

**Louvain School of Management**

# **Insuring against natural disasters**

The impacts of climate change on reinsurance and insurance-linked securities

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## Table of contents

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|                                                                                      |     |
|--------------------------------------------------------------------------------------|-----|
| Table of contents.....                                                               | II  |
| List of figures .....                                                                | VI  |
| List of abbreviations .....                                                          | VII |
| Introduction .....                                                                   | 1   |
| Part 1: Literature review .....                                                      | 3   |
| Chapter 1: The role of private insurers and States during climate catastrophes ..... | 3   |
| 1.1. Private insurer role .....                                                      | 3   |
| 1.2. State role.....                                                                 | 4   |
| 1.2.1. The US case.....                                                              | 6   |
| 1.2.2. The European case .....                                                       | 6   |
| 1.2.3. The case of Belgium.....                                                      | 7   |
| 1.3. Conclusion.....                                                                 | 9   |
| Chapter 2: Consequences of climate change .....                                      | 10  |
| 2.1. Climate catastrophes in the future .....                                        | 10  |
| 2.2. Climate commitments .....                                                       | 15  |
| 2.3. Conclusion.....                                                                 | 17  |
| Chapter 3: Impacts of climate change on the insurance industry .....                 | 18  |
| Chapter 4: Extreme events risk financing .....                                       | 22  |
| 4.1. Reinsurance .....                                                               | 22  |
| 4.2. Insurance-linked securities (ILS) .....                                         | 24  |
| 4.2.1 Catastrophe bonds (CAT bonds) .....                                            | 27  |
| 4.2.2. Collateralized reinsurance .....                                              | 30  |
| 4.2.3. Industry loss warranties (ILW) .....                                          | 31  |

|                                                                                |    |
|--------------------------------------------------------------------------------|----|
| 4.2.4. Sidecar .....                                                           | 32 |
| 4.2.5. Catastrophe options (CAT options).....                                  | 33 |
| 4.3. Moral hazard/Basis risk/Credit risk.....                                  | 34 |
| 4.3.1. Moral hazard .....                                                      | 34 |
| 4.3.2. Basis Risk.....                                                         | 36 |
| 4.3.3. Credit Risk.....                                                        | 36 |
| 4.3.4. Summary .....                                                           | 37 |
| 4.4. Challenges ILS .....                                                      | 38 |
| 4.4.1. From the investors point of view.....                                   | 38 |
| 4.5. Critics of ILS .....                                                      | 39 |
| Part 2: Analytical research .....                                              | 42 |
| Chapter 5: Research problem and methodology .....                              | 42 |
| 5.1. Context .....                                                             | 42 |
| 5.2. Research problem .....                                                    | 42 |
| 5.3. Methodology .....                                                         | 43 |
| 5.3.1. Research strategy.....                                                  | 43 |
| 5.3.2. Semi-structured interviews.....                                         | 43 |
| 5.3.3. Interviewees selection .....                                            | 44 |
| 5.3.4. Data analysis Method .....                                              | 46 |
| Chapter 6: Result analysis .....                                               | 47 |
| 6.1. Impacts of climate change on reinsurance .....                            | 47 |
| 6.1.1. Impacts of climate change on the price of reinsurance .....             | 47 |
| 6.1.2. Future evolution of reinsurance capacity .....                          | 50 |
| 6.1.3. Climate change as a vector of risks and opportunities .....             | 53 |
| 6.1.4. Impacts of climate change on disaster modeling .....                    | 54 |
| 6.1.5. The development of reinsurers will differ according to their size ..... | 56 |

|                                                                                                                                               |     |
|-----------------------------------------------------------------------------------------------------------------------------------------------|-----|
| 6.1.6. Reinsurance will remain the best option .....                                                                                          | 56  |
| 6.2. Impacts of climate change on Insurance-Linked Securities (ILS) .....                                                                     | 58  |
| 6.2.1. Evolution of competition between ILS and reinsurance .....                                                                             | 58  |
| 6.2.2. Impacts of climate change on the price of ILS .....                                                                                    | 60  |
| 6.2.3. Future development of ILS .....                                                                                                        | 61  |
| 6.2.4. Private direct investment. ....                                                                                                        | 62  |
| 6.2.5. The most common ILS in the future .....                                                                                                | 64  |
| 6.2.6. Creation of new ILS .....                                                                                                              | 65  |
| 6.2.7. ILS development differs as a function of their size .....                                                                              | 66  |
| 6.2.8. ILS, a safe mechanism? .....                                                                                                           | 66  |
| 6.2.9. Climate change will not disrupt the reinsurance market. ....                                                                           | 67  |
| 6.2.10. Climate change will not affect the capital market via ILS and reinsurance. ....                                                       | 69  |
| 6.2.11. Impacts of climate change on the pricing of ILS .....                                                                                 | 70  |
| 6.2.12. Impacts of climate change on the regulation .....                                                                                     | 70  |
| 6.3. Impacts of climate change on the society .....                                                                                           | 72  |
| 6.3.1. The role of the State .....                                                                                                            | 72  |
| Conclusion .....                                                                                                                              | 76  |
| Bibliography .....                                                                                                                            | 80  |
| Appendices .....                                                                                                                              | 94  |
| Appendix 1: Proportion of alternative capital (ILS) to traditional capital (traditional reinsurance), in US\$ billion from 2013 to 2021 ..... | 94  |
| Appendix 2: CAT bonds volume .....                                                                                                            | 94  |
| Appendix 3: Aggregate XOL .....                                                                                                               | 95  |
| Appendix 4: Interview guide .....                                                                                                             | 96  |
| Appendix 5: Interview with Dominique Lemonier .....                                                                                           | 99  |
| Appendix 6: Interview with Maurizio Savina .....                                                                                              | 129 |

|                                                            |     |
|------------------------------------------------------------|-----|
| Appendix 7: Interview with Jean-François Walhin.....       | 147 |
| Appendix 8 : Interview with Manuel Prechtl .....           | 173 |
| Appendix 9 : Interview with Michel Herssens .....          | 193 |
| Appendix 10 : Interview with Philippe De Longueville ..... | 230 |
| Appendix 11: Interview with Thomas Kroely.....             | 258 |
| Appendix 12: Interview with Nicolas Mérigot.....           | 282 |
| Appendix 13: Interview with Ivo Hux .....                  | 299 |
| Appendix 14: Interview with Quentin Perrot .....           | 316 |
| Appendix 15: Interview with Eddy Vanbeneden .....          | 340 |
| Appendix 16: Interview with Jeroen Vermaas .....           | 369 |
| Appendix 17: Interview with Luuk Mulders.....              | 384 |
| Appendix 18: Interview with Clarence Wong.....             | 395 |

## List of figures

---

|                                                                                                             |     |
|-------------------------------------------------------------------------------------------------------------|-----|
| Figure 1: Trend in the number of weather and climate related catastrophic events between 1990 and 2014..... | 11  |
| Figure 2: Insured losses, 1970-2021, in US\$ billion at 2021 prices.....                                    | 12  |
| Figure 3: ILS market development, in US\$ billion, from 2002 to 2021.....                                   | 25  |
| Figure 4: Typical structure of a CAT bond.....                                                              | 28  |
| Figure 5: Dedicated reinsurance sector capital – 2013 to 2021.....                                          | 101 |
| Figure 6: Outstanding and cumulative catastrophe bond volume, in US\$ million from 2010 to 2021.....        | 101 |

## List of abbreviations

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| Abbreviation | Meaning                                               |
|--------------|-------------------------------------------------------|
| ART          | Alternative Risk Transfer                             |
| CAT          | Catastrophe                                           |
| CAT bond     | Catastrophe bond                                      |
| CAT fund     | Catastrophe fund                                      |
| CAT losses   | Catastrophe losses                                    |
| CAT market   | Catastrophe market                                    |
| CAT option   | Catastrophe option                                    |
| CCR          | Caisse Centrale de Réassurance                        |
| CDO          | Collateralized Debt Obligation                        |
| CEA          | California Earthquake Authority                       |
| CNC          | Caisse Nationale des Calamités                        |
| EUSF         | European Union Solidarity Fund                        |
| FCR          | Financial Condition Report                            |
| FHCF         | Florida Hurricane Catastrophe Fund                    |
| IARD         | Incendies Accidents Risques Divers                    |
| ILS          | Insurance-Linked Securities                           |
| ILW          | Industry loss warranties                              |
| IPCC         | Intergovernmental Panel on Climate Change             |
| MBS          | Mortgage-Backed Securities                            |
| Nat CAT      | Natural Catastrophe                                   |
| NDC          | Nationally Determined Contribution                    |
| NFIP         | National Flood Insurance Program                      |
| NSA          | Non-State Actors                                      |
| NZIA         | Net-Zero Insurance Alliance                           |
| PPP          | Public-Private Partnership                            |
| SBT          | Science-Based Targets                                 |
| SPV          | Special Purpose Vehicle                               |
| TCFD         | Task Force on Climate-related Financial Disclosures.  |
| TERI         | Transnational Emission Reduction Initiatives          |
| UNFCCC       | United Nations Framework Convention on Climate Change |

# Introduction

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In July 2021, rainfall over a broad region of Europe, from the Czech Republic to the East, across Germany, to the Benelux countries to the West, reached historic proportions. The ensuing floods were unprecedented. As a result of this tragedy, 41 people died in Belgium, and 200 in Germany. In Wallonia alone, the water destroyed nearly 50,000 homes, leaving between 80,000 and 100,000 people affected (Walhin, 2021). The insured damages are estimated at more than €2 billion (US\$ 2 billion at today's exchange rate), which is considerable (Assuralia, 2021).

For that same year, 2021, at the global level, the value of insured damages due to natural catastrophes was estimated at US\$ 105 billion. This made it the fourth most expensive year since 1970, contributing to the average annual increase of 5 to 6 percent in losses related to natural disasters in the last decades (Swiss Re Institute, 2021). The trend is likely to continue in the future: the Intergovernmental Panel on Climate Change (IPCC) has warned repeatedly in its various reports that climate change will exacerbate the frequency and severity of these catastrophes.

Insurance companies are severely affected by climatic catastrophes. When natural disasters do occur, few of them have the financial capacity in their own reserves to cover their policyholders. Anticipating this, they therefore insure themselves either with other companies, a process called reinsurance, or via the capital markets, through the issuance of insurance-linked securities (ILS). Given the climate trends, including in the near term, it is therefore of great interest to understand how these instruments will evolve. More precisely, our thesis aims to describe and understand the impacts of climate change on reinsurance and insurance-linked securities, with a focus on the next decade.

To gain additional understanding on the different trends in reinsurance and ILSs, we conducted interviews with fourteen professionals from specialized firms in this domain. Their expertise covers a broad span of approaches, and these experts work in twelve different companies, in seven countries, on two continents. Our data is drawn from the semi-directive interviews that were conducted remotely in French or English.

This thesis has three main parts. In part one, we carry out a literature review where we discuss the role of private insurers and the State. In this part, we also describe current knowledge about

climate change and its impacts on future climate disasters, with particular attention to the consequences of climate change on insurance companies. Finally, we describe in depth the instruments used by insurance companies to cover themselves, especially reinsurance and ILS, including their functioning, weaknesses and criticisms.

The second part of this thesis is the empirical part. We first define the problem and the methodology. Then we explain the different answers to our question. We structure these answers in three sub-sections, one specifically on reinsurance, another on ILS, and the third, shorter but at a different level of concern, on the broader impacts on our society.

Finally, the third part of this thesis concludes by summarizing our research, with an effort to provide a clear and concise synthesis of our findings. We also expose the limitations of our thesis and discuss ideas for future research.

We hope this thesis will be of interest to both the professionals, namely the insurance and reinsurance companies that deal every day with these instruments, and will need them increasingly in years to come, but also to the lay reader, people that asks themselves how the world will cope with these tragedies, as they recur and become more severe every year, and could happen to them.

## Part 1: Literature review

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### **Chapter 1: The role of private insurers and States during climate catastrophes**

During the occurrence of a disaster, two different and complementary economic actors play major roles. They are, on the one hand, the private insurers, and on the other, the State. In this section, we will examine in more depth the roles they play and the limits of their respective contributions. Furthermore, we will highlight the differences in the role of governments in the US and Europe, and then more specifically Belgium.

#### **1.1. Private insurer role**

Insurance plays a critical role in the financial sector (Dlugolecki, 2008). In 2018, worldwide insurance was worth US\$ 5.2 trillion, or 6% of global gross domestic product (IAIS, 2020)

More precisely, the role of an insurance company is to cover a financial loss related to a damage in exchange for a payment, called a “premium” (Dlugolecki, 2008; Kunreuther & Michel-Kerjan, 2011). In the case of risks of an earthquake, for example, the insured decides to pay a certain premium to an insurance company to cover a possible future earthquake damage and, if the earthquake does occur, the insured's losses are covered, in whole or in part, by the insurer (Kunreuther & Michel-Kerjan, 2011). The amount of the premium, which is supposed to reflect the risk to which the insured is exposed, serves to perform what Abraham (1985) has described as one of the three economic functions of insurance namely risk allocation. Indeed, if the premium is based on risk, the riskiest people are the ones who pay the highest price. This can, in a way, reward people who make efforts to reduce their exposure to risk (Porrini & Schwartz, 2012).

The second function is risk pooling. Insurance companies pool the risks incurred by their customers. Individual risks are summed across a large number of policyholders (Kron, Löw & Kundzewicz, 2019) and a diversification of risks is created allowing the average cost of risk to be reduced (Herweijer, Ranger & Ward, 2009). Hence, whenever some of the policy holders

experience damage, the premiums collected from all of them are used to compensate for the damage (Kunreuther, 2015). In addition, insurers can draw additional resources by investing the premiums received from their clients as well as their funds from shareholders (Dlugolecki, 2008) and earning financial returns. Finally, the third function of insurance is the transfer of risk from a risk averse person to a risk neutral person (Abraham, 1985).

Because of these activities, insurance companies play an essential role in a variety of sectors. For example, they play a crucial role in the banking industry (Dlugolecki, 2008). Moreover, by helping those affected by a loss, insurance promotes social welfare (Porrini & Schwartz, 2012). This is particularly noticeable during the occurrence of a disaster. Indeed, insurance plays a direct role in covering the costs of the damages, which acts as a buffer and provides the victims with resources enabling them to bounce back from the disaster (Porrini & Schwartz, 2012).

Nevertheless, when it comes to natural catastrophes, which are typically geographically focused, insurers themselves face the risk of a huge loss (Kunreuther & Michel-Kerjan, 2011), because thousands of people are affected at the same time (Keucheyan, 2018) and the risks underwritten are not statistically independent (Walhin, 2021). Due to this high correlation of risks, the law of large numbers is therefore no longer applicable, and diversification of risk is not possible (Doherty, 1997). In response, insurers tend to limit coverage in hazard-prone areas, besides diversifying geographically (Kunreuther & Michel-Kerjan, 2011) to bear sufficiently uncorrelated risks (Keucheyan, 2018).

Since these events are rare and their cost substantial, insurance companies must rely on modeling to determine the amount of loss related to a climate catastrophe that they are willing to insure and set the appropriate premiums. The use of these so-called “CAT models” is now required by many regulatory agencies (Franzke, 2017). Catastrophe risk modelling remains a real challenge, however, because of the large uncertainty and the enormous informational challenges affecting the various parameters of the modelling (Franzke, 2017; Kunreuther & Michel-Kerjan, 2011).

## **1.2. State role**

Besides private insurers, the State is the other main economic actor involved in insurance. The main objective of the State is to decrease the underlying risks incurred by society (Kron et al., 2019). To do so, governments currently play the role of regulator in the insurance world

(Collier, Elliott & Lehtonen, 2021; Keucheyan, 2018; Klein & Wang, 2009). They regulate for example the financing, underwriting and the management of catastrophe risk of private insurances (Klein & Wang, 2009). They are responsible for ensuring that insurance policies offered by private companies are available and affordable to customers (Klein & Wang, 2009; Mills, 2009). Regulators seek to ensure that insurers have an appropriate level of liquidity, capital reserves and reinsurance (Mills, 2009). Furthermore, they play an important role in helping people understand climate risk. They are educating consumers to take actions that reduce their impact on climate change, and help ensure a viable insurance market, if needed by adapting the regulations to achieve this goal (Kron et al., 2019; Mills, 2009).

