/pjl11-491.html`.

A third argument can be added to those given by Coate (1995): public assistance may distort the fiscal system and, consequently, redistribution between the rich and the poor. For example, in the United States, after Hurricane Andrew in 1992, assistance to the rich was funded by the poor, as Federal assistance was counterbalanced by a reduction of the social budget (Favier and Pfister, 2007). On the contrary, in the French overseas departments, low-income households benefit from more assistance after natural disasters (for example via the disaster relief fund for overseas areas). Indeed, this helps explain why it is the poor who are uninsured in these departments (Subsection 5.2).

How can charity hazard be reduced? As in many countries, reducing public assistance is unlikely to be considered by politicians. Not only is massive investment in *ex post* assistance is strongly rewarded,[73] but little short-term benefit can be gained from developing the supply of insurance or encouraging insurance demand (Cavallo and Noy, 2009). As recalled by James Lee Witt in April 1996, when he was director of the Federal Emergency Management Agency, "disasters are very political events" (Krueger, 2005).[74] A simple reduction of assistance would be even less reasonable in countries where assistance was developed precisely to make up for a limited supply of private insurance, as it would imply a lower level of compensation after disasters, at least for a transition period.

Economic or regulatory incentives to purchase home insurance would make it possible to increase the proportion of insured households and then to decrease *ex post* public financial assistance. The results show that the existing insurance purchase constraints at the moment of the settling in are operant (Subsection 5.2). Thus, new regulatory measures - checking insurance renewal and targeting other uninsured households - could be considered.[75]

[73] In Germany, Chancellor Schröder's decision to provide large amounts of public funds to compensate flood victims in 2002 contributed to his re-election the same year (Schwarze and Wagner, 2007).

[74] See Eisensee and Strömberg (2007) for an estimation of the influence of mass media on US government relief after natural disasters, and Besley and Burgess (2002) for their analysis of the impact of newspaper circulation and electoral accountability on the Indian government's response to flood damage to crops.

[75] Recent legislation, on the contrary, provides for the possibility to cancel home insurance policies at any time from the 13th month, which could lead to an increase of underinsurance in overseas France. This measure is included in the Hamon bill on consumption passed by the National

7 Conclusion

This paper studies the reasons for underinsurance against natural disasters in highly exposed areas. A limited supply of insurance is commonly identified as a primary causal factor for low insurance coverage in exposed areas. The French overseas departments provide a rare natural experiment of a well-developed supply of natural disasters insurance in highly exposed regions. The French natural disasters insurance system is underwritten and regulated by the French government; first intended only for metropolitan France, it was extended to overseas departments after Hurricane Hugo in 1989, in a state of emergency. This natural experiment makes it possible to analyze the determinants of insurance coverage on the demand side.

Based on unique household-level micro-data about the insured and the uninsured, I estimate a model of equilibrium on the insurance market which had not yet been empirically tested. Using this structural approach, it is possible to measure distortions in natural risk pricing due to insurance supply regulation, and to disentangle the various possible causes of underinsurance on the demand side. I show that the main explanations for the low insurance penetration rate are neither perception biases nor unaffordable insurance, but uninsurable housing and the anticipation of assistance, which crowds out insurance. Furthermore, neighbors' insurance choices impact individuals' decision to purchase insurance decision through peer effects and neighborhood eligibility for assistance. Finally, I show that the existing insurance obligations (*de facto* for homeowners with outstanding loans, as in most Caribbean countries, and *de jure* for French tenants) are operant but do not guarantee that targeted households are insured, as they may choose not to renew their insurance policies once they have settled in.