But these are not the only roles of governments. Indeed, they also act as a bulwark against the bankruptcy of these private insurers (Mills, 2009), monitoring the rates charged by insurance companies as well as, for example, the repayment capacity of state-operated insurance pools (Mills, 2009). Finally, governments also act as “insurer of last resort”, particularly during severe catastrophes (Keucheyan, 2018; Kron et al., 2019; Porrini & Schartz, 2012), by bearing the cost of damages not covered by private insurers (Thirawat, Udampol & Ponjan, 2017). It is thus ultimately the residents' taxes that are used to pay for climate disasters not insured by the private sector (Dlugolecki, 2008; Nussbaum, 2013; Porrini & Schwartz, 2012). To manage the fiscal impact of these disasters, governments often find it convenient to set up special vehicles, such as natural disaster funds, which can take several different forms depending on the country. They help provide short-term financial assistance and also finance long-term reconstruction (Keucheyan, 2018).

In order to manage natural disasters, partnerships between the private and the public sector (namely public-private partnership (PPP)) have been set up. They involve governments, private insurers, and multinational corporations, but also non-profit organizations and foundations (Collier et al., 2021). These partnerships enable a better mix between adaptation and disaster management, and they therefore foster sustainable economic development (Dlugolecki, 2008, Kunreuther, 2015).

Although the different roles of governments are common, countries have specific institutional frameworks and, therefore, regulations vary depending on the location. In the US, for example, it is states that act as regulators (Klein & Wang, 2009), and, as a result, regulations in one state may differ sharply from those in another state. In Europe, it is mostly national governments that play the role of regulator (Charpentier, 2008).

### ***1.2.1. The US case***

A high degree of contractual freedom is allowed in the US and primary insurers are therefore free to choose the premiums they charge. Thus, in certain risky areas, the premiums are enormous, and some insurers decide not to cover the risk. In those areas, it has fallen on the state to step in and provide insurance, often through special entities financed by private funds, allowing American citizens to be covered for certain specific risks at affordable rates (Atlas-mag, 2019). Examples include the Florida Hurricane Catastrophe Fund (FHCF), which is funded by some Florida insurers, and the privately funded California Earthquake Authority (CEA) (Bouriaux & MacMinn, 2009). Moreover, for risks of flooding, it is at the federal level that an insurance program has been set up, the National Flood Insurance Program (NFIP), allowing residents of at-risk areas to subscribe to an insurance given that very few private insurers offered coverage. This said, even though this program is funded by the State, it is, by and large, not widely used (Atlas-mag, 2019).

### ***1.2.2. The European case***

In terms of coverage of natural events in Europe, each country has its own insurance policy framework. There are, however, two schemes that apply on a cross-country basis, the "voluntary insurance scheme" or the "compulsory insurance scheme" (Nussbaum, 2007; Paleari, 2019).

In the voluntary insurance scheme, as its name indicates, residents "opt in" to get coverage for damage caused by a natural disaster. This insurance is provided by private insurers and bases its premium calculation on the risk incurred by the policyholder. The penetration of insurance in a voluntary scheme is low (Nussbaum, 2007), and thus the risk of adverse selection<sup>1</sup> is very high. Indeed, it is often the most at-risk people who subscribe to this insurance. As a result, when a disaster does strike, it leads to a request for ex-post government assistance (Freeman & Scott, 2005; OECD, 2016 as cited in Paleari, 2019; Paleari, 2019)

In contrast, the compulsory scheme imposes, by definition, an option covering property damage caused by a climate disaster. To foster the availability and affordability of this insurance, the premium does not vary with risks. The insurance penetration is therefore very high, and so is

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<sup>1</sup> Adverse selection: Information asymmetry where the policyholder has more information about his risk than the insurer (Cohen & Siegelman, 2010)

the loss potential. Thus, these schemes are supported by governments (Freeman & Scott, 2005; OECD, 2016 as cited in Paleari, 2019).

Only a few European countries have opted for a compulsory insurance scheme (they are Romania, France, Spain and Belgium). A major reason why a country chooses voluntary vs. compulsory is the degree of risk involved. In fact, it is generally those countries that have experienced the most damage that opt for the voluntary scheme (Paleari, 2019).

Overall, the respective roles played by the State and by private insurance in covering disasters vary greatly from country to country. For example, the State covers natural disasters in The Netherlands. Thus, private insurance has a minor role in this country in terms of catastrophe coverage. In Germany, however, the insurance system is exclusively private. Nevertheless, when a disaster does happen, the government steps in, notionally on an exceptional basis, although this is not deemed a "right" as such (Porrini & Schwartz, 2012). Still, this government relief in Germany (as is also the case in Italy) results in a low penetration of private weather catastrophe insurance (Faure, 2006). France, for its part, has created a public-private partnership (namely Caisse Centrale de Réassurance, CCR) (CCR, 2015), where the state guarantees the financing of catastrophes in an unlimited manner (Charpentier, 2008). Insurers take on a certain percentage of the risk, and the State acts as a reinsurer (Nussbaum, 2007), and reinsures private insurers who request it (CCR, 2015).

Finally, it should also be noted that there is a European fund, called the European Union Solidarity Fund (EUSF), put in place to provide assistance to member countries after a disaster. Its budget is €5 billion, and it has already aided 24 European countries for climatic disasters such as hurricanes, forest fires or storms (Kron et al., 2019). Moreover, there is also a push for a European Union-wide CAT-insurance system, instead of a country-based system, because disasters are not confined within country borders but generally affect several countries at the same time (Commission of the European Communities, 2009).

### ***1.2.3. The case of Belgium***

In 2007, Belgium created the “Caisse Nationale des Calamités” (CNC) which operates as a Public-Private Partnership (PPP). This insurance program, inspired by the French model, acts as an insurer of last resort. It offers full compensation up to a ceiling, and a gradually declining compensation thereafter (Consorcio de Compensacion de Seguros, 2008, as cited in Paleari,

2019). Belgium is one of the eight European countries in which the government is directly involved in the insurance scheme (Paleari, 2019). In the event of a natural disaster, insurers are required to compensate policyholders up to a certain ceiling, called the intervention limit. This intervention limit was created to protect insurers from bankruptcy (Noulet, 2021, Walhin, 2021). If the cost of a natural disaster exceeds this intervention limit, it falls to the CNC to compensate the victims (Walhin, 2021).

Handled at first at the federal level from 2007 to 2014, the management of this fund has been regionalized since that date (Finances Belgium, n.d.). Following this regionalization, different schemes emerged. As initially foreseen when the CNC was created at the federal level, the Flemish region has a fund that provides for coverage of the costs of natural disasters above the mandatory intervention limit imposed by the law. For their parts, the Walloon and the Brussels regions are not intended to cover damage exceeding the intervention limit arising from so-called “simple” risks (defined as damages to housing and small businesses essentially) (Walhin, 2021).

In July 2021, one of the most severe natural disasters in Europe took place. Spectacular floods hit Germany, the Netherlands, Belgium, and Luxembourg, and nearly 240 people died. The physical damage was estimated at €38 billion, the world’s second most expensive natural disaster of 2021 after Hurricane Ida (The Brussels Times, 2021).

In Belgium, the intervention limit was €350 million in 2021. The damage from the floods, however, was estimated at almost five times the intervention limit, above €1.6 billion (Noulet, 2021, Walhin, 2021). Given that the damage was severe and affected many people, the government of Wallonia (the region affected by these floods in Belgium) decided to intervene. For those who were insured in simple risk, the government decided to compensate them for 100 percent of their damage (Walhin, 2021), under an agreement between the regional government and the insurers where the former agreed to pay a total amount that exceeded the ceiling, at €613 million (38 percent of damages), while the government committed to pay the rest, €990 million (Noulet, 2021; Walhin, 2021). In turn, the Walloon government will borrow part of the money from the insurance companies themselves, at zero interest, and repay it over several years, in order to reduce the burden on the public finances (Noulet, 2021; Walhin, 2021).

Under this same agreement, people whose house was not insured will be compensated for 50 percent of the damages, up to a ceiling of €80 000. In choosing these numbers, the Walloon government wanted to take into account the fact that a majority of the uninsured are poor people.

At the same time, it did not want to encourage the failure of people to insure in the future, hence the 50 percent maximum coverage (Noulet, 2021).

This agreement between private insurers and the regional government is unique. However, it raises questions for the future if catastrophes of such magnitude were to take place again, and if private insurers were required to exceed the legal ceiling once again. Therefore, private insurers are currently looking for a new, more suitable system to last (Noulet, 2021).

### **1.3. Conclusion**

To conclude, the private insurer has a major role in the current economy. It compensates disaster victims in exchange for a regular payment (the premium) and fulfills three main roles, namely risk allocation, risk pooling and risk transfer. Also, their involvement in the occurrence of a large-scale natural disaster is rather limited given the fact that risk is non-diversifiable.

Regarding the government, it plays a very important role in catastrophe insurance. Indeed, it is both a regulator and a direct provider of insurance. Moreover, it is the insurer of last resort, and, in that role, it pays for the damages caused by natural disasters that are not covered by private insurers (Dlugolecki, 2008; Nussbaum, 2013). Hence, climate change and its consequences through more frequent and more extensive climate disasters constitute a considerable challenge for governments (Keucheyan, 2018). To manage these disasters, some states are creating partnerships with the private sector.

Although these roles played by government are somewhat common throughout the world, each country has a specific institutional framework and a distinct organization. For example, in the United States, states play these roles, and some state funds are in place to cover catastrophic risks. In Europe, two insurance schemes exist, the voluntary scheme, which is the most widespread, and the compulsory scheme. Moreover, some countries have created State pools to protect themselves against climate-related disasters, as it is the case in France. On the contrary, others like Germany rely on private insurance. Finally, Belgium has set up a public-private partnership that acts as an insurer of last resort. Nevertheless, this fund, which was initially national, has been regionalized and the different Belgian regions therefore operate differently. The floods that occurred in July 2021 have highlighted the huge dysfunctions of this fund, and it will be rethought in order to be really efficient.

## **Chapter 2: Consequences of climate change**

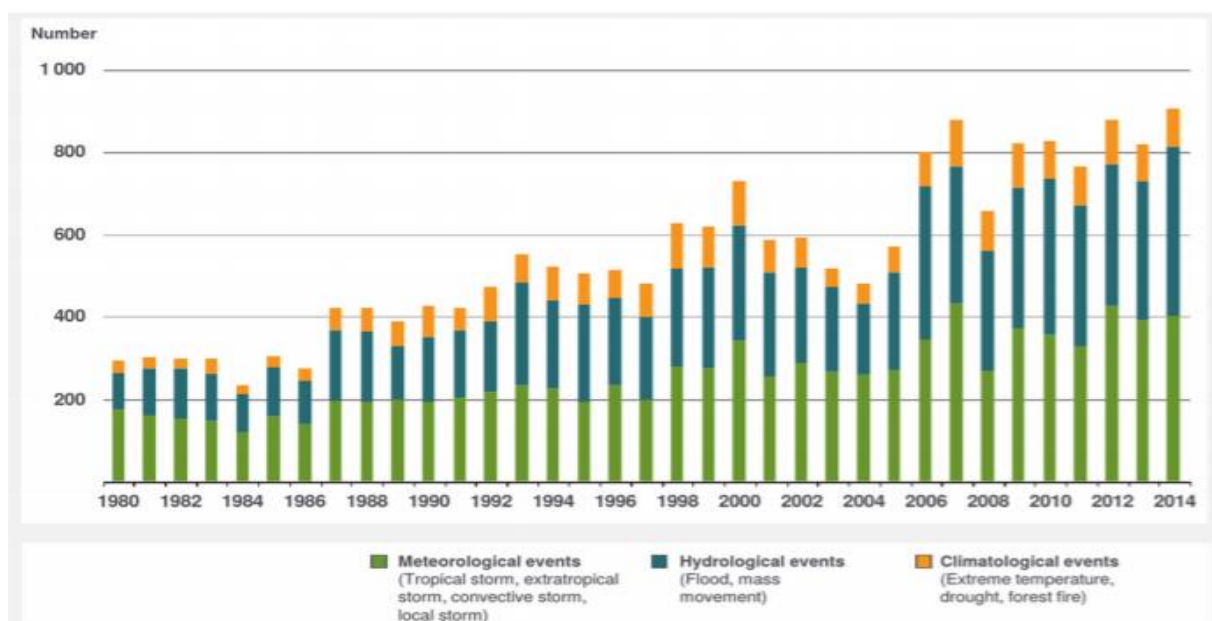
In this section, we will try to understand what influences the economic costs of a climate disaster as well as the effects of climate change on the occurrence of these disasters. Then, we will look in more detail at the commitments made specifically by countries and those made by non-state actors in order to reduce the causes of climate change.

### **2.1. Climate catastrophes in the future**

First of all, a climate catastrophe can be defined as an extreme event with low frequency of occurrence but a high magnitude of damage, either in the short term or cumulatively over time (Franzke, 2017; Wu & Chung, 2010). These events are characterized by quantitative scales with thresholds that indicate their power and the extent of the impacts they cause (Franzke, 2017; Porrini & Schwarze, 2012). It is according to these scales that the responses of the public authorities on the one hand, and of the insurers on the other, are activated or not (Franzke, 2017).

These events can be divided into two categories, rapid and slow events. Rapid events do not last more than a few days and are geographically concentrated. Some examples of this type of extreme events are hurricanes, winter storms or tornadoes (Franzke, 2017). At the opposite, slow events, like droughts, can last several years and have an impact on large regions, even entire continents (Franzke, 2017). In this thesis, we will focus on the first type, rapid extreme events.

Since the early 1990s, the number of climate catastrophes world-wide has steadily increased over the years (Charpentier, 2008; Chemarin & Picard, 2008; Franzke, 2017; Michel-Kerjan & Morlaye, 2008; Swiss Re institute, 2021). This is shown clearly in figure 1, which reports the number of weather and climate related catastrophic events between 1990 and 2014. As the graph indicates, this includes storms, floods or forest fires. Their number rose from less than 300 in 1980 to more than 900 in 2014.

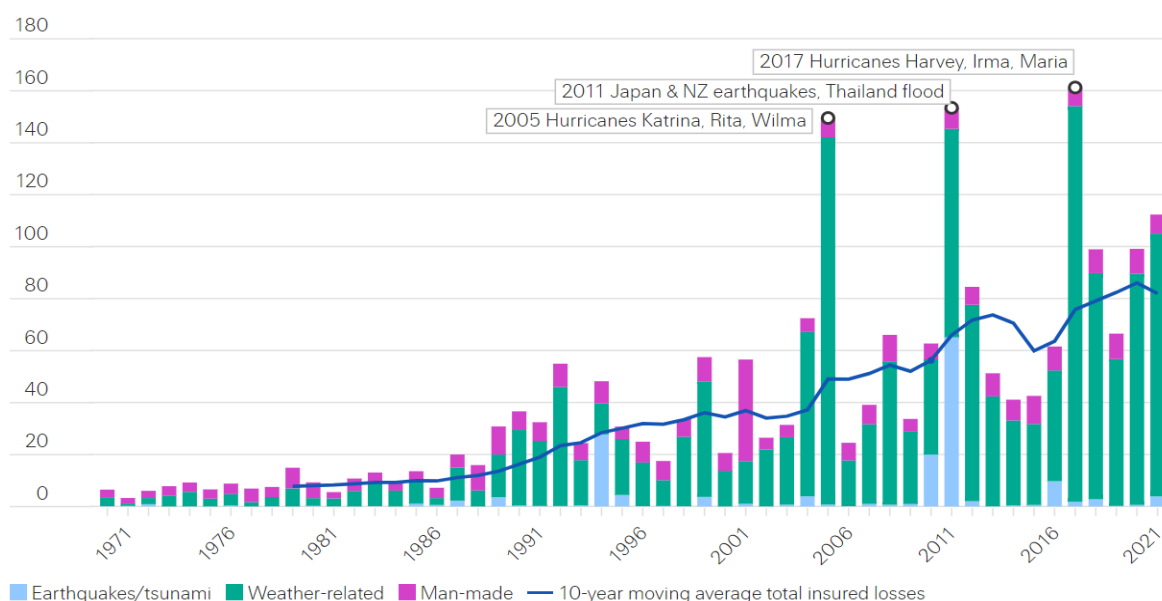


Source: Geo Risks Research, 2015, as cited in Franzke, 2017

*Figure 1: Trend in the number of weather and climate related catastrophic events between 1990 and 2014*

Moreover, not only has the number of these disasters increased, but so has their cost (Franzke, 2017; Kron et al., 2019; Kunreuther & Michel-Kerjan, 2011).

For example, we can see in figure 2 below the upward trend of the inflation-adjusted cost of natural disasters over the years since 1970. The graph shows costs, evaluated at 2021 prices, growing from a few billion in 1970 to more than US\$ 105 billion in 2021. These climate-related losses have been increasing on average by 5 to 6% over the past decades (Swiss Re institute, 2021). There are peaks in certain years corresponding to specific disasters such as the devastating earthquake in Japan that gave rise to the 2011 Fukushima disaster, and several of the hurricane disasters in the US, such as Hurricanes Katrina, Rita, and Wilma in 2005, and Hurricanes Harvey, Irma and Maria in 2017. As Kunreuther and Michel-Kerjan note in their 2011 study, among the 25 most costly disasters over their review period of 50 years, 24 were of natural origin. The only exception was the September 11 attacks in 2001 (Kunreuther & Michel-Kerjan, 2011).



Source: Swiss Re institute (2021)

*Figure 2: Insured losses, 1970-2021, in US\$ billion at 2021 prices*

The observed sharp growth in the average cost of disasters can be explained by different socio-economic factors (Kunreuther, Michel-Kerjan & Ranger, 2013). First of all, the population in the areas at risk has strongly risen (Chemarin & Picard, 2008; Guo, Kubli & Saner 2021; Hallegatte, 2014; Klein & Wang, 2009; Kunreuther et al., 2013; Linnerooth & Hochrainer-Stigler, 2015; Mills, 2005) and the corresponding rise in urbanization in these areas plays a large role in explaining the rise in costs of disaster (Bougen, 2003; Franzke, 2017; Keucheyan, 2018; Kron et al., 2019; Kunreuther et al., 2013; Michel-Kerjan & Morlaye, 2008). In particular, along the rise in the number of people in these areas, there has been a large increase in the number of buildings and structures, and therefore in the value at risk (Charpentier, 2008; Chemarin & Picard, 2008; Franzke, 2017; Kron et al., 2019; Kunreuther et al., 2013; Linnerooth & Hochrainer-Stigler, 2015; Michel-Kerjan & Morlaye, 2008). A second factor, specific to the cost exposure of insurers, is the increase in the density of insurance coverage, that is, in the share of people taking up insurance (Kunreuther et al., 2013). Finally, the impact of global warming would have more than likely affected the frequency and severity of certain disasters such as hurricanes or floods (Charpentier, 2008; Chemarin & Picard, 2008; Klein & Wang, 2009; Kron et al., 2019; Kunreuther et al., 2013).

Nevertheless, on this last point, a certain debate between experts is taking place (Charpentier, 2008; Michel-Kerjan & Morlaye, 2008), because the impacts of climate change are uncertain

(Johnson, 2014; Kunreuther et al., 2013) and it is very complicated to know if these changes are the cause of human-induced global warming, or if it belongs to other elements (Charpentier, 2008; Franzke, 2017; Kunreuther et al., 2013). Indeed, there is insufficient data to prove with certainty the impact of global warming on these disasters (Kunreuther et al., 2013). Some authors argued that the severity and frequency of catastrophes resulted from a mix of climate change and factors like natural cycles or natural climate variability for example (Franzke, 2017; Klein & Wang, 2009; Michel-Kerjan & Morlaye, 2008). Moreover, some other authors claimed that the rising costs of catastrophes could be fully, or to a great extent, explained by socio-economic factors only (Hallegatte, 2014; Linnerooth & Hochrainer-Stigler, 2015; Michel-Kerjan & Morlaye, 2008).

In the most recent literature, however, there is no doubt about the role of climate change, and in particular global warming, in explaining the increase in the number and intensity of disasters in the past decades (Guo, Kubli & Saner 2021; Mal, Singh & Huggel, 2018).

This has also long been confirmed for several years now by the Intergovernmental Panel on Climate Change (IPCC). The IPCC is a body created by the United Nations that represents the scientific consensus on climate change (Intergovernmental Panel on Climate Change [IPCC], n.d.; Mills, 2009). More importantly, the IPCC released in August 2021 a new report on the impacts of climate change on future disaster events. Although predicting the future in an exact manner is impossible, it is possible to devise various probable scenarios and evaluate their impacts (Hallegatte, 2014). In this vein, IPCC scientists have studied several scenarios, with the rise in average global temperature ranging from +1.9° to +8.5° compared to the temperature in the period 1850-1900 (IPCC, 2021).

Their findings about disasters are unequivocal. Regardless of the scenario, IPCC predicts an “Increase in the frequency and intensity of hot extremes, marine heatwaves, and heavy precipitation, agricultural and ecological droughts in some regions, and proportion of intense tropical cyclones, as well as reductions in Arctic Sea ice, snow cover and permafrost” (IPCC, 2021, p.19).

Moreover, the stronger the global warming, the more pronounced the change in extreme events (IPCC, 2021).

The IPCC is not the only source of these important warnings. Several authors have drawn the same conclusions on the potential effects of climate change on the increase in the frequency

and number of climate disasters in the future (Charpentier, 2008; Clemo, 2008; Diffenbaugh, Sing & Mankin, 2018; Dlugolecki, 2008; Franzke, 2017; Guo, Kubli & Saner 2021; Hallegatte, 2014; Johnson, 2014; Kron et al., 2019; Mal et al., 2018; Michel-Kerjan & Morlaye, 2008; Mills, 2009), though it should also be pointed out that the increase in disaster costs may not be stable and easily predictable (Crichton, 2005).

Most types of climate disasters are projected to be impacted by climate change. For example, experts predict a decrease in the number of storms, but an increase in the intensity of the severe ones (Hallegatte, 2014; Knutson et al., 2010; Webster, 2005 as cited in Kunreuther & Michel-Kerjan, 2011) making hurricanes even more dangerous, particularly in the North Atlantic (Hallegatte, 2014; Kunreuther & Michel-Kerjan, 2011).

Growing precipitations will have a serious impact on river and flash floods (Crichton, 2005; Hallegatte, 2014). Furthermore, rising sea levels will have consequences on the floods caused by storm surges (Clemon, 2008; Hallegatte, 2014) and on the severity of tsunamis (Crichton, 2005).

In parallel, the number of cold spells will decline (Hallegatte, 2014), while that of wildfires will rise, and so will other high temperature events, like heat waves (Hallegatte, 2014). According to the European Environment Agency, the number of hot summers will be multiplied by 10 in 2080 compared to their level in 2008 (Chemarin & Picard, 2008).

As already noted above, the consequences of this increase in the number and intensity of disasters will be to further increase the human and material losses (Hallegatte, 2014; Johnson, 2014; Keucheyan, 2018; Kunreuther et al., 2013; Linnerooth & Hochrainer-Stigler, 2015).

However, these catastrophes will not hit different regions of the world in the same manner, or in the same proportion (Franzke, 2017). For example, many parts of Europe are more likely to suffer from extreme floods, windstorms, and increased rainfalls, while the Mediterranean region as a whole, as well as Latin America and Southeast Asia may experience more severe droughts (Chemarin & Picard, 2008; Guo, Kubli & Saner 2021). At a broader level, in the world, developing countries may also be more affected than developed ones because they are less prepared and more vulnerable (Guo, Kubli & Saner 2021; IPCC 2014 as cited in Mal et al., 2018; Poterie and Baudoin 2015; Thirawat et al., 2017; UNISDR 2008, 2009, 2015 as cited in Mal et al., 2018;)

All told, climate change is expected to have a huge impact on the insurance industry (Dlugolecki, 2008; Leggett, 1993 as cited in Charpentier, 2008) and, at the current juncture, the climate catastrophe forecasts even raise doubts on the insurability of the major ones (Collier et al., 2021; Franzke, 2017; Kunreuther et al., 2013).

## **2.2. Climate commitments**

In order to limit as much as possible the devastating effects of climate change on our environment, international agreements have been put in place. Indeed, an overarching global treaty was established between 1992 and 1994, the United Nations Framework Convention on Climate Change (UNFCCC). This Framework Convention aims to align the countries of the world in the direction of tackling together this global problem (Conseil de l'Union Européenne, n.d.; Roelfsema, Harmsen, Olivier, Hof & Van Vuuren, 2018).

It is under the UNFCCC that the Paris Agreement was adopted in 2015. This agreement legally requires each signatory country to meet its “Nationally Determined Contribution” (NDC), which are country-specific mitigation measures (Streck, Keenlyside & Von Unger, 2016). The overall objective of the Paris Agreement was to limit the rise in average global temperature to below 2°C compared to pre-industrial averages and preferably contain it to 1.5 °C (Roelfsema et al., 2018; Streck et al., 2016).

However, one can already conclude that the various policies adopted by national governments are too weak to hope to limit average global warming to 2 degrees. This is why the role of Non-State Actors (NSA), such as regions, cities and businesses, has become critical to achieving this goal (Kuramochi et al., 2020; Roelfsema et al., 2018; Streck et al., 2016). There has been an emergence of many initiatives that specifically target these Non-State-Actors, such as the Transnational Emission Reduction Initiatives (TERIs) or Science-Based Targets (SBTs), in order to foster a much more extensive climate action (Roelfsema et al., 2018; Streck et al., 2016). Moreover, nearly 500 new commitments, complementary to national policies, specifically targeting NSAs have been adopted following the Global Climate Action Summit in 2018 (Kuramochi et al., 2020).

Against this background, the European Union (EU), in particular, is aiming to raise its climate ambitions. It has adopted an agreement to reduce its greenhouse gas emissions by nearly 55% by 2030 compared to 1990 levels, and it aims to be climate neutral by 2050, by a combination

of reductions in avoidable emissions and of offsets to unavoidable ones (Conseil de l'Union Européenne, n.d.).

In autumn 2021, a new climate summit, COP26, took place in Glasgow, Scotland. Overall, the outcomes of this summit were somewhat disappointing. COP26 failed to raise global ambitions and targets to meet the 1.5° limit, even as the NDCs presented by governments fell short of scientists' expectations (Golnaraghi, 2021).

Despite this, several topics involving insurers were addressed (Smedley, 2021). In fact, building resilience to climate change by decarbonizing the economy was a central theme of this COP26 (Golnaraghi, 2021). This is expected to be a massive undertaking, with total costs of this transition estimated at more than US\$100 trillion (Dawson, 2021). This is a domain in which the insurance industry is currently a leader (Dawson, 2021). Many opportunities exist for the insurance industry to promote resilience, in particular by developing sustainable insurance in order to reduce the under-coverage gap between insured and real damage (Dawson, 2021; Golnaraghi, 2021). This is done through public-private partnerships between academia, international organizations like the United Nations and the World Bank, and governments to create adaptation and mitigation measures as well as to develop resources and assess risks through metrics (Golnaraghi, 2021; Smedley, 2021). Also, the use of new technologies to decarbonize the economy will bring new categories of risks, for which insurers will play an essential role in pricing, assessing, and managing them (Golnaraghi, 2021).

The COP26 also saw the launch of the Net-Zero Insurance Alliance (NZIA). This Alliance includes insurance companies committed to transforming their portfolios to be carbon neutral by 2050. It includes major insurance players such as AXA, SCOR, Allianz, Swiss Re and others. The Alliance will focus on science-based targets and commit to reporting on their progress annually (Smedley, 2021).

Nevertheless, even if all the commitments made by the Governments and by NSAs are respected or even reinforced, the effects of climate change on the increase in the number and power of catastrophic events will remain significant (Crichton, 2005; IPCC, 2021). It is therefore crucial that, in addition to mitigation measures, States and NSAs also take measures to adapt to the consequences of global warming and limit future losses, even if the costs of these measures is considerable (Chemarin & Picard, 2008).

## 2.3. Conclusion

In conclusion, we have been witnessing for decades a trend of progressive increase in the number of climate disasters in the world. In addition to their number, their cost is also dramatically rising, with an annual average increase between 5 and 6%. These costs have jumped from a few billion in the 1980s to over 100 billion last year.

The costs of disasters are caused by several socio-economic factors such as the increase in population, the increase in value at risk as well as the increase in insurance coverage. In addition, although it is debated among some authors, climate change has been reported to impact the frequency and severity of some disasters in previous decades.

Although its role is still disputed regarding the past causes of disaster costs, it is nevertheless certain today that climate change will have an immense impact on the frequency and severity of climate-related disasters in the future. Moreover, the more pronounced the global warming, the more intense and frequent the climate catastrophes will be. This will have a significant impact on future property and casualty losses and consequently on the insurance industry.

To tackle the problem of climate change, several international treaties have been established. These aim to encourage signatories to take measures to limit the causes of climate change. These treaties target not only state actors but also non-state actors, as the policies adopted by states will not be sufficient to limit the average temperature increase. Despite all these commitments, the effects of climate change will still be considerable on the increase in the number and intensity of disasters, and it is therefore essential, besides fostering mitigation measures, to develop adaptation measures to the consequences of climate change.

### **Chapter 3: Impacts of climate change on the insurance industry**

Among the many voices that highlight the devastating potential of climate change, the insurance industry stands as one of the most concerned (Geneva Association, 2009 as cited in Johnson, 2015). We know that climate change will have a large negative impact on insurance on property, health, life and liability to name only a few (Mills, 2005). In this thesis, we will focus primarily on non-life insurance.

The increase of climate-related disasters that scientists predict will inevitably translate into an increase in the number of claims (Anderson, 2003; Clemo, 2008; Collier et al., 2021; Dlugolecki, 2008; Keucheyan, 2018; Swiss Re, 2021). At current pricing, this will in turn provoke a drop in capital reserves, loss of profitability (Botzen, Van Den Bergh & Bouwer, 2010) and, in worst case scenarios, insolvency (Collier et al., 2021; Mills, 2009).

As a result, one of the most important measures adopted by insurance companies will be to increase prices for certain catastrophic risks (Collier et al., 2021; Keucheyan, 2018; Mills, 2009; Wahlin, 2021).

Moreover, not everyone will be able to afford coverage against these risks, and those who don't, or those who get only partial coverage, will have to rely on public or humanitarian assistance (Keucheyan, 2018). This could create a vicious circle: as premiums depend in part on the number of insureds, an increase in premiums may reduce their number, which will potentially lead to the need for further increases in premiums (Keucheyan, 2018).

In addition, some risks, by becoming too frequent or too large, could become uninsurable (Bougen, 2003; Charpentier, 2008). Private insurance companies may have to refuse to insure certain risks or regions (Collier et al., 2021; Keucheyan, 2018), such as fire-prone areas in the Western states in the United States for example (Flavelle, 2019).

The combination of declining demand for insurance due to higher premiums (Dlugolecki, 2008), and the proliferation of uninsurable risks in certain regions or areas that insurance companies will no longer cover (Botzen et al, 2010), will lead to a decline in insurers' revenues, threatening the profitability of some insurance companies (Johnson, 2015), and even pushing some into bankruptcy (Mills, 2005).

The consequences of these trends in insurance will not only affect insurers but all citizens. When some people will not afford or will not buy insurance policies, and some risks will remain uninsured (Doherty, 1997), a significant portion of the risks will be passed directly or indirectly to the victims of catastrophes, or to the State (Mills, 2005). The State could absorb a part of the charge of these disasters, which implies that citizens will bear the additional burden via taxes and or contributions (Wahlin, 2021). Thus, either way, the citizen will be the one to pay the extra price of these disasters, either by paying a higher insurance premium, by taking on a larger share of risks, or by paying taxes (Wahlin, 2021).

For insurance company, this profitability issue will also be driven by other impacts of climate change. For example, certain risks may potentially increase capital costs (Hawker, 2007 as cited in Stechmesser, Endrikat, Grasshoff & Guenther, 2015), their operating costs (Mills, 2009), and the returns on their portfolios of investments if these are affected by climate change (Dlugolecki, 2008). Indeed, it is almost certain that climate change will reduce the value of the so-called built environment<sup>2</sup> (Johnson, 2015). Finally, as climate disasters increase portfolio volatility, investors in insurance companies will demand a greater return on equity (Kunreuther & Michel-Kerjan, 2009). Thus, both sides of insurance companies' balance sheets will be impacted by climate change (Maynard, 2008).

An important aspect of climate change is the increase in the frequency of climate extremes, and, equivalently, a reduction in the length of time between their re-occurrence (Dlugolecki, 2008; Mills, 2005). For example, extreme temperatures are expected to occur 25 times more often over a 60-year period (Dlugolecki, 2008). These extreme temperatures, although not intrinsically very dangerous for property risks, are correlated with catastrophic events that then can be dangerous (Dlugolecki, 2008). This will impact insurance industry in several ways.

First of all, the models historically used to price risks are becoming obsolete because the historical data is no longer sufficient to capture the right information (Linnerooth-Bayer & Hochrainer-Stigler, 2015). As a result, risks are incorrectly calculated and underestimated for extreme events (Munich Re, 2006 as cited in Dlugolecki, 2008). This underestimation in turn leads to a far too high exposure to such risks as well as to an insufficient capacity to manage them. Moreover, the premiums charged by the insurance companies are therefore too low relative to the losses actually incurred, and the gap between the premiums paid in, and the losses

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<sup>2</sup> The built environment can be defined as the man-made environment that enables the development of human activity. This refers to the various buildings constructed, cities, energy networks etc (Wikipedia, n.d.)

paid out, has narrowed (Mills, 2005). Adjusting these prices and minimum reserves is also complicated by the claim patterns which are changing due to climate change. Indeed, the losses incurred will be even more variable in the future, both in absolute and relative terms (Mills, 2005).