There are two substantive lessons to be learned from this analysis. First, the main reasons for the low demand for insurance coverage against natural disasters in exposed areas are uninsurable housing, which mainly applies in developing countries, and charity hazard, which also largely applies in developed countries. Second, and consequently, these findings suggest that the development of an affordable supply of

Assembly on June 25, 2013; it aims to stimulate competition and lower insurance prices.

natural disasters coverage would probably increase the insurance penetration rate in disaster-prone areas, but would be unlikely to lead to the majority of households being insured, not only because the social equilibrium of uninsurance has to be broken, but also because of charity hazard and, in developing countries, because of uninsurable housing. Thus, the development of a supply of natural disasters coverage in disaster-prone areas (through either governmental initiatives or microinsurance) would be unlikely to enable governments to massively transfer catastrophic risk via coverage mechanisms if it is not combined with policies to reduce charity hazard and, in developing countries, uninsurable housing.

References

Abel, A., 1986. Capital Accumulation with Adverse Selection and Uncertain Lifetimes. Econometrica 54, 1079–97.

Analytica, O., 1997. Caribbean: Catastrophe Risk. September 3, 1997. Technical Report. Oxford Analytica Brief.

Arvan, L., Nickerson, D., 2006. Private Investment, Public Aid and Endogenous Divergence in the Evolution of Urban Neighborhoods. Journal of Real Estate Finance and Economics 32, 83–100.

Auffret, P., 2003. Catastrophe Insurance Market in the Caribbean Region: Market Failures and Recommendations for Public Sector Interventions. Working Paper 2963. World Bank Policy Research.

Barnett, B.J., Barrett, C.B., Skees, J.R., 2008. Poverty Traps and Index-Based Risk Transfer Products. World Development 36, 1766–1785.

Barredo, J.I., 2009. Normalised Flood Losses in Europe: 1970-2006. Natural Hazards and Earth System Sciences 9, 97–104.

Besley, T., Burgess, R., 2002. The Political Economy of Government Responsiveness: Theory and Evidence from India. Quarterly Journal of Economics 117, 1415–1451.

Bevere, L., Rogers, B., Grollimund, B., 2011. Sigma Report: Natural Catastrophes and Man-made Disasters in 2010: A Year of Devastating and Costly Events. Technical Report. Swiss Re.

Bidan, P., 2000. Indemnisation des Catastrophes Naturelles : de la Naissance vers l'Age Adulte. Risques Numéro 42.

Borensztein, E., Cavallo, E., Valenzuela, P., 2009. Debt Sustainability under Catastrophic Risk: The Case for Government Budget Insurance. Risk Management and Insurance Review 12, 273–294.

Bouwer, L.M., Huitema, D., Aerts, J.C., 2007. Adaptive Flood Management: The Role of Insurance and Compensation in Europe. Technical Report. 2007 Amsterdam Conference - Conference on the Human Dimensions of Global Environmental Change, 24-26 May 2007, Amsterdam, The Netherlands.

Brown, D.P., 1990. Age Clienteles Induced by Liquidity Constraints. International Economic Review 31, 891–912.

Brown, J.R., Finkelstein, A., 2008. The Interaction of Public and Private Insurance: Medicaid and the Long-Term Care Insurance Market. American Economic Review 98, 1083–1102.

Browne, M.J., Hoyt, R.E., 2000. The Demand for Flood Insurance: Empirical Evidence. Journal of Risk and Uncertainty 20:3, 291–306.

Calvet, L., Grislain-Letrémy, C., 2011. L'Assurance Habitation dans les Départements d'Outre-mer : Une Faible Souscription. Economie et Statistique Numéro 447, 57–70.

Castéran, B., Ricroch, L., 2008. Les Logements en 2006. Le Confort S'Améliore, Mais Pas Pour Tous. INSEE Première Numéro 1202.

Cavallo, E.A., Noy, I., 2009. The Economics of Natural Disasters: A Survey. Inter-American Development Bank Working Paper 35.

Charvériat, C., 2000. Natural Disasters in Latin America and the Caribbean: An Overview of Risk. Inter-American Development Bank Working Paper 434.

Chernew, M., Cutler, D., Keenan, P.S., 2005. Charity Care, Risk Pooling, and the Decline in Private Health Insurance. American Economic Review Papers and Proceedings of the One Hundred Seventeenth Annual Meeting of the American Economic Association, January 7-9, 2005 95, 209–213.

Chiappori, P.A., Salanié, B., 2008. Modeling Competition and Market Equilibrium in Insurance: Empirical Issues. American Economic Review: Papers & Proceedings 98, 146–150.

Cleeton, D.L., Zellner, B.B., 1993. Income, Risk Aversion, and the Demand for Insurance. Southern Economic Journal 60, 146–156.

Coate, S., 1995. Altruism, the Samaritan's Dilemma, and Government Transfer Policy. American Economic Review 85, 46–57.

Deryugina, T., Kirwan, B., 2012. Charity Hazard in Crop Insurance. Preliminary draft .

DIREN, 2005. Tableau de Bord de l'Environnement, Martinique 2005. Technical Report. Direction Régionale de l'Environnement Martinique.

Dixon, L., Clancy, N., Seabury, S.A., Overton, A., 2006. The National Flood Insurance Program's Market Penetration Rate. Technical Report. RAND Corporation.

Dumas, P., Chavarot, A., Legrand, H., Macaire, A., Dimitrov, C., Martin, X., Queffelec, C., 2005. Rapport Particulier sur la Prévention des Risques Naturels et la Responsabilisation des Acteurs. Mission d'Enquête sur le Régime d'Indemnisation des Victimes de Catastrophes Naturelles. French Treasury General Inspection, French Environment General Inspection and French General Council of Civil Engineering.

Eisensee, T., Strömberg, D., 2007. News Droughts, News Floods and U.S. Disaster Relief. Quarterly Journal of Economics 122, 693–728.

Erhard-Cassegrain, A., Massé, E., Momal, P., 2006. Evolution du régime d'indemnisation des catastrophes naturelles. Document de travail de la Direction des Etudes Economiques et de l'Evaluation Environnementale, Série Synthèses Numéro 04-S06 .

Evans, A.F., 1996. Insurance, Reinsurance and Catastrophe Protection in the Caribbean. Technical Report. Organization of American States General Secretariat. Working Paper prepared in collaboration with the World Bank.

Favier, R., Larhra, U., 2007. From Solidarity to Individual Compensation: Assistance Mechanisms Faced with the Emergence of Liberalism in France during the 18th Century. In Solidarité et Assurance : Les Sociétés Européennes Face aux Catastrophes (17e-21e s.). CNRS MSH-Alpes. pp. 57–79.

Favier, R., Pfister, C., 2007. Introduction. In Solidarité et Assurance : Les Sociétés Européennes Face aux Catastrophes (17e-21e s.). CNRS MSH-Alpes. pp. 9–13.

Fay, M., Wellenstein, A., 2005. The Urban Poor in Latin America. World Bank. chapter Keeping a Roof over One's Head: Improving Access to Safe and Decent Shelter. pp. 91–124.

FFSA, 2006. Présentation de la Fédération Française des Sociétés d'Assurance au Séminaire MultiRisques Habitation du 16 mai 2006. http://www.ffsa.fr/sites/upload/reprise/docs/application/pdf/2010-02/apmrhmai06.pdf. Technical Report.

Forgeot, G., Celma, C., 2009. Les Inégalités aux Antilles Guyane : Dix Ans d'Evolution. Technical Report. Institut National de la Statistique et des Etudes Economiques (INSEE) and Caisses d'Allocations Familiales d'Antilles-Guyane.

Freeman, P.K., Keen, M., Manil, M., 2003. Dealing with Increased Risk of Natural Disasters: Challenges and Options. Technical Report. International Monetary Fund Working Paper No. 03/197.

Garnesson, C., Hecquet, V., 2007. Le Logement Dans les DOM. Technical Report 67. Antiane.

Garrett, T.A., Sobel, R.S., 2003. The Political Economy of FEMA Disaster Payments. Economic Inquiry 41, 496–509.