Another channel for the impact of climate change on insurers is the likely change in the credit ratings for their debt by credit rating agencies. So far, credit ratings have not been adjusted to the changing profitability profile of insurers, which implies an exposure to unexpected risks for investors, as well as to uncoverable reinsurance contracts for insurers (Dlugolecki, 2008). To address this, however, rating agencies have started to require that insurance companies increase reserve capital to cover potential future losses (Lewis, 2007 as cited in Johnson, 2015).

A major avenue by which climate change will affect the insurance industry will be the action of regulators. Indeed, it is likely that regulators will become more stringent with insurance companies regarding the disclosure of their exposure to climate risks, via stress-tests or climate scenarios for example (Bachir, Gokhale, & Ashani, 2019). In addition, there will probably be a demand for more disclosure of how climate change data is handled and more disclosure of adaptation measures to reduce the impacts of climate risk (Bachir et al., 2019).

In order to reduce its potential future losses, the insurance industry itself will continue to be a key player in climate change adaptation and mitigation (Mills, 2007; Porrini & Schwartz, 2012). Insurance companies are already beefing up their effort at raising awareness, and developing prevention and preparedness measures (Crichton, 2005). One of their objectives is to reduce the risks taken by policyholders (Crichton 2007). Indeed, the insurance industry can promote the adoption of pollution-reducing behavior (Porrini & Schwarze, 2012), and it has an important role to play in raising the awareness of its customers about the risks of climate change, including via its prices, by increasing them in higher-risk locations for instance (Clemo, 2008). Insurance companies can use premium reductions as incentives to encourage people to invest in non-risk areas (Bachir et al., 2019; Linnerooth-Bayer et al., 2009; Porrini & Schwartz, 2012), or to invest in damage resistant materials (Ward, Herweijer, Patmore & Muir Wood, 2008).

Additional examples of mitigation measures induced by the insurance industry are building codes and safety regulations, which are essential to get insured (Maynard & Ranger, 2012). In fact, climate change is likely to foster an even stronger collaboration between government and private insurance to encourage the adoption of measures and public policies that limit its

impacts (Bachir et al., 2019). Public policy would include measures to strongly discourage development in risky areas, and rules to encourage the use of materials adapted to future climate impacts (Bachir et al., 2019; Clemo, 2008). Thus, these two major actors are likely to work together to innovate and to better manage the impacts of climate change (Mills, 2005).

Having said this, it is worth noting that not all impacts of climate change are going to be negative. Although it is one of the most important issues that confronts the industry (Ernst and Young, 2008 as cited in Linnerooth-Bayer & Hochrainer-Stigler, 2015; Keucheyan, 2018; Mills, 2009; Swiss Re 2006, as cited in Michel-Kerjan & Morlaye, 2008), some effects may turn out to be favorable from the industry's perspective (Charpentier, 2008). As Warren Buffet stated in 2016:

As a citizen, you may understandably find climate change keeping you up at nights. As a homeowner in a low-lying area, you may wish to consider moving. But when you are thinking only as a shareholder of a major insurer, climate change should not be on your list of worries (Buffet, 2016 as cited in Keucheyan, 2018, p.484).

For Buffet, although climate change will have a clear impact on the number of catastrophes, insurers can adapt and still be profitable (Keucheyan, 2018). Moreover, these changes in the industry are a source of new opportunities and innovation (Collier et al., 2021). Climate change is even considered by some as a major growth factor for the insurance industry (Kent, 2010 as cited in Johnson, 2015).

In conclusion, climate change will have significant negative impacts on the insurance industry, such as a decrease in capital reserves, loss of profitability and even insolvency in some cases. In addition, the models used to predict these risks are becoming obsolete as the frequency, intensity and variability of catastrophes increase. As a result, insurers have no choice but to raise their prices and select the risks they want to cover. The consequences on citizens are therefore considerable. Some people will not be able to pay the premiums, and some risks will not be insured anymore. Regulators and rating agencies will become more and more strict, and it is expected that stress-tests and climate disclosures will increase. To limit these impacts, insurance companies will be at the forefront of climate adaptation and mitigation measures, notably through collaboration with national governments.

Nevertheless, climate change will not only have negative effects on insurance. It is even considered by some industry experts as an opportunity to innovate and grow the business.

## Chapter 4: Extreme events risk financing

In this chapter, we will investigate how insurance companies insure themselves against climate disasters. We will first discuss reinsurance, which is the primary system used by insurance companies to cover themselves. We will then talk about other financial mechanisms and focus specifically on financial instruments such as insurance-linked securities. These instruments allow insurers to pass on the catastrophe risks to the markets, but they have several challenges and drawbacks, which we will discuss along with other criticisms.

### 4.1. Reinsurance

As mentioned above (cf. section 1.1.), when a loss occurs, it is the primary insurer's responsibility to pay the victims for their losses. In the event of a major catastrophe, however, a significant part of the population suffers large damages at the same time, so the spreading of risks through diversification is not possible (Hofmann & Pooser, 2017). Indeed, when a severe catastrophe happens, a large number of insurers are affected simultaneously. In these cases, therefore, the law of large numbers is inapplicable, and the risk does not disappear (Doherty, 1997).

In order to limit their own risks and therefore retain the capacity to insure their clients, primary insurers often use reinsurance. This is true as well in the context of risks of catastrophes. In fact, this method is the most common one for these types of risks (Bougen, 2003; Doherty, 1997; Hofmann & Pooser, 2017; Klein & Wang, 2009).

The operating principle of reinsurance is very similar that of insurance. The reinsurer provides coverage to the insurance company, paying out in case of damage in exchange for the payment of premiums. In doing this, the insurance company transfers its risk to one or more reinsurers, and is protected if the disaster actually occurs (Hofmann & Pooser, 2017; Kunreuther & Michel-Kerjan, 2011; Patrik, 2006).

As such, reinsurance offers a greater level of risk sharing (“mutualization”) than simple insurance (Keucheyan, 2018; Kron et al., 2019). With this additional layer of protection against massive losses, insurance companies can in turn reduce (at least, in theory) the premiums that they charge to policyholders (Keucheyan, 2018).

In addition, reinsurers are highly globalized and they diversify their activities across geographic areas and economic sectors more easily than smaller insurers (Ben Ammar, Eling & Braun, 2015), making this mutualization easier (Keucheyan, 2018; Kunreuther & Michel-Kerjan, 2011).

The two major reinsurers in the world are Munich Re and Swiss Re. Also, other important reinsurance players are Lloyd's, Hanover Re, Gen Re, Berkshire Hathaway, and SCOR (Keucheyan, 2018). In 2020, the global reinsurance capital was US\$ 429 billion (Guy Carpenter, n.d.) (Appendix 1). By comparison, the non-life insurance market in 2020 was US\$ 3.4 trillion (Yahoo-Finances, 2022).

Reinsurance plays a crucial role in insurance (Keucheyan, 2018): indeed, the scale of the coverage that an insurance company will choose to provide in an area at risk directly depends on the percentage of its portfolio that it can reinsure (Kunreuther & Michel-Kerjan, 2011).

Moreover, supply and demand for reinsurance tend to follow a cyclical pattern (Wattman & Feig, 2008). Following a major catastrophe, the supply and capacity of reinsurance tends to decrease, while, at the same time, demand tends to increase. With these two forces, the premiums demanded by reinsurers can be increased, allowing them to absorb their losses and create reserves in anticipation of future catastrophes. This is called a “hard” market (Bougen, 2003; Wattman & Feig, 2008). Afterwards, follows a period of “soft” market (if there are no new catastrophes), where reinsurance capacity increases, and premiums decline, until the next catastrophe (Kunreuther & Michel-Kerjan, 2011; Wattman & Feig, 2008).

The relationship between a reinsurer and its clients is, in a large part, a long term one (Hofmann & Pooser, 2017; Lonkevitch, 1999 as cited in Bougen, 2003).

It is also frequent for reinsurers to purchase insurance contracts from other reinsurers, a process known as retrocession (Brockett, Witt & Aird, 1991; Von Dahlen & Von Pete, 2012). It allows reinsurers to diversify their risk, increase their capacity and strengthen their solvency (Brockett et al., 1991).

Nevertheless, it is important to point out that reinsurance has some limitations. First, its cost is very high, reflecting the fact that even a single catastrophe could exceed an insurance company's ability to cover the losses (Doherty, 1997; Hofmann & Pooser, 2017). Second, with the growing cost of disasters, we are reaching a capacity limit for reinsurance (Nell & Richter, 2004). The

risk is becoming too large for the reinsurance industry to be able to diversify enough, and in turn to be able to provide enough funding to cover the potential losses (Charpentier, 2008). And, finally, the mismatch between supply and demand for reinsurance implies that it is not always available when needed (Wattman & Feig, 2008).

In summary, reinsurance is a mechanism widely used by insurance companies to cover themselves in the event of a climate disaster. Nevertheless, traditional reinsurance faces serious capacity issues (Nell & Richter, 2004). This limitation raises questions about the long-term viability of reinsurance (Hofmann & Pooser, 2017). A more solid solution to cover risks linked to low frequency and high severity events such as natural catastrophes is therefore securitization<sup>3</sup> (Cummins & Trainar, 2009 as cited in Ben Ammar et al., 2015), to which we now turn.

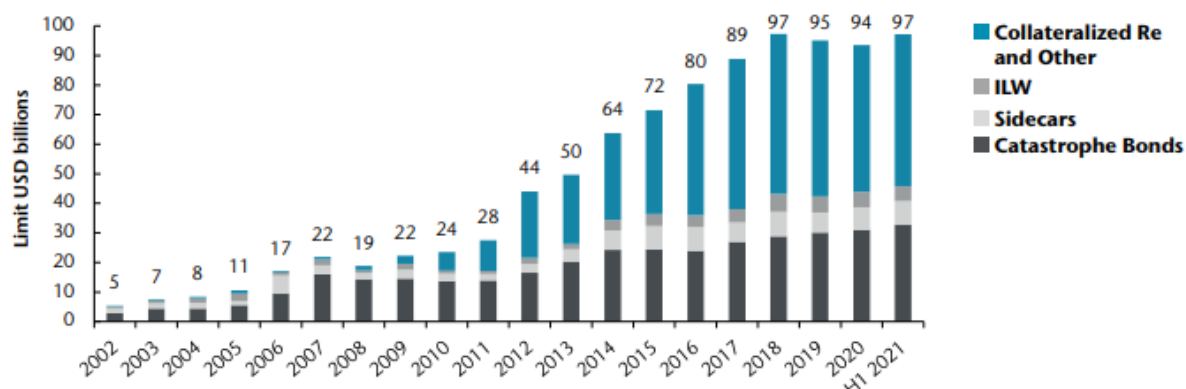
#### **4.2. Insurance-linked securities (ILS)**

As argued above, the rise in losses due to catastrophic climate events will certainly cause an increase in the demand for insurance contracts and various other insurance products (Mills, 2009). Among these new products are insurance-linked securities (ILS), also known as “Alternative Risk Transfer” (ART) (Ben Ammar et al., 2015; Keucheyan, 2018).

Insurance-linked securities are a class of financial instruments used to transfer the risks related to natural disasters that are borne by insurance or reinsurance companies to the capital markets through securitization in exchange for a payment from these companies (Bougen, 2003; Carayannopoulos, Kovacs & Leadbetter, 2003; Cummins 2008; Götze & Gütlér, 2020; Hofmann & Pooser, 2017). The leading ILS in the market are catastrophe bonds, collateralized reinsurance, industry loss warranties (ILW) and sidecars. Although CAT bonds were historically the most prevalent ILS, today it is collateralized reinsurance that has the largest market share (Aon securities, 2021), as we can see in figure 3.

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<sup>3</sup> Securitization: Process in which a bank or other credit organization pools different loans in securities, with the aim of selling them to investors. It allows the bank to transfer the risk associated with these loans to other investors. (European Commission, n.d.).



Source: Aon Securities, 2021

*Figure 3: ILS market development, in US\$ billion, from 2002 to 2021*

Most of these instruments use “Special Purpose Vehicles<sup>4</sup>” (SPV) to carry the risk originally carried by insurance firms (Hofmann & Pooser, 2017).

In recent decades, as we have entered into a new era of natural catastrophes (Michel-Kerjan & Morlaye, 2008), ILS have been created in order to respond to an increased demand for catastrophic risk coverage (Wattman & Feig, 2008). Indeed, the reinsurance market was already considered to be too limited (Wattman & Feig, 2008) and could not meet the demand while it was clear that the capital markets are considerably larger (Carayannopoulos et al., 2003; Doherty, 1997; Hofmann & Pooser, 2017; Wattman & Feig, 2008). As a complementary solution to reinsurance, ILS made it possible to overcome the volume and geographical capacity limits of reinsurers while offering diversified assets to investors (Bougen, 2003; Carayannopoulos et al., 2003; Christophers, Bigger & Johnson, 2020; Hofmann & Pooser, 2017; Michel-Kerjan & Morlaye, 2008; Taylor & Kunreuther, 2002 as cited in Hofmann & Pooser, 2017).

In addition, the price of reinsurance is volatile (Anderson et al., 1998, as cited in Carayannopoulos et al., 2003) and it varies in line with the occurrence of catastrophes. Thus, another feature of these instruments is that they are protected against that rise in reinsurance rates (Carayannopoulos et al., 2003), and their creation was originally intended to provide a cheaper protection solution (Doherty, 1997; Klein & Wang, 2009; Michel-Kerjan & Morlaye, 2008).

<sup>4</sup> For more details, see section 4.2.1.

Nevertheless, in reality, these instruments have not proven to be cheaper than traditional reinsurance (Michel-Kerjan & Morlaye, 2008). In fact, because they entail high transaction costs (Hofmann & Pooser, 2017), they are even generally much more expensive (Bantwal & Kunreuther 2000, as cited in Carayannopoulos et al., 2003).

Given these different features – the complexity of the products, the large amounts involved, and the expertise required to assess the value of these securities – most ILS investors are specialized (Johnson, 2014; Thirawat et al., 2017). The main investors in ILS are, on the one hand, insurance and reinsurance companies (Carayannopoulos et al., 2003; Collier, Elliott & Lehtonen, 2021) that are acquainted with risk and want to diversify, and, on the other, so-called "alternative investors", such as private equity funds, hedge funds, sovereign funds and CAT funds (Keucheyan, 2018; Michel-Kerjan & Morlaye, 2008). All of them are attracted by a wide range of potential advantages. These include, as the case may be, (i) the high yields (Ben Ammar et al., 2015; Doherty, 1997), which ranges from 5 to 15 percent annually (Keucheyan, 2018), (ii) the lack of correlation with the broader capital market (Ben Ammar et al., 2015; Johnson, 2014; Keucheyan, 2018; Kunreuther & Michel-Kerjan, 2009), (iii) the low volatility (Ben Ammar et al., 2015), (iv) the scalability (Johnson, 2014), (v) the flexibility in coverage terms (Carayannopoulos et al., 2003), (vi) the protection against the credit risk thanks to the collateralization of some ILS (Carayannopoulos et al., 2003; Michel-Kerjan & Morlaye, 2008) and (vii) the scope for diversification (Johnson, 2014; Hofmann & Pooser, 2017) that ILS instruments offer (Johnson 2015; Michel-Kerjan & Morlaye, 2008). A final and very attractive feature of some of these securities is that ILS with an index-based trigger<sup>5</sup> allows claims to be paid faster than ordinary reinsurance (Hofmann & Pooser, 2017).

The idea of transferring the risk of natural disasters to the capital market was triggered by Hurricane Andrew in 1992 (Keucheyan, 2018), a disaster of enormous magnitude (Doherty, 1997; McChristian, 2012). The ILS market remained fairly small at the time (Ben Ammar, 2015; Bougen, 2003; Carayannopoulos et al., 2003) but has since been steadily growing (Götze & Gütlér, 2020). By 2021, this market was worth US\$ 97 billion (Aon securities, 2021) while reinsurance market was worth US\$ 441 billion (Appendix 1) (Guy Carpenter, n.d.).

The increase in reinsurance prices as well as the tightening of the rating agencies' criteria regarding the coverage of catastrophic events has resulted in a surge in demand for ILS products

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<sup>5</sup> This trigger will be explained in the section 4.2.1.