Gaschen, S., Hausmann, P., Menzinger, I., Schaad, W., 1998. Floods - An Insurable Risk? A Market Survey. Technical Report. Swiss Re.

Gilbert, R., 2001. Doing More for Those Made Homeless by Natural Disasters. Technical Report. World Bank.

Gollier, C., 2003. To Insure or Not to Insure?: An Insurance Puzzle. Geneva Papers on Risk and Insurance - Theory 28, 5–24.

Gollier, C., 2007. Comment Intégrer le Risque Dans le Calcul Economique ? Revue d'économie politique 117, 209–223.

Grace, M.F., Klein, R.W., Kleindorfer, P.R., 2004. Homeowner's Insurance with Bundled Catastrophe Coverage. Journal of Risk and Insurance 71, 351–379.

Grislain-Letrémy, C., Peinturier, C., 2010. Le Régime des Catastrophes Naturelles en France Métropolitaine. Etudes et Documents, Ministère de l'Ecologie, de l'Energie, du Développement Durable et de l'Aménagement du Territoire 22.

Halek, M., Eisenhauer, J.G., 2001. Demography of Risk Aversion. Journal of Risk and Insurance 68, 1–24.

Hayes, T.L., Neal, D.A., 2009. Actuarial Rate Review, National Flood Insurance Program. Technical Report. Federal Emergency Management Agency.

Heger, M., Julca, A., Paddison, O., 2008. Analysing the Impact of Natural Hazards in Small Economies: The Caribbean Case. Technical Report. United Nations University - World Institute for Development Economics Research. Research Paper No. 2008/25.

Hernández-Murillo, R., Sengupta, R., 2012. The Effect of Neighborhood Spillovers on Mortgage Selection. Preliminary draft .

Herring, B., 2005. Does Access to Charity Care for the Uninsured Crowd Out Private Health Insurance Coverage? Journal of Health Economics 24, 225–252.

IDB (Ed.), 2000. Social Protection for Equity and Growth. Washington, DC, United States: Inter-American Development Bank. chapter Protecting the Poor Against Natural Disasters. pp. 47–76.

IPCC, 2007. Fourth Assessment Report: Climate Change. Technical Report. Intergovernmental Panel on Climate Change.

Jianakoplos, N.A., Bernasek, A., 1998. Are Women More Risk Averse? Economic Inquiry 36, 620–630.

Joskow, P., Tirole, J., 2006. Retail Electricity Competition. RAND Journal of Economics 37, 799–815.

Kreimer, A., Arnold, M., Barham, C., Freeman, P., Gilbert, R., Krimgold, F., Lester, R., Pollner, J.D., Vogt, T., 1999. Managing Disaster Risk in Mexico: Market Incentives for Mitigation Investment, The World Bank, Washington, D.C. Technical Report. World Bank.

Krueger, A.B., 2005. At FEMA, Disasters and Politics Go Hand in Hand. Technical Report. New York Times, 15 September. http://www.nytimes.com/2005/09/15/business/15scene.html?pagewanted=all.

Kunreuther, H., 1984. Causes of Underinsurance Against Natural Disasters. Geneva Papers on Risk and Insurance 9, 206–220.

Kunreuther, H., Novemsky, N., Kahneman, D., 2001. Making Low Probabilities Useful. Journal of Risk and Uncertainty 23, 103–120.

Kunreuther, H., Pauly, M., 2004. Neglecting Disaster: Why Don't People Insure Against Large Losses? Journal of Risk and Uncertainty 28, 5–21.

Kunreuther, H., Pauly, M., 2005. Insurance Decision-Making and Market Behavior. Foundations and Trends in Microeconomics 1, 63–127.

Kunreuther, H., Pauly, M., 2006. Rules Rather than Discretion: Lessons from Hurricane Katrina. Journal of Risk and Uncertainty 33, 101–116.

Landry, C.E., Jahan-Parvar, M.R., 2011. Flood Insurance Coverage in the Coastal Zone. Journal of Risk and Insurance 78, 361–388.