(Kunreuther & Michel-Kerjan, 2011), although “in absolute terms, however, this market remains a tiny niche” (Michel-Kerjan & Morlaye, 2008, p.156)

To summarize, an insurance company wishing to cover its risk induced by a climatic catastrophe can therefore either use "classic" reinsurance or transfer its risk to the capital market via an ILS instrument. We will now take a closer look at the main ILS available on the reinsurance market, which are catastrophe bonds, collateralized reinsurance, sidecars, ILW (Aon Securities, 2021) and CAT options. Other ILS, such as catastrophe swaps, contingent capital facility or catastrophe equity puts are also active in the market, but we have decided not to consider them in this thesis given their relatively low importance.

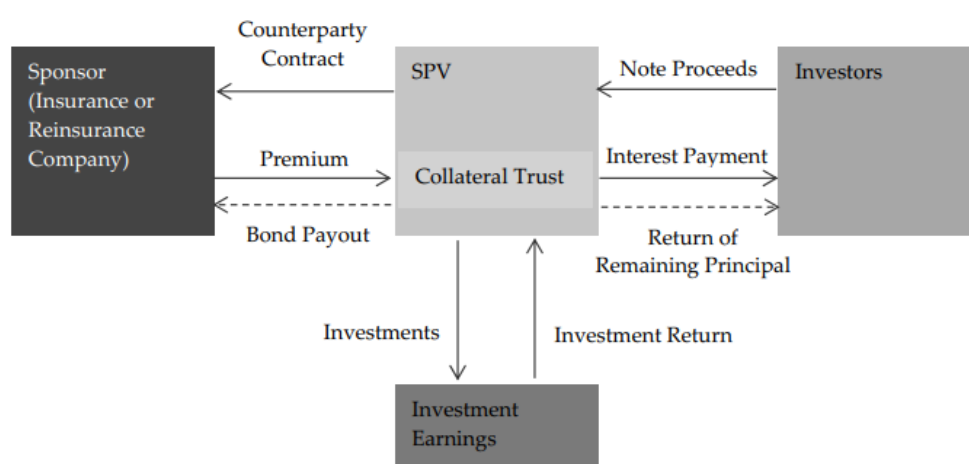
#### ***4.2.1 Catastrophe bonds (CAT bonds)***

Among all the insurance-linked securities, catastrophe bonds (CAT bonds) were the most prominent (Barrieu & Albertini, 2010; Braun, 2016; Carayannopoulos et al., 2003; Cummins & Barrieu, 2013; Götze & Gürtler, 2020), until years 2011-2012, when the leading position changed for collateralized reinsurance (Aon Securities, 2021). The CAT bonds market is growing, specifically since the debt crisis in 2010 (Deloitte, 2016). Between 2002 and 2021, the CAT bonds issued rose from a few US\$ billion per year (Aon Securities, 2021) to more than US\$ 32 billion (Appendix 2) (Aon Securities, 2021; Guy Carpenter, n.d.). Demand is so high that it greatly exceeds supply, and some investors are complaining about the lack of availability of CAT bonds (Johnson, 2014).

The purpose of a catastrophe bond is to transfer the risk associated with the occurrence of a natural disaster to capital market investors (Wattman & Feig, 2008). It works as follows: an insurance or reinsurance company, a State or a corporation, known as the “sponsor” or “cedent” will create a “Special Purpose Vehicle” (SPV), an independent company that is most of the time located in a tax-favored jurisdiction such as Cayman Islands, Bahamas, Bermuda or Ireland (Hofmann & Pooser, 2017; Johnson, 2014; Keucheyan, 2018; Wattman & Feig, 2008). The sponsor (cedent) will pay a premium to the SPV, and the principal invested by the investor will also be placed in that trust (Johnson, 2014). This SPV will then issue the CAT bond to the investors. In exchange to lending a certain amount of money by buying the catastrophe bond to the sponsor, the investor receives quarterly coupons via the SPV. At the end of the maturity

date of the bond and if the event covered by the bond did not occur, the investor receives its investment back and earns money thanks to interests' payments.

On the contrary, if the event occurs, the transaction is closed, and the sponsor keep part, or all the principal initially invested by the investor who loses part of all the principal and future coupons (Ben Ammar et al., 2015). The money is then used by the sponsor to reimburse its policyholders who suffered from the damages of the catastrophic event (Ben Ammar and al., 2015; Hofmann & Pooser, 2017; Johnson, 2014; Keucheyan, 2018; Wattman & Feig, 2008).



Source: Ben Ammar et al., 2015

*Figure 4: Typical structure of a CAT bond*

The interest received by the investor is equivalent to a risk-free rate, usually the LIBOR, added to a risk premium (Charpentier, 2008). The main investors of catastrophe bonds are hedge funds, banks, insurance companies, pension funds or specialized funds (Hofmann & Pooser, 2017).

The principal is usually divided into different tranches. Those tranches can cover different catastrophic events in different locations and each tranche could be protected or not (Carayannopoulos et al., 2003; Johnson, 2014; Kunreuther & Michel-Kerjan, 2011). In the case of an unprotected tranche, if the specific event occurs, then the investors lose both the principal and the interests. On the contrary, in the case of a protected tranche, the investor will receive the principal back, and only the interests will be lost if the catastrophe happens (Kunreuther & Michel-Kerjan, 2011). The unprotected tranches offer higher returns to the investors but are riskier than the protected ones (Johnson, 2014).

CAT bonds are multiyear contracts varying between 1 and 5 years, but last generally 3 years, which is quite rare in the reinsurance market and is a valuable asset in an industry as cyclical as reinsurance (Ben Ammar et al., 2015; Johnson, 2014; Keucheyan, 2018; Kunreuther & Michel-Kerjan, 2011; Wattman & Feig, 2008). Typically, the size of the CAT bond varies between US\$ 50 million and US\$ 200 million, even though the largest bond issued was US\$1.2 billion (Kunreuther & Michel-Kerjan, 2011).

In order to be covered by a CAT bond, an event must be spatially et temporarily localized (Johnson, 2014; Keucheyan, 2018). Events such as sea rising, or desertification could not be insured through CAT bonds because it is impossible to localize in space and time (Keucheyan, 2018). The main events insured by CAT bonds are US Hurricane, US earthquake, Japan earthquake and European windstorm. Other events like UK flood, ice storms, Californian wildfires and tornados could also be securitized through the emission of CAT bonds (Johnson, 2014; Wattman & Feig, 2008). Large investors prefer to invest in events known as peak perils, which offer higher rates of return per unit of risk than the other perils. They are localized in specific regions in which there are considerable amounts of value at risk and in which a catastrophic event could result in a tremendous amount of loss (Johnson, 2014).

Catastrophe bonds offer various advantages to investors and sponsors. From the investor point of view, those bonds provide a diversification asset because natural disasters are not correlated with the stock market (Carayannopoulos et al., 2003; Hofmann & Pooser, 2017; Keucheyan, 2018; Swiss Re as cited in Ben Ammar and al., 2015; Wattman & Feig, 2008). Moreover, CAT bonds offer high interest rates and an impressive performance in comparison to other bonds (Ben Ammar and al., 2015; Carayannopoulos et al., 2003; Doherty, 1997; Hofmann & Pooser, 2017; Kunreuther & Michel-Kerjan, 2011; Wattman & Feig, 2008). Finally, the probability of a catastrophe bond to be triggered is quite low, estimated between 0,5 and 2% (Mortimer, 2012 as cited in Keucheyan, 2018; Wattman & Feig, 2008).

The main advantages of CAT bonds for sponsors, in addition to those of insurance-linked securities in general, is that CAT bonds allow to diversify the risk through space and time (Keucheyan, 2018). Besides, the value of fund is guaranteed in case of a loss, thus CAT bonds act like a collateralized reinsurance contract (Hofmann & Pooser, 2017). Nevertheless, CAT bonds also have a few drawbacks. For instance, their liquidity level is lower than the one of other debt instruments and, due to its complexity, CAT bond market is more limited than the classic bond market (Thirawat et al., 2017).

Different kind of triggers can be used in a catastrophe bond. The bond could be activated depending to either the actual losses incurred by the sponsor, which is called an indemnity trigger (Cummins, 2008) and is comparable to classic reinsurance, or to an industry-index trigger, i.e a trigger that is based on the losses of the whole industry and is computed using a specific industry index (Ben Ammar et al., 2015; Doherty, 1997; Götze & Gürtler, 2020; Hofmann & Pooser, 2017; Kunreuther & Michel-Kerjan, 2011). Moreover, the trigger could not only be determined by the damages, but also by specific characteristics of the event, which is called a parametric index (Ben Ammar et al., 2015; Hofmann & Pooser, 2017; Keucheyan, 2018; Kunreuther & Michel-Kerjan, 2011). Those characteristics could be, for a hurricane, the wind speed or its radius for example (Ben Ammar et al., 2015).

Finally, it should be noted that CAT bonds are not only used to insure climate catastrophes, but also other types of extreme events such as flu pandemic (Keucheyan, 2018), terrorism (Kunreuther & Michel-Kerjan, 2011; Scism & Das, 2016 as cited in Hofmann & Pooser, 2017) or cyber hacking (Scism & Das, 2016 as cited in Hofmann & Pooser, 2017) for examples.

#### ***4.2.2. Collateralized reinsurance***

Collateralized reinsurance has become the leading ILS in terms of market share over the last ten years (Aon Securities, 2021). It was worth about US\$ 50 billion in 2021 (Aon Securities, 2021; Evans, 2021). Collateralized reinsurance can be defined as "Privately structured contracts which insure a portfolio of specific insurance policies against losses caused by (a) predefined peril(s)" (Ben Ammar et al, 2015, p.158). Collateralized reinsurance is similar to reinsurance, except that a collateral is granted (Bodoff, 2010; Fermat Capital Management, 2014 as cited in Ben Ammar & al., 2015). This collateral can reach up to the amount of the covered loss, thus removing the counterparty risk<sup>6</sup> (Evans, 2020 as cited in Bockius & Gatzert, 2022).

These contracts are customized according to the counterparties' needs, which makes them very flexible but non-tradable (Risk.net, 2014 as cited in Ben Ammar et al., 2015). Like reinsurance contracts, collateralized reinsurance generally runs for one year (Krutov, 2010 as cited in Ben Ammar et al., 2015). In addition, they offer wider spreads than CAT bonds (Willis Capital Markets & Advisory, 2013 as cited in Ben Ammar et al., 2015).

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<sup>6</sup> Counterparty risk: Counterparty risk is the risk to a contractor that the counterparty will not meet its contractual obligations (Biais, Heider & Hoerova, 2012).

Nevertheless, these contracts require high volumes and are therefore only accessible to the largest investors. Moreover, they are illiquid and require expertise due to their complexity (Risk. Net, 2014 as cited in Ben Ammar). Finally, the collateral is not immediately available once the contract is completed and is most often released once the loss is quantified, which means that the collateral is trapped and therefore cannot be used for other purposes (Aon Securities, 2019).

Despite these disadvantages, collateralized reinsurance has strongly developed in recent years (Ben Ammar et al, 2015), representing nearly 50% of alternative capital capacity (Aon Securities, 2021).

#### ***4.2.3. Industry loss warranties (ILW)***

Another instrument used to cover catastrophe risks is industry loss warranties (ILW) (Ben Ammar et al., 2015; Kunreuther & Michel-Kerjan, 2011). The market share was worth less than US\$ 5 billion in 2021 (Aon Securities, 2021). Their objective is to protect both the insurer and the reinsurer in the event of a catastrophe (Kunreuther & Michel-Kerjan, 2011).

The buyer of an ILW, who wants to protect himself against a catastrophic risk, pays a premium to the ILW seller. If a catastrophe occurs in the industry, and if the industry loss index exceeds a certain threshold (trigger), the ILW buyer can request a claim from the ILW seller up to a certain amount (a predefined limit), regardless of the actual losses incurred by the buyer. Thus, ILW is very closely related to excess-of-loss reinsurance<sup>7</sup> (Kunreuther & Michel-Kerjan, 2011).

Moreover, in a large majority of ILWs, a second trigger appears. The ILW buyer receives an amount equal to the ILW limit only if the industry loss index is above a certain level and the second trigger, called the indemnity trigger, which is the buyer's actual loss, also exceeds a predefined level (Ben Ammar et al., 2015).

ILWs are typically purchased by insurers, reinsurers or large companies with a high concentration of business in a small number of locations, allowing them to expand their exposure (Kunreuther & Michel-Kerjan, 2011).

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<sup>7</sup> Excess-of-loss contract: A type of non-proportional reinsurance contract whereby the ceding company will be compensated by the reinsurer if the losses incurred are superior to a certain value (Brockett & al., 1991).

ILW contracts generally do not exceed 1 year, unlike CAT bonds, which are multi-year contracts (Ben Ammar et al., 2015). Moreover, ILWs cover amounts ranging from 1 to 250 million USD, which makes them much more accessible than CAT bonds (World Economic Forum, 2008 as cited in Ben Ammar et al., 2015). In addition, ILWs have relatively low transaction costs for all parties involved (Kunreuther & Michel-Kerjan, 2011).

#### **4.2.4. Sidecar**

A sidecar is a special purpose insurance vehicle (SPV) that is created by capital market investors and in which an insurance or reinsurance company will cede a certain percentage of its risk. The investor of a sidecar will bear a certain percentage of the risk of a portfolio of the (re)insurance company and will receive premiums on a pro rata basis (Hofmann & Pooser, 2017; Kunreuther & Michel-Kerjan, 2011; Wattman & Feig, 2008). In 2021, the worldwide market value of sidecars was about US\$ 10 billion (Aon Securities, 2021).

While ILWs operate as excess-of-loss financing, sidecars rely on a quota-share principle<sup>8</sup> (Kunreuther & Michel-Kerjan, 2011; Wu & Soanes, 2007). Thus, the sidecar investor splits the risk with the insurance company in exchange for a percentage of the premiums plus dividends in shares (Kunreuther & Michel-Kerjan, 2011). Moreover, the premiums paid by the (re)insurance company (the cedent) to the investor are not fixed but are “equity-like”, meaning that they vary depending on the value of the claims (Ben Ammar et al., 2015).

Sidecars allow investors to invest in the risk of an (re)insurance company's portfolio, unlike CAT bonds, which enable investors to invest in one or more specific catastrophes (Ben Ammar et al., 2015; Kunreuther & Michel-Kerjan, 2011). One part of the portfolio can be negotiated by the investor in order to maximize its profit (Michel-Kerjan & Morlaye, 2008).

Sidecars are offered by licensed reinsurers, in most cases specialized CAT reinsurers (Ben Ammar et al., 2015; Kunreuther & Michel-Kerjan, 2011; Wattman & Feig, 2008). Typical investors are hedge funds and private equity funds (Wattman & Feig, 2008).

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<sup>7</sup> Quota-share contract: Type of proportional reinsurance contract where a fixed percentage of the contract is paid to the reinsurer (Brockett & al., 1991).

Sidecars usually have a duration of 2 years, and at the end of this period they can be either self-liquidated or renewed (Kunreuther & Michel-Kerjan, 2011; Michel-Kerjan & Morlaye, 2008). Most of the sidecars range between US\$ 200 and 300 million, larger than CAT bonds (Kunreuther & Michel-Kerjan, 2011).

Sidecars are used by insurance companies to raise capital during the “hard” market, i.e after a catastrophe, and tend to decrease strongly during soft markets (World Economic Forum, 2008 as cited in Ben Ammar, 2015). As explained in the reinsurance part (cf. section 4.1.), after a major catastrophe, premium rates rise sharply while the demand to insure catastrophes increase too. The combination of these two factors provides ideal conditions for the creation of sidecars (Wattman & Feig, 2008).

Nevertheless, several drawbacks appear. First, sidecars structures have relatively high fees compared to the other risk transfer instruments (Ben Ammar et al., 2015). Moreover, the price of risk stays quite high, and it is transferred to the clients (Michel-Kerjan & Morlaye, 2008). Finally, the cedent has an incentive to place “bad” risk in the sidecar at the time of portfolio creation, instead of putting their capital base risk (Ben Ammar et al., 2015).

#### ***4.2.5. Catastrophe options (CAT options)***

A catastrophe option consists of a contract between two parties and is based on a loss index which can be national or regional (Doherty, 1997; Hofmann & Pooser, 2017). When a catastrophe hits and the loss index is above a precise threshold, called the strike price, the purchaser of the option who wants to hedge against a major loss receives the difference between the loss index and that strike price (Charpentier, 2008; Doherty, 1997; Hofmann & Pooser, 2017). Consequently, the value of the contract grows with the loss index starting from the strike price, but worth nothing under it (Ben Ammar et al., 2015).

The main advantage of CAT options compared to CAT bonds is that CAT options are much more reachable and easier to buy. Thus, small insurer can use this instrument, which is not always possible when it comes to CAT bonds (Hofmann & Pooser, 2017).

Nevertheless, the instrument did not really succeed, due to unfavorable regulation (Ben Ammar et al., 2015; Klein & Wang, 2009) and low accounting acceptance (Ben Ammar et al., 2015), although there is some attempts to reintroduce them into the market (Klein & Wang, 2009).

### **4.3. Moral hazard/Basis risk/Credit risk**

Three major issues arise when an insurance company transfers its risk, either through reinsurance or via insurance-linked securities, namely moral hazard, basis risk and credit risk (Carayannopoulos et al., 2003).

#### **4.3.1. Moral hazard**

Moral hazard, which is one of the most important issues in the insurance market (Götze & Gürtler, 2020), is the risk for a reinsurer that the primary insurer who covers himself against a catastrophe relaxes his vigilance and does not strive to reduce the risks (Hofmann & Pooser, 2017; Linnerooth-Bayer & Hochrainer-Stigler, 2015), by being, for example, less cautious when underwriting new contracts (Carayannopoulos et al., 2003), or by being more generous in settling claims than if they were uninsured (Hofmann & Pooser, 2017). The primary insurer could also be more likely to engage in risky behavior, which increases the final risk of the reinsurer (Götze & Gürtler, 2020).

Regarding reinsurance, most of the relationships between reinsurers and their clients are long term (cf. section 4.1.) (Carayannopoulos et al., 2003; Doherty, 1997; Hofmann & Pooser, 2017), which tends to reduce the incentive for the primary insurer to take advantage of this problem (Hofmann & Pooser, 2017). Moreover, premiums may be retroactive, therefore encouraging the primary insurer to become more cautious (Carayannopoulos et al., 2003; Doherty, 1997).

As far as ILS are concerned, the consequences of moral hazard are significant, as reflected in the high transaction costs. This problem must be solved so that insurance-linked securities can compete with reinsurance (Doherty, 1997). To do this, several solutions exist. First, the ultimate insurer may monitor the actions of the primary insurer (Carayannopoulos et al., 2003; Doherty, 1997; Hofmann & Pooser, 2017). Nevertheless, mitigation is costly (Carayannopoulos et al., 2003; Doherty, 1997), and this has consequences on the price of ILS (Carayannopoulos et al., 2003).

Another solution is to eliminate the moral hazard between the policyholder and the primary insurer. The primary insurer would take action to ensure that the policyholder does not file fraudulent claims, so that the primary insurer does not have to pass on the consequences of this

act to the ultimate risk bearer. In addition, in order to limit moral hazard, the policyholder can be directly involved and share with the insurer part of the losses incurred through the use of non-indemnity contracts, making the policyholder's dividends proportional to the losses (Smith & Stultzer as cited in Doherty, 1997). For instance, those contracts may consist of deductibles or policy limits (Shavell, 1979 as cited in Doherty, 1997). It would thus be in the policyholder's interest to take measures to limit the risk. Therefore, the moral hazard could be suppressed at the root of the problem (Doherty, 1997).

Also, the use of index-based contracts helps to reduce the moral hazard (Carayannopoulos et al., 2003; Doherty, 1997; Hofmann & Pooser, 2017; Linnerooth-Bayer & Hochrainer-Stigler, 2015). Indeed, the risk of moral hazard exists when the primary insurer is insured up to its real losses. If it is only hedged according to the losses of an index based on the major players in the sector, its maneuvering space is limited (Charpentier, 2008). Nevertheless, if the index used includes the primary insurance company, a certain proportion of moral hazard remains present given the fact that the company may manipulate the index. Thus, a solution often used is the creation of an index including representative insurers and excluding the insurance company hedging its risk, in order to completely eliminate the moral hazard (Doherty, 1997).

Finally, some transactions use non-standard approaches (relying on parametric contracts) to reduce the moral hazard. The two main non-standardized approaches are the tariff approach and the model payoff approach (Doherty, 1997). Doherty (1997, p.94) defines the tariff approach as "a contract whose payoff would be defined purely as a function of the physical event". For instance, it could be the magnitude of an earthquake or the wind speed of a hurricane (Carayannopoulos et al., 2003). A payoff model, on the other hand, is a model that predicts the impact of a catastrophe and the expected losses. The insurer then decides to cover itself based on the post-loss predictions of this model, and not on the losses he will actually incur when the catastrophe occurs (Doherty, 1997). Thus, by reducing the monitoring costs by using non indemnity triggers, the transaction price is considerably lowered (Carayannopoulos et al., 2003).

However, lowering the moral hazard reduces the flexibility of primary insurers and the amount of risk-bearing, resulting in some costs for them (Doherty, 1997). In addition, these solutions can significantly increase the basis risk incurred by primary insurers (Carayannopoulos et al., 2003; Doherty, 1997).

### **4.3.2. Basis Risk**

Basis risk can be defined as the difference between the loss incurred by the primary insurer and the loss insured by the reinsurance company (Croson & Kunreuther, 1999 as cited in Carayannopoulos et al., 2003; Hofmann & Pooser, 2017). Hence, this risk is present for the primary insurer when its reinsurance contract does not cover its actual future losses but is based on parametric or index triggers (Ben Ammar et al., 2015). Thus, because they cover the real risks of the primary insurer, the “classic” reinsurance contracts are free of basis risk (Doherty, 1997; Hofmann & Pooser, 2017). Basis risk is one of the most important issues for primary insurers, especially the smaller ones (Cummins, Lalonde & Phillips, 2004), and its absence when using indemnity trigger explains the popularity of this type of trigger with primary insurers (Ben Ammar et al., 2015). In addition to “classic” reinsurance, a limited number of ILS use that kind of trigger, which involves an in-depth analysis of the insurer’s book of business, underwriting practices and loss control methods (Carayannopoulos et al., 2003).

However, as soon as a hedging contract is based on indices or to physical attributes and not on an indemnity trigger, which is the case in the majority of securitized risk transfer products (Carayannopoulos et al., 2003), the primary insurer faces basis risk (Carayannopoulos et al., 2003; Doherty, 1997). The level of basis risk assumed by the primary insurer depends on the correlation between its loss and the loss of the index. The higher the correlation, the lower the basis risk (Doherty, 1997). Basis risk is strongly reduced for insurance companies with a significant market share, as their losses will be strongly represented in the industry losses index (Kunreuther & Michel-Kerjan, 2011).

### **4.3.3. Credit Risk**

Credit risk is the risk that the reinsurer is financially unable to honor its contract and insure the primary insurer when a catastrophe occurs (Charpentier, 2008; Doherty, 1997; Hofmann & Pooser, 2017).

This risk, which is particularly present in reinsurance, can be reduced by choosing a financially strong reinsurer and by diversifying the number of reinsurers (Carayannopoulos et al., 2003). Also, it could be required for the investors of the product to keep a margin account. In order to

make it effective, that account should be close to the level of losses that may be suffered by primary insurer (Doherty, 1997).

To limit credit risk, primary insurers are turning to capital market solutions (via securitization) (Carayannopoulos et al., 2003; Charpentier, 2008). Moreover, primary insurers favor the use of collateralization, the combination of in-trust held funds (Carayannopoulos et al., 2003), and letters of credit (Culp, 2009). Nevertheless, this risk is still present with ILS despite what investors thought in the early 2000s, as demonstrated by the Lehmann Brothers bankruptcy and the 2008 crisis, as well as the technical defaults of some catastrophe bonds (Ben Ammar, 2015).

#### 4.3.4. Summary

Each reinsurance/ILS product comprises, to a greater or lesser extent, one of the 3 issues we have just mentioned, mostly depending on the type of trigger used.

Here is a summary of the issues faced by each instrument.

| Instrument            | Moral hazard                                  | Basis risk                                                              | Credit risk                                                                           |
|-----------------------|-----------------------------------------------|-------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Reinsurance           | High<br>(Charpentier, 2008;<br>Doherty, 1997) | No<br>(Doherty, 1997; Hofmann<br>& Pooser, 2017)                        | High<br>(Charpentier, 2008;<br>Doherty, 1997;<br>Wattman & Feig,<br>2008)             |
| Indexed CAT<br>bond   | Low<br>(Hofmann & Pooser,<br>2017)            | High<br>(Kunreuther & Michel-<br>Kerjan, 2011)                          | Low, because money<br>is held in a SPV<br>(Wattman & Feig,<br>2008)                   |
| Indemnity<br>CAT bond | High<br>(Doherty, 1997)                       | Low<br>(Ben Ammar et al, 2015;<br>Kunreuther & Michel-<br>Kerjan, 2011) | Low, because money<br>is held in a SPV<br>(Doherty, 1997;<br>Wattman & Feig,<br>2008) |

|                              |                                                          |                                                                         |                                                                |
|------------------------------|----------------------------------------------------------|-------------------------------------------------------------------------|----------------------------------------------------------------|
| Collateralized reinsurance   | Could be present<br>(Ben Ammar et al., 2015)             | No<br>(Ben Ammar et al, 2015; Bockius & Gatzert, 2022)                  | No, because of collateralization<br>(Bodoff, 2010)             |
| Industry-loss warranty (ILW) | Low<br>(Ben Ammar et al.,2015)                           | High<br>(Kunreuther & Michel-Kerjan, 2011)                              | High, unless some collateralization<br>(Ben Ammar et al.,2015) |
| Sidecars                     | Low, even if indemnity based<br>(Ben Ammar et al., 2015) | No<br>(Ben Ammar et al., 2015)                                          | No<br>(Ben Ammar et al., 2015)                                 |
| Catastrophe options          | Low<br>(Doherty, 1997, Hofmann & Pooser, 2017)           | High, depending on the index<br>(Doherty, 1997; Hofmann & Pooser, 2017) | Low<br>(Ben Ammar et al., 2015)                                |

We therefore note that some balance between these three major issues must be found in order to satisfy both sponsors and investors (Doherty, 1997). Nevertheless, given that the ILS market is demand-driven, it is expected that indemnity triggers, because it reduces basis risk, will become the norm in the future of ILS (Ben Ammar et al., 2015).

#### **4.4. Challenges ILS**

In addition to the above-mentioned disadvantages, other drawbacks potentially hinder the development of ILS. They can be distinguished according to the point of view of the sponsor of the ILS or the investor.

##### ***4.4.1. From the investors point of view***

First of all, given the fact that investors in ILS's products seek above all the tranches with the highest yields (Michel-Kerjan & Morlaye, 2008) and that these products require more and more expertise as the valuation complexity increases (Ben Ammar et al., 2015), ILS products are hardly accessible to traditional investors (Michel-Kerjan & Morlaye, 2008).

Moreover, although transaction costs are decreasing and will continue to decrease with the growth in competition, they remain expensive and slow down the development of ILS (Ben Ammar et al., 2015).

Other factors such as (i) the illiquidity of the majority of ILS (Ben Ammar et al., 2015; Michel-Kerjan & Morlaye, 2008), (ii) their volatility, (iii) the long payout-periods, (iv) the lack of transparent data (Ben Ammar et al., 2015) and (v) the lack of global knowledge of these products (Michel-Kerjan & Morlaye, 2008) also hamper their growth.

#### *4.4.2. From the sponsors point of view*

One of the major challenges of ILS from the sponsors' point of view is their pricing, which is very complicated to achieve. As a result, the cost of ILS is quite expensive, even to the point that they are not always competitive with reinsurance prices (Michel-Kerjan & Morlaye, 2008).

In addition, the difficulty of renewing the contract after the occurrence of a catastrophic event as well as the rather limited scope of ILS are obstacles to their growth (Ben Ammar et al., 2015).

Finally, the uncertainty of the regulatory environment for ILS is also a major hindrance to their development (Ben Ammar et al., 2015).

### **4.5. Critics of ILS**

The use of insurance-linked securities is encouraged by many authors in the literature (Johnson, 2014), and also by IPCC and other international organizations (IPCC, 2014 as cited in Keucheyan). A concrete example is the issuance of a CAT bond in 2014 by the World Bank to cover some Caribbean islands against the risk of hurricanes and earthquakes (Harding, 2014 as cited in Keucheyan, 2018).

Nevertheless, other authors are much more reluctant to this solution and draw a parallel with mortgage-backed securities (MBS) and credit derivatives, which were financial instruments that were very active during the crisis in 2007-2008 (Johnson, 2014). To recall, debt financing via the capital market allowed a new part of the population to own their property, while diversifying risk via the capital market (Ashton 2009; Wyly, Moos, Hammel & Kabahizi, 2009). However, the securitization of risks created a real estate bubble that ultimately burst, and propagated globally (Aalbers, 2009; Martin, 2011 as cited in Johnson, 2014).

In the same vein, ILS, and in particular CAT bonds, are seen as financial instruments to momentarily address the government's failure to tackle climate change. As a result, there is concern that, as was the case with mortgage-backed securities, these instruments will create a bubble that could burst and spread throughout the financial markets (Johnson, 2014).

Moreover, as finance itself is subject to crises on a regular basis (Keucheyan, 2018), it is difficult to believe the promise that ILS, and more generally the financialization of climate change, will be able to reduce or at least properly distribute climate change risk (Johnson, 2014). As Keucheyan (2018, p.497) said; “Adding financial instability to environmental instability can only increase the impact of disasters”.

In addition, investors are willing to take on more risk, since yield is a function of risk, rather than encouraging them to be more cautious (Johnson, 2014). As already mentioned (cf. section 4.2.1.), peak perils attract a significant amount of capital, and very risky regions with large value concentrations, such as Florida for example, may paradoxically receive more capital to pay off claims, which would then encourage investment in those high-risk areas instead of reducing them (Johnson, 2014). Also, the CAT bond market, being in competition with the reinsurance market, undercuts reinsurance price. Thus, it prevents reinsurers from applying high prices in risky areas in order to force people to take into consideration impacts of climate change on their investment decisions (Herweijer et al., 2009).

Finally, not only will ILS not undermine the state's role as insurer of last resort, but it will enhance it. This may happen either (i) because the State will be forced to intervene during a financial crisis (Keucheyan, 2018), or (ii) because it will have to support primary insurers that will no longer find private investors interested in these products (Johnson, 2014), or (iii) because the market could put pressure on the State to subsidize CAT bonds if they lose their financial attractiveness (Keucheyan, 2018).

To sum up, some authors argue that the securitization of climatic risks brings maladaptive responses to climatic problems (Johnson, 2014). According to Keucheyan, (2018, p.498), “What is needed is less reliance on the logic of financial markets, and more environmental long-term planning”. He further argues that “Financializing adaptation would put adaptation policies at the mercy of the erratic behavior of financial markets” (Keucheyan, 2018, p.497).

## 4.6. Conclusion

In conclusion, reinsurance remains the main instrument used by insurers to protect themselves from the risks of a natural disaster. Because of the high globalization of reinsurers, they can diversify their risk better than insurers and therefore have a greater level of risk mutualization. Reinsurance is crucial for insurers who need it to offer insurance policies to policyholders. Nevertheless, reinsurance has certain disadvantages, such as its high price and capacity limit. This leads insurers to pass the risk of climate catastrophes to the broader capital markets via insurance-linked securities (ILS). In addition, these instruments allow insurers to protect themselves from price fluctuations induced by the reinsurance cycle.

Most ILS investors are either insurers and reinsurers, or institutional investors, such as hedge funds. They are attracted by the high yields and the non-correlation of natural catastrophes with the capital market, allowing them to diversify their investments. The main ILS are collateralized reinsurance, CAT bonds, ILW and sidecars. In 2021, the market was worth just under US\$ 100 billion, while the reinsurance market was worth US\$ 441 billion.

Reinsurance and ILS face several major risks, such as moral hazard, basis risk and credit risk. Insurers, when choosing their natural catastrophe risk transfer instrument, must therefore be aware of and balance these different risks.

Concerning ILS, several challenges hinder their development, whether it is their price and complexity for investors, or their pricing and legal uncertainty for sponsors. Finally, ILS, although encouraged by some authors and international organizations, are subject to criticism. Some authors compare them to mortgages-backed securities (MBS) and fear that, like MBS during the 2007-2008 crisis, ILS will create a bubble that will explode and have major consequences on the capital market. These authors argue that the securitization of climate risks will enhance the role of the state as an insurer of last resort, and that relying on the capital market is an inadequate response to climatic issues.

## Part 2: Analytical research

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### **Chapter 5: Research problem and methodology**

#### **5.1. Context**

The literature review conducted in the first part of this dissertation allowed us to highlight that the role of an insurance company in modern society is to cover policyholders in the event of a disaster. We have also noted that the State, in the case of abnormally large disasters, could play the role of insurer of last resort in order to help its citizens most affected by the disaster.