Laroque, G., Salanié, B., 2002. Labour Market Institutions and Employment in France. Journal of Applied Econometrics 17, 25–48.

Letrémy, C., 2009. Le Rôle de l'Assurance Dans la Prévention des Catastrophes Naturelles. Le Point Sur, Economie et Evaluation, Ministère de l'Ecologie, de l'Energie, du Développement Durable et de l'Amènagement du Territoire 9.

Levin, I.P., Snyder, M.A., Chapman, D.P., 1988. The Interaction of Experiential and Situational Factors and Gender in a Simulated Risky Decision-Making Task. Journal of Psychology 122, 173–181.

Lin, Y.S., 2005. Estimations of the Probability of Fire Occurrences in Buildings. Fire Safety Journal 40, 728–735.

Maccaferri, S., Cariboni, F., Campolongo, F., 2012. Natural Catastrophes: Risk Relevance and Insurance Coverage in the EU. Technical Report. European Commission, Joint Research Centre, Scientific Support to Financial Analysis Unit, Institute for the Protection and Security of the Citizen.

Mechler, R., Linnerooth-Bayer, J., Peppiatt, D., 2006. Microinsurance for Natural Disaster Risks in Developing Countries. Benefits, Limitations and Viability. A ProVention/IIASA study. Draft for discussion .

Michel, C., Theulière, M., Missègue, N., 2010. Les Inégalités de Revenus entre les DOM et la Métropole. INSEE Première Numéro 1279.

Morin, R.A., Suarez, A.F., 1983. Risk Aversion Revisited. The Journal of Finance 38, 1201–1216.

MunichRe, 2012. TOPICS GEO Natural Catastrophes 2012. Analyses, Assessments, Positions. Technical Report.

Mustafa, D., 2003. Reinforcing Vulnerability? Disaster Relief, Recovery and Response to the 2001 Flood in Rawalpindi, Pakistan. Environmental Hazards 5, 71–82.

Niel, X., Beaumel, C., 2010. Le Nombre de Décès Augmente, l'Espérance de Vie Aussi. INSEE Première 1318.

Office, U.G.A., 1983. The Effect of Premium Increases on Achieving the National Flood Insurance Program's Objectives. Technical Report RCED-83-107.

Olive, V., Riviere, F., 2010. L'Habitat Dans les Outre-mer Français : Progrès, Enjeux, Disparités. Technical Report. Institut d'Emission des Départements d'Outre Mer, Institut d'Emission d'Outre Mer.

Outreville, J.F., 2000. Handbook of Insurance. chapter The Retention Capacity of Insurance Markets in Developing Countries. pp. 749–766.

Palsson, A.M., 1996. Does the Degree of Relative Risk Aversion Vary with Household Characteristics? Journal of Economic Psychology 17, 771–787.

Pauly, M.V., 1974. Overinsurance and Public Provision of Insurance: The Roles of Moral Hazard and Adverse Selection. Quarterly Journal of Economics 88, 44–62.

Pelling, M., Uitto, J.I., 2001. Small Island Developing States: Natural Disaster Vulnerability and Global Change. Environmental Hazards 3, 49–62.

von Peter, G., von Dahlen, S., Saxena, S., 2012. Unmitigated Disasters? New Evidence on the Macroeconomic Cost of Natural Catastrophes. BIS Working Papers 394.

Petrolia, D.R., Landry, C.E., Coble, K.H., 2012. Risk Preferences, Risk Perceptions, and Flood Insurance .

Pollner, J., 2000. The Management of Catastrophic Risks using Pooled Insurance Structures and Alternative Financing & Risk Transfer Mechanisms. Technical Report. World Bank.

Powell, M., Ansic, D., 1997. Gender Differences in Risk Behaviour in Financial Decision-Making: An Experimental Analysis. Journal of Economic Psychology 18, 605–628.

Raschky, P.A., Schwarze, R., Schwindt, M., Zahn, F., 2010. Uncertainty of Governmental Relief and the Crowding out of Insurance. Monash University Discussion paper 05/10.

Raschky, P.A., Weck-Hannemann, H., 2007. Charity Hazard - A Real Hazard to Natural Disaster Insurance? Environmental Hazards 7, 321–329.

Rasmussen, T.N., 2004. Macroeconomic Implications of Natural Disasters in the Caribbean. International Monetary Fund Working Paper WP/04/224.

Rothschild, M., Stiglitz, J., 1976. Equilibrium in Competitive Insurance Markets: An Essay on the Economics of Imperfect Information. Quarterly Journal of Economics 90, 629–649.

Schlesinger, H., 2000. The Theory of Insurance Demand. G. Dionne, Handbook of Insurance. chapter 5. pp. 131–151.

Schubert, R., Brown, M., Gysler, M., Brachinger, H.W., 1999. Financial Decision-Making: Are Women Really More Risk-Averse? American Economic Review 89, 381–385.

Schwarze, R., Wagner, G.G., 2007. The Political Economy of Natural Disaster Insurance: Lessons from the Failure of a Proposed Compulsory Insurance Scheme in Germany. European Environment 17, 403–415.

Senate, F., 2005. Session at the French Senate on February 17, 2005. Comprehensive report of debates. French Senate http://www.senat.fr/seances/s200502/s20050217/s20050217002.html.

Short, M.B., D'Orsogna, M.R., Brantingham, P.J., Tita, G.E., 2009. Measuring and Modeling Repeat and Near-Repeat Burglary Effects. Journal of Quantitative Criminology 25, 325–339.

Tallon, J.M., Vergnaud, J.C., 2007. Incertitude en Economie de l'Environnement. Université Paris 1 Panthéon-Sorbonne (Post-Print and Working Papers). HAL.

Tjibaou, M.C., 2004. Le Logement Dans l'Outre-mer Français. Technical Report. Conseil Economique et Social.

Tversky, A., Kahneman, D., 1973. Availability: A Heuristic for Judging Frequency and Probability. Cognitive Psychology 5, 207–232.

Tversky, A., Kahneman, D., 1981. The Framing of Decisions and the Psychology of Choice. Science, New Series 211, 453–458.

WB, 1999. Proposed Strategy for a Small State Regional Catastrophe Insurance Program. Technical Report. World Bank, Caribbean Country Department.

WB, 2011. Insuring Against Natural Disaster Risk in Mexico. Technical Report. World Bank, Treasury.

Weitzman, M.L., 2009. On Modeling and Interpreting the Economics of Catastrophic Climate Change. The Review of Economics and Statistics 91, 1–19.

A Appendix

Estimation is based on maximum log-likelihood. The calculation of the likelihood is detailed hereafter.

Recall that the estimated model is

$$\begin{cases} \alpha_i = 1 \Leftrightarrow [\log(W_i - \pi_i) - \log(W_i)] + \tilde{\boldsymbol{p}}_{\boldsymbol{o}}[\log(W_i) - \log(W_i - L_{oi})] \\ \qquad +[qS_i + \theta E(Z_{\text{aid},i})S_i][\log(W_i) - \log(W_i - \boldsymbol{\beta} L_{oi})] + o_t O_{ti} + o_l O_{li} \\ \qquad +h_c H_{ci} + h_w H_{wi} + h_d H_{di} + h_t H_{ti} + \delta E(Z_{\text{peer},i}) + b_m B_{cli} + b_a B_{ai} + \nu\epsilon_i + \eta_i \geq 0, & (28) \\ \text{if } \alpha_i = 1, \log(\pi_i) = c_\pi + y\log(Y_i) + n\log(N_i) + \log(1 - \tau O_{ti}) \\ \qquad - \log(1 - \boldsymbol{\kappa} - \rho R_i) + \sigma\epsilon_i, & (29) \\ \text{if } \alpha_i = 0, \pi_i = 0. \end{cases}$$