In a second part of the literature review, we have shown that climate change will influence the frequency and intensity of natural disasters. The higher the average temperature increase, the more frequent and intense the disasters will be. Climate change is having a significant impact on the insurance industry. In order to address the issue, the insurance industry is protecting itself through private reinsurance or the capital market via ILS. Nevertheless, the impacts of climate change will not be uniquely negative, and could even be a source of opportunities

#### **5.2. Research problem**

The consequences of climate change on insurance companies are well documented in the literature. Indeed, several authors have highlighted the likely changes that insurance companies will face in the future.

However, a much less studied area is the evolution of the instruments used by insurance companies to insure against natural catastrophes in the coming years. It is likely that climate change, by increasing the frequency and intensity of disasters, will have an impact on their financing. It is therefore from this blurring of the current literature that, modestly, we try to investigate what the impacts of climate change will be on reinsurance and insurance-linked securities.

### **5.3. Methodology**

#### ***5.3.1. Research strategy***

In order to have a holistic view on the various impacts of climate change on reinsurance and insurance-linked securities (ILS), we decided to opt for an exploratory research strategy for this thesis, since we have no preconceived idea of the final result we want to obtain. Indeed, we do not want to confirm or refute a specific hypothesis. Thus, to answer our research question and determine the "what" and "how", the qualitative approach is the most appropriate (Miles & Huberman 1994, as cited in Basias & Pollalis, 2018). This method, referred to as a comprehensive method, is indeed ideal for this type of research (Aubin-Augier et al., 2008). It will allow us to understand in depth the scope of our research question, the results thereby obtained (Benbasat et al, 1987, as cited in Basias & Pollalis, 2018), and will also allow us to interpret them (Aubin-Augier et al, 2008).

Nevertheless, the reader should be aware that this method leaves room for a certain subjectivity (Eisner, 1991, as cited in Basias & Pollalis, 2018), which we will try to reduce to a minimum.

This exploratory research strategy was based on primary data methodically collected and then rigorously analyzed.

#### ***5.3.2. Semi-structured interviews***

Since our research strategy is exploratory, we decided to collect primary data through individual qualitative interviews of 14 respondents. The interviews were semi-structured, with specific and open-ended questions. We asked the same questions to each interviewee (the list of questions can be found in appendix 4). The questions focus on three main themes: the impacts of climate change on reinsurance, the impacts on insurance-linked securities, and the impacts on society more generally. They were designed to address the most recurrent topics found in the literature.

The number of interviews conducted (14) is explained by the fact that we consider that we have reached saturation, i.e., new additional data would not provide new elements to our research (Aubin-Augier et al, 2008).

All interviews were conducted via video conference because of the pandemic situation and also because the interviewees were located in 7 different countries. These interviews can be found in appendix 5 to 18.

At the beginning of each interview, we introduced ourselves and explained the objective of our thesis. We then asked the interviewees to briefly introduce themselves, present the company they were working for and their role within the company. At the end of the interview, we asked them if we could quote them in the thesis and if they wanted to review the interview.

All the interviews were recorded on a cell phone and were transcribed as accurately as possible, first via a transcription software and then by carefully listening to the recordings.

### ***5.3.3. Interviewees selection***

We have interviewed fourteen people (managers, underwriters, brokers, etc) from twelve different companies working in insurance, reinsurance or insurance-linked securities field. Most of them work in the largest reinsurance companies in the world, such as Swiss Re, Gallagher Re, AON, Guy Carpenter or SCOR, or in insurance companies such as Zurich Insurance Company or Belfius, and are spread across seven countries (Belgium, France, Luxembourg, Switzerland, The Netherlands, United-Kingdom, and Hong Kong). Thus, by choosing interviewees working in different companies, in different positions and in different countries, we have collected a large and varied sample of views on the impact of climate change on the reinsurance and ILS business. It is interesting to note that interviewees located in the same countries and sometimes even working in the same companies can have different opinions.

The interviews were collected over a 2-month period, between January 10 and February 28, 2022. The duration of the interviews varied from 39 minutes to 1 hour and 41 minutes, with an average of about 1 hour.

You can find more details in the table below.

| First Name + Name       | Position                                                                                                      | Company                                                                          | Location                  | Interview date | Interview length |
|-------------------------|---------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|---------------------------|----------------|------------------|
| Dominique Lemonier      | Chief underwriting officer                                                                                    | Transatlantic Re                                                                 | Paris, France             | 10/01/2022     | 51 :40           |
| Maurizio Savina         | Head of CAT R&D                                                                                               | SCOR                                                                             | Zurich, Switzerland       | 14/01/2022     | 58 :09           |
| Jean-François Walhin    | Reinsurance broker, University professor                                                                      | AON, Université catholique de Louvain (UCL), Université Libre de Bruxelles (ULB) | Brussels, Belgium         | 21/01/2022     | 59 :15           |
| Manuel Prechtel         | Risk Manager for Natural catastrophe Risk                                                                     | Deutsche Rueckversicherung Schweiz AG                                            | Zurich, Switzerland       | 24/01/2022     | 1 :11 :43        |
| Michel Herssens         | Head of reinsurance                                                                                           | Belfius                                                                          | Brussels, Belgium         | 26/01/2022     | 1 :41 :00        |
| Philippe De Longueville | Independent consultant<br>Invited lecturer                                                                    | Act-Unity, Université catholique de Louvain (UCL)                                | Louvain-la-Neuve, Belgium | 26/01/2022     | 1 :17 :57        |
| Thomas Kroely           | Reinsurance broker                                                                                            | Gallagher Re                                                                     | Paris, France             | 01/02/2022     | 1 :05 :23        |
| Nicolas Mérigot         | Head of global structured credit & solutions France and Global head of bank, insurance, and pension solutions | Natixis                                                                          | Paris, France             | 02/02/2022     | 46 :16           |

|                    |                                                                                                             |                                |                                   |            |           |
|--------------------|-------------------------------------------------------------------------------------------------------------|--------------------------------|-----------------------------------|------------|-----------|
| Ivo Hux            | General Manager<br>Luxembourg                                                                               | Swiss Re                       | Luxembourg<br>city,<br>Luxembourg | 02/02/2022 | 53 :45    |
| Quentin<br>Perrot  | Managing director of Guy<br>Carpenter Securities                                                            | Guy<br>Carpenter               | London,<br>United-<br>Kingdom     | 04/02/2022 | 1 :01 :33 |
| Eddy<br>Vanbeneden | Actuary- Global Strategic<br>Advisory & Analytics-<br>Head Guy Carpenter<br>Analytics continental<br>Europe | Guy<br>Carpenter               | Brussels,<br>Belgium              | 08/02/2022 | 52 : 29   |
| Jeroen<br>Vermaas  | Head of property, Marine<br>and Technical Lines<br>Benelux                                                  | Zurich<br>Insurance<br>Company | Den Haag, The<br>Netherlands      | 22/02/2022 | 46 : 44   |
| Luuk<br>Mulders    | Property underwriter                                                                                        | Zurich<br>insurance<br>Company | Den Haag, The<br>Netherlands      | 22/02/2022 | 39 : 08   |
| Clarence<br>Wong   | Chief economist                                                                                             | Peak<br>Reinsurance            | Hong-Kong,<br>China               | 28/02/2022 | 57 :20    |

#### ***5.3.4. Data analysis Method***

The analysis of the data collected during the interviews was carried out according to the Miles and Huberman method, which consists of synthesizing the qualitative data, cutting them up and reassembling them according to certain codes (Pourtois, 1993).

The interviews were first sliced up by global themes and the answers were then further broken down into more specific codes and reassembled in order to be compared and analyzed. It allows for the interpretation of the qualitative data by comparing the answers of the interviewees and revealing the commonalities but also divergences of views among the interviewees.

To carry out this analysis, the coding was done manually, without the help of computer software.

Also, in order to gain additional granularity in the analysis of the answers, each answer was tabulated from “do not agree” to “agree” based on a statement derived from the interviews.

## Chapter 6: Result analysis

### 6.1. Impacts of climate change on reinsurance

#### 6.1.1. Impacts of climate change on the price of reinsurance

One of the major findings from the interviews is that all interviewees anticipate an average increase in the price of reinsurance coverage in the coming years.

*Statement A: Price of reinsurance will increase.*

|                        | No answer | Do not agree | Partially disagree | Neutral | Partially agree | Agree |
|------------------------|-----------|--------------|--------------------|---------|-----------------|-------|
| Number of interviewees |           |              |                    |         | 3               | 11    |

The price increase in reinsurance can be explained by different factors, some of which are similar to those explaining the increase in insurance prices (cf. section 2.1.). These factors include, for example, (i) wealthier populations, which means more possessions - usually of higher values - (Herssens (appendix 9), Hux (appendix 13), Wong (appendix 18)) often combined with a higher concentration of such possessions in risky areas (coastal areas, rivers, etc.) (Herssens, Hux). The value of the assets to be insured is expected to double in the next 20 years, thus resulting in an increased demand for reinsurance capacity (Hux);

*"You find a lot of these values today in more exposed locations, either in flood plains, or by the sea, [...]. I think there is primarily a phenomenon of increasing exposure by the growth of the economy and the situation where these values are located."* (Hux, own translation)

Another driver of the price increase (ii) is the growing need of the insurance and reinsurance companies for capital to comply with regulations and stress-tests (Vanbeneden, appendix 15).

An additional factor (iii) put forward by 5 interviewees (Herssens, Hux, Kroely (appendix 11), Vanbeneden, Wong) to explain the future increase in prices is the fact that for the past 10 to 20 years in Europe, the reinsurance market was in a "soft market", with generally very low and competitive prices due to a lack of significant catastrophes (Herssens, Hux, Kroely). These low prices are not sustainable for reinsurance companies and therefore there will be a hardening of the property CAT market (Wong) and the prices will then increase.

The last main driver (iv) is the strong influence of the disasters that took place the year(s) before (De Longueville (appendix 11), Hux, Kroely, Mérigot (appendix 12), Mulders (appendix 17), Perrot (appendix 14), Prechtl (appendix 8), Savina (appendix 6), Walhin (appendix 7)). Indeed, reinsurance is a cyclical mechanism and prices are adjusted each year on the losses of the previous year, and this is one of the factors that influences price increase the most in the short term. Prices of reinsurance in Belgium for example increased in 2022 in comparison to 2021 prices due to the floods that happened in July (De Longueville, Prechtl, Walhin). The price change is estimated to be between 5 and 10% (Prechtl).

In summary, the short-term pricing of reinsurance is flexible and volatile, and this allows reinsurers to react very quickly (Prechtl). The main consequence is therefore an up and down price trend. They rise sharply after a disaster, only to fall afterwards if no major disaster occurs the following year (Kroely).

On the specific influence of climate change on the reinsurance price increase, the 14 interviewees all agree: climate change will definitely play a role.

*Statement B: Climate change will drive up reinsurance prices over the long term.*

|                        | No answer | Do not agree | Partially disagree | Neutral | Partially agree | Agree |
|------------------------|-----------|--------------|--------------------|---------|-----------------|-------|
| Number of interviewees |           |              |                    |         | 4               | 10    |

Climate change will influence the frequency and severity of catastrophe losses (“CAT losses”) leading to a higher volume of claims. The surge in the number of disasters will also boost the demand for protection, especially in countries where insurance is not mandatory (Hux). It is therefore necessary for reinsurers to increase their prices.

*“Prices are going to rise, it's impossible otherwise. There are more storms, more floods, it's going to cost more insured loss and the reinsurers are going to pay-out more claims”*  
(Walhin, own translation)

The reinsurance models are also deemed to evolve to take on other perils. Indeed, there is an increasingly systematic inclusion of secondary perils (Herssens, Mérigot, Vanbeneden). These perils are for example forest fires or floods. Initially, secondary perils were not included in the various reinsurance models (Herssens, Mérigot, Vanbeneden). For instance, in Belgium, the reinsurance price was calculated according to models that only took storms into account

(Vanbeneden). Reinsurers will most likely add floods and earthquakes loadings to these prices (Herssens). In the United States, these models considered mostly hurricanes and earthquakes. Now, some American reinsurers include severe convective storms as well as forest fires for example (Vanbeneden).

*“The pure premium goes up because the number of perils that we calculate goes up. So that's it, it's an automatic effect.”* (Vanbeneden, own translation).

A reinsurance price increase in soft market is not systematic though and should be nuanced. Indeed, after the Ella disaster in 2014 (Herssens) and the 2021 Bernd flooding, prices did not go up as much as one could expect –to the reinsurers’ disappointment (Lemonier, appendix 5).

The price increase is not as important as it might be (Lemonier, Savina). The rationale is: claims result in price increase, price increase attracts new investors, investors bring money, money makes the prices go down (Lemonier). This inflow of capital is even more critical in a low interest rate setting where profitable investment opportunities are scarce, and reinsurance are seen as offering attractive rates (Kroely, Savina). Thus, this excess of global liquidity combined with the few barriers to entry into reinsurance encourages competition between reinsurers, which results in low price increases after a catastrophe (Perrot). Moreover, the price increase is partly governed by the law of supply and demand, as the more people want to invest their capital in reinsurance, the lower the price increase (Kroely).

Perrot makes a further distinction between what is called the “bottom of the program”, i.e., the less expensive disasters and the “top of the program”, i.e., the most expensive ones. According to him, it is the lower part of the program that has been the most impacted over the recent years, and therefore it is the one that has seen a strong increase in prices, while the price of the higher part of the program has decreased.

Also, the price variation will depend on the different regions (Perrot) and markets (Wong), depending on the exposure of the regions to perils. For example, it is expected that the price increase in Europe will not be as significant as in the US (Vermaas, appendix 16).

In conclusion, all interviewees agree that reinsurance prices will increase in the long term, mainly due to the global warming that will provoke more natural catastrophes, but they also agree that such price increase will not be linear and will vary from year to year.

As for the impact on insurance and reinsurance companies, it is likely that higher prices coupled with a growing volume of possessions to be insured will boost the profitability of the reinsurance companies (Mérigot). Insurance companies on the other hand which, unlike the reinsurers, are bound by long-term contracts, will have to anticipate climate change and assess the inclusion of certain climate risks in their coverage very carefully (Precht). In any case, the increase of reinsurance price will lead to more expensive insurance premium that will inevitably be passed on to the final consumer (De Longueville).

### **6.1.2. Future evolution of reinsurance capacity**

Although, as seen in the previous section, there is a common view on the evolution of reinsurance prices, the opinion on the evolution of reinsurance capacity is somewhat more divided. 8 interviewees out of 13 believe that capacity will be present in the future to insure climate catastrophes.

*Statement C: Reinsurance supply will grow in the future.*

|                        | No answer | Do not agree | Partially disagree | Neutral | Partially agree | Agree |
|------------------------|-----------|--------------|--------------------|---------|-----------------|-------|
| Number of interviewees | 1         | 2            | 1                  | 2       | 2               | 6     |

*"The pool of capital is going to grow, so from an industry perspective I don't think it's an industry that has too much to worry about [...]" (Kroely, own translation)*

According to Vanbeneden, the supply of reinsurance in the market will keep up with demand, and that demand for capacity will increase in the future (Herssens, Precht). The growth in demand can be explained in part by (i) an increase in the volume of values to be insured; (ii) high inflation leading to an increase of insured exposures and; (iii) repair costs resulting in a higher demand for additional capacity (Herssens), on top of the other elements as explained in the previous section.

In fact, as long as there is a willingness on the part of insurers to pay the premium demanded by reinsurance companies, the capacity offered will be present (Herssens, Vanbeneden, Walhin). Nevertheless, as we have seen in the above section, this will cost insurers more (Walhin). Similarly, if the willingness to pay is not there, then mechanically the supply will

decrease, by the law of supply and demand as the capacity will be allocated by reinsurers in regions that will generate higher returns (Herssens)

The growing reinsurance capacity refers to the overall capacity in the market, as the capacity offered by individual reinsurers is decreasing (Vanbeneden). Indeed, some reinsurers have realized that they were far too exposed to perils and that their volatility was too great (De Longueville, Vanbeneden). Also, part of their capital was consumed due to a catastrophe (De Longueville). Others consider that the increase in the premium is insufficient to balance the risks due to climate change, margins are negative therefore they prefer to reduce their offer (De Longueville, Herssens, Vanbeneden), or not to raise it (Herssens).

Nevertheless, new players have appeared on the market, so that the overall capacity is increasing (Hux, Vanbeneden), and in the next 10 to 20 years, the capacity will still be there (Vanbeneden).

One reason for this influx of capital is the low interest rates that attract new investors (Mérigot, Walhin), as explained in the previous section. On the contrary, higher interest rates discourage investors from investing in reinsurance where losses can be more significant (Perrot).