where $\boldsymbol{\kappa}$ is a calibrated parameter. I denote

$$\begin{aligned} Z_\alpha &= \tilde{\boldsymbol{p}}_{\boldsymbol{o}}[\log(W_i) - \log(W_i - L_{oi})] + [qS_i + \theta E(Z_{\text{aid},i})S_i][\log(W_i) - \log(W_i - \boldsymbol{\beta} L_{oi})] \\ &\quad + o_t O_t + o_l O_l + h_c H_c + h_w H_w + h_d H_d + h_t H_t + \delta E(Z_{\text{peer}}) + b_m B_m + b_a B_a, && (30) \\ Z_\pi &= c_\pi + y\log(Y) + n\log(N) + \log(1 - \tau O_t) - \log(1 - \boldsymbol{\kappa} - \rho R). && (31) \end{aligned}$$

Besides, the probability density function of centered normal distribution with unit variance is denoted $\varphi(\cdot)$ and the cumulative density function is denoted by $\Phi(\cdot)$.

For an insured household that pays a premium π, the probability of purchasing insurance can be directly calculated using (19). Using the symmetry of the normal distribution, I get

$$Pr\Bigg(\eta \geq -(\log\left(1-\frac{\pi}{W}\right)+Z_\alpha+\nu\epsilon)\Bigg)=\Phi\Bigg(\log\left(1-\frac{\pi}{W}\right)+Z_\alpha+\nu\epsilon\Bigg), \tag{32}$$

and the hazard is $\epsilon = (\log(\pi) - Z_\pi)/\sigma$ with probability $1/\sigma \cdot \varphi\left((\log(\pi) - Z_\pi)/\sigma\right)$. Thus, for an insured household that pays a premium π, the likelihood function is

$$\frac{1}{\sigma}\varphi\left(\frac{\log(\pi)-Z_\pi}{\sigma}\right)\Phi\Bigg(\log\left(1-\frac{\pi}{W}\right)+Z_\alpha+\nu\frac{\log(\pi)-Z_\pi}{\sigma}\Bigg), \tag{33}$$

For an uninsured household, the premium is not observed. Thus, the expected value of the probability of not purchasing insurance is[76]

$$1-\int_{\mathbb{R}}\underbrace{\Phi\Bigg(\log\left(1-\frac{\exp(Z_\pi+\sigma\epsilon)}{W}\right)+Z_\alpha+\nu\epsilon\Bigg)}_{F(\epsilon)}\varphi(\epsilon)d\epsilon. \tag{34}$$

I use the method exposed by Laroque and Salanié (2002) to approximate the integral that appears in the likelihood.[77] Following their estimation method, I denote by ϵ_i the ith m-quantile ($\Phi(\epsilon_i) = i/m$) and calculate $\bar{\epsilon}_i$, the average normal-weighted point in each interval $[\epsilon_i, \epsilon_{i+1}]$. As $x\varphi(x) = -\varphi'(x)$,

$$\bar{\epsilon}_i=\frac{\int_{\epsilon_i}^{\epsilon_{i+1}}x\varphi(x)dx}{\Phi(\epsilon_{i+1})-\Phi(\epsilon_i)}=m\Big[\varphi(\epsilon_i)-\varphi(\epsilon_{i+1})\Big], \tag{35}$$

and the integral can be approximated by

$$\int_{\mathbb{R}}F(\epsilon)\varphi(\epsilon)d\epsilon\approx\frac{1}{m}\sum_{i=0}^{m-1}F(\bar{\epsilon}_i). \tag{36}$$

Results are presented here for $m = 10$; they are robust when using $m = 20$.

[76] The likelihood function for the uninsured takes into account the fact that the selection bias $\nu\epsilon$ and the estimated premium for the uninsured both depend on the error term ϵ (Equation 34).

[77] Laroque and Salanié (2002) explain the wage and the participation decision on the labor market, taking into account the fact that the decision to work depends on the wage. Their estimation is based on maximum likelihood and requires the approximation of a similar integral.