Also, for some time there has been liquidity indexed by central banks so that investors must invest this liquidity in different asset classes (Mérigot). Thus, investors will look at the different investment opportunities and will compare the profitability of an investment in reinsurance and in other asset classes, and as long as the return is higher than in other assets, the capacity will remain (Mérigot, Walhin).

*“So, there is a liquidity effect, an interest rate effect, and there is a profitability effect. And that's what's going to determine the capacity”* (Mérigot, own translation)

In addition, the pattern of the reinsurance cycle will also influence the capacity. Prices increase following the occurrence of a disaster (often due to climate change), higher prices attract new investors, creating additional capacity (Vanbeneden), broader capacity will lower prices, which prices will rise again upon occurrence of a new disaster; this new catastrophe will in turn reduce capacity because reinsurers' margins are impacted thus inducing a new price increase (Mérigot, Perrot). Such reinsurance cycle will go on (Mérigot), with prices and capacity generally increasing. We observe that after each disaster, capacity has come back to the market

(Vanbeneden), as for example after the attacks of September 11 (Walhin) or the 2021 disasters (Hux).

The reinsurance offer will also vary depending on the type of disaster (Perrot, Vanbeneden). For example, reinsurers may maintain coverage for storms and earthquakes but may choose to reduce coverage for floods (Vanbeneden); the appetite from reinsurers to cover flooding will indeed depend on the ability to model it in the future (Vanbeneden), and same for all the secondary perils which have not been properly modelled yet (Wong).

The capacity offer will also vary if we are in a “single event” setting or in a “multi-events” setting. The offer for multiple events coverage is expected to decrease as it is currently the case for the "aggregate XOL" insurance product (appendix 3) (Lemonier, Vanbeneden).

It should also be pointed out that capacity is much lower for the minor risks lying at the bottom of the program (Perrot, Vanbeneden) than for the major risks at the top of the program, the most attractive ones. Not surprisingly, the capacity for the top of the program is almost excessive while capacity for the bottom is, in comparison, pretty low (Perrot). And rightly so, indeed, the purpose of reinsurance is to deal with major, more occasional risks; smaller, more frequent risks remaining in the shop of the insurance companies (Vanbeneden).

Finally, we're witnessing a growing demand for capacity from alternative sources of capital such as the insurance-linked securities (ILS) (Herssens, Hux, Lemonier), especially for perils with a return period of more than 250 years (Lemonier). We will discuss these ILS in more details in section 6.2.

*"I think that part of alternative capital and especially CAT bonds, I really think we'll see additional growth in these instruments in the coming years."* (Hux, own translation)

In conclusion, 60% of the interviewees think that reinsurance capacity will still be available in the future, despite the negative effects of climate change. Individual reinsurers will limit or reduce their offer, but new players will enter the market attracted by climate change-induced price increases, low interest rates and high market liquidity. And it is expected that a new form of capacity coming from the capital market (ILS) will come to reinforce the ‘traditional’ one.

### 6.1.3. Climate change as a vector of risks and opportunities

From a reinsurance perspective, climate change can be perceived as a threat or an opportunity, with differing views among the 14 interviewees. Fifty percent of the interviewees see climate change as an opportunity for reinsurance companies, twenty percent see it as a real mix between threat and opportunity, and the remaining perceive it as a threat.

*Statement D: Climate change is an opportunity for reinsurance companies.*

|                        | No answer | Do not agree | Partially disagree | Neutral | Partially agree | Agree |
|------------------------|-----------|--------------|--------------------|---------|-----------------|-------|
| Number of interviewees | 0         | 1            | 3                  | 3       | 2               | 5     |

Those who see climate change as an opportunity believe that reinsurers will be able to adapt and benefit from the increase in reinsurance prices (Mulders, Perrot, Vanbeneden, Walhin). Reinsurers have made money over the last 20 years (Hux), and it is expected that climate change will continue to generate revenues (Mulders). Indeed, while climate change triggers losses, it also boosts the demand for reinsurance (Mérigot). Climate change will also create opportunities for reinsurers to diversify their products and differentiate themselves from competitors through new strategies that climate change will foster (Mulders).

As the science progresses, risks associated to climate change are better predicted hence allowing reinsurers to model the climate change risks more accurately. The risk is then quantifiable and climate change is therefore an opportunity for reinsurers (Precht). Although some specific disasters are not expected (De Longueville, Precht), there are no surprises on the trend and reinsurers have been able to anticipate for years (De Longueville).

Nevertheless, 4 respondents believe that climate change is a threat to reinsurers. Large catastrophes surprise the reinsurance community with their scale (Wong). For those interviewees, the current models are obsolete because they are based on past data (Vermaas) and they do not capture the induced losses with sufficient accuracy (Wong). It results in price misalignment (Lemonier) and a potential threat to the company's results (Vermaas). As Lemonier further explains, natural catastrophes have been a source of profit for reinsurers for about 20 years but since the past 5 years, reinsurers have been losing money over climate change and reinsurance market has become less and less appealing on the stock exchange market (Lemonier).

In summary, 50 percent of respondents believe that climate change will be an opportunity for reinsurance, while 30 percent see it more as a threat.

#### ***6.1.4. Impacts of climate change on disaster modeling***

Of 10 respondents, 8 are confident that disaster modeling will improve in the future.

*Statement E: Disaster modelling will improve in future years.*

|                        | No answer | Do not agree | Partially disagree | Neutral | Partially agree | Agree |
|------------------------|-----------|--------------|--------------------|---------|-----------------|-------|
| Number of interviewees | 4         | 0            | 0                  | 2       | 1               | 7     |

Currently, the various models used by reinsurers for understanding catastrophic risks and estimating their costs are not always reliable nor accurate (Herssens, Perrot) and do not take climate change into account (Perrot), or only to a small extent (Mulders).

*"Now we have volatility, and we have the feeling that the modeling is not adapted"*  
(Perrot, own translation).

Models are built to capture stationary climates, but today climate has become non-stationary (Vanbeneden). Models are based on historical data (Vanbeneden, Vermaas, Wong), while it is key to be able to look forward (Vermaas) and anticipate the frequency and costs of such disasters.

Also, the current models are essentially focused on primary perils, such as hurricanes, typhoons, or storms (Hux), which makes them more mature models than the modeling of secondary perils, such as flooding for instance (Perrot, Vanbeneden).

There has been some progress in the modeling of disasters over the last 40 years (Hux) though to take into account and anticipate climate change (Herssens, Lemonier, Perrot, Walhin). Thus, the models will greatly evolve and improve in the future (De Longueville, Herssens, Hux, Vanbeneden, Walhin). Californian wildfires for examples were, until a few years ago, poorly modeled but now that they occur almost every year, their modelling has improved dramatically (Perrot). Such improvement will mainly benefit to the understanding of secondary perils (Herssens, Hux, Mériqot, Perrot), such as floods, hail (Hux) or forest fires (Perrot), as well as

to the correlation between primary and secondary perils (Wong) since these secondary perils will grow with climate change (Herssens).

Progress will be made possible through the use of bigdata (Herssens, Mulders) and information available both at country level (Herssens, Mulders) and in specialized companies (Herssens). Improvement will also benefit from technological developments, such as artificial intelligence and machine learning (Wong), and the contribution of satellite images for example (Herssens).

New models will be able to make climate projections (Savina, Vanbeneden) and even calculate future loss distributions over the next 5, 10 or 20 years (Savina).

These new models will not only have to take into account the hazards but also the various measures adopted by the authorities to mitigate the climate change risks (Herssens, Vanbeneden), such as for examples coastal and river dikes (Herssens). Should new models concentrate only on the risks, certain perils would appear uninsurable, and no reinsurer would take the challenge (Vanbeneden).

Even if the various models improve in the future, modeling of disaster impacts will remain uncertain (Lemonier, Mulders) and will become more complex (De Longueville, Wong) because of the very unpredictable nature of climate change (De Longueville).

*"Modeling is inherently never correct, but global warming will increase the risk of error, both in severity and return period."* (Herssens, own translation).

As a result of this uncertainty, insurers will be more cautious and buy more reinsurance capacity (Herssens). Reinsurance companies on their part will adapt their prices (De Longueville, Perrot) and become more conservative regarding the risk taken (Perrot).

Authorities may also have a role to play in disaster modeling moving forward as it was recently the case in Belgium where the modeling of drought was forced to evolve following an interpretative law that included drought on the list of natural catastrophes (Herssens).

In conclusion, 8 out of 10 interviewees believe that climate change will improve the modeling of disasters, in particular secondary perils, but they also acknowledge that the unpredictability of climate change will render such modeling much more complex.

### 6.1.5. The development of reinsurers will differ according to their size

All respondents who answered agree that the large reinsurers will expand more than the smaller ones.

*Statement F: Larger reinsurers will develop the most.*

|                        | No answer | Do not agree | Partially disagree | Neutral | Partially agree | Agree |
|------------------------|-----------|--------------|--------------------|---------|-----------------|-------|
| Number of interviewees | 9         | 0            | 0                  | 0       | 1               | 4     |

Reason is large reinsurers have the expertise and tools to properly assess the risks and manage them in the best way (Lemonier). Smaller insurers on the contrary have a hard time in diversifying, offering attractive prices and attracting talents. Their only way out is to specialize in niche markets (Hux). The best deals are also generally offered to reinsurers with the largest financial resources and the best ratings, thus fostering their development (Lemonier). We also note a concentration of the reinsurance market, which means that the number of small players is decreasing (De Longueville).

*"The smaller ones will grow to a lesser extent"* (Lemonier, own translation)

### 6.1.6. Reinsurance will remain the best option

Although climate change will impact reinsurance in the coming years, the 14 interviewees agree that reinsurance will remain the best option for managing large and non-frequent disasters.

*Statement G: Reinsurance will remain the best option to insure climate change.*

|                        | No answer | Do not agree | Partially disagree | Neutral | Partially agree | Agree |
|------------------------|-----------|--------------|--------------------|---------|-----------------|-------|
| Number of interviewees | 0         | 0            | 0                  | 0       | 0               | 14    |

Where the bottom of the exposure curve will remain mainly in the insurers' shop, the middle and top of the exposure curve, i.e. events with higher volatility - also known as tail events (Prechtel) - will stay with the reinsurers (Vanbeneden). Reinsurance indeed allows for a higher degree of diversification compared to insurance (Perrot, Walhin), and such global pooling remains the best way to deal with large catastrophes, provided the pricing is adequate and reflects evolving values (Hux).

*“Reinsurance, for now, is really the best way to protect yourself against the risk of bankruptcy” (Herssens, own translation)*

Under Solvency II<sup>9</sup>, using reinsurance makes it possible to release capital and to reinvest it in order to have a return higher than the cost of the reinsurance (Herssens). Moreover, the reinsurance mechanism is very simple compared to other risk carriers, such as CAT bonds that require heavier legal and statutory constraints (Lemonier).

*“Since I’ve been working in reinsurance, I’ve always been told that CAT bonds are the future, but in fact today they represent, I believe, a maximum of 10% of the world’s capacity. So, in fact it is not very important. I think that it will never become the dominant trend.” (Lemonier, own translation)*

ILS are another disaster protection instrument, but the market remains small and is mostly concentrated in the United States. This can be explained in particular by their price, high compared to traditional reinsurance, and the difficulty of implementing them (Walhin). The ILS would be appropriate for extreme risks for example, those at the very end of the tail, with return period of more than 500 years (Prechtl).

Events beyond the capacity of traditional reinsurance will require the intervention of the governments (Hux, Mérigot) through public-private partnerships for examples (De Longueville, Vanbeneden), as we will further explain in section 6.3.1. Furthermore, the State will have a primordial part to play in the adaptation measures that will be put in place and that will allow reinsurers to ensure their role in the future (Vanbeneden).

In conclusion, reinsurers are well appraised of the climate change risks (Herssens, Kroely) and reinsurance will remain the best instrument to cover the ever more frequent climate change disasters (Herssens); either reinsurance alone or coupled to ILS or public-private partnerships where the catastrophes exceed the limits of reinsurance.

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<sup>9</sup> Solvency II is defined as “A European Union Directive that sets out a single set of prudential and supervisory requirements for almost all European insurance and reinsurance companies” (ABI, n.d.).

## 6.2. Impacts of climate change on Insurance-Linked Securities (ILS)

### 6.2.1. Evolution of competition between ILS and reinsurance

Now that we have demonstrated that reinsurance would remain the best option to cover natural catastrophes in the future, it is interesting to examine the relationship between reinsurance and ILS. 9 of the 13 interviewees do not consider ILS to be a competitor to reinsurance, contrary to what has been reported in the literature (cf. section 4.5.)

*Statement H: ILS will be in competition with reinsurance.*

|                        | No answer | Do not agree | Partially disagree | Neutral | Partially agree | Agree |
|------------------------|-----------|--------------|--------------------|---------|-----------------|-------|
| Number of interviewees | 1         | 6            | 3                  | 0       | 3               | 1     |

Reinsurance and ILS are not competing instruments, on the contrary, they are seen by the interviewees as complementary (Herssens, Kroely, Mérigot, Vanbeneden, Walhin), in particular in Europe (Kroely). ILS are more frequent in the USA compared to Europe (Herssens, Hux, Kroely), where they are essentially developed for large groups (Herssens). This is because the price of risk in Europe is low, and thus not very attractive for investors. As a consequence, the competition between ILS and reinsurance in Europe is weak (Hux).

Besides, reinsurers themselves use ILS (Hux, Vanbeneden), that they consider (i) key to protect themselves against risk (Walhin); (ii) to offer more capacity on the market (Hux, Vanbeneden) to the benefit of insurance companies (Herssens, Vanbeneden).; and (iii) a diversification of their business (Wong).

Since the beginning, it is mainly the reinsurers who have tried to develop the ILS market, they continue to do so and they see it not as competition, but as a management tool for the expansion of their business (Wong).

*"And that's why I say it's complementary, is that in the meantime, reinsurers have adapted to the ILS market, they have taken it more as friend than enemy" (Vanbeneden, own translation).*

Another reason why ILS do not compete with reinsurance are the costs associated to the implementation of ILS. As briefly discussed previously, implementing ILS is a heavy and

expensive process in particular because it requires strong legal input, which renders it uncompetitive with the price of traditional reinsurance (Vanbeneden).

In addition, there is so much demand in the market that the supply provided by ILS does not threaten reinsurance. It is capacity that is lacking, not demand, especially in the areas most affected by disasters (Mulders, Vermaas). Moreover, this demand for capacity will be increased (Prechtl), partly due to climate change, as explained in section 6.1.1.

Furthermore, smaller insurers are not willing to invest in ILS, given the minimal capacity to take and the price still too high compared to reinsurance (Vanbeneden). The insurers investing today in ILS do so mainly to have a first expertise with this market, without it being a priority for them (Vanbeneden).

Another major difference between reinsurance and ILS is that reinsurance requires a deep risk analysis, while ILS “only” finance the risk with no need to dig into its root causes (Kroely, Wong). This is why ILS funds essentially want standard risks, which are much easier to understand (Kroely). Thus, the reinsurance offer is different from the ILS fund offer (Kroely). Reinsurers will offer a service, an ability to understand claims (Kroely, Wong), and to price them (Wong). Also, it is the reinsurers who help to structure and place the various covers on the capital market (Hux). Thus, reinsurance will always be useful and cannot be competed so easily by ILS (Wong).

Finally, ILS and reinsurance do not target the same perils. Where ILS specifically focus on the very top of the program (De Longueville, Perrot) - because this is where the return on investment is the most profitable - reinsurance has a much wider scope, ranging from the top of the program to bottom of program (Perrot). Currently competition is only limited to a small part of the offer and is rather seen as a complement to the traditional offer (Perrot).

For the time being, retrocession market is more impacted by the ILS competition than reinsurance (Mérigot, Perrot). Indeed, it is a rather opportunistic and therefore quite volatile market, where only few players are present. Reinsurers are slowly changing behavior and turn more and more towards ILS instead of retrocession (Mérigot). The retrocession market is currently split 50% via classic retrocession and 50% via ILS (Perrot).

In conclusion, we have seen that according to 9 out of the 13 interviewees, ILS and reinsurance are not competitors but rather complementary. In the short term, say in the next 5-10 years, this

complementarity will likely not change (Vanbeneden), because the risks, including those due to climate change, are expected to increase (Kroely).

### 6.2.2. Impacts of climate change on the price of ILS

Regarding the price of ILS, all 13 respondents agree that, in the long term, climate change will have such an impact on losses and claims that price will definitely increase.

*Statement I: Climate change will drive up ILS prices.*

|                        | No answer | Do not agree | Partially disagree | Neutral | Partially agree | Agree |
|------------------------|-----------|--------------|--------------------|---------|-----------------|-------|
| Number of interviewees | 1         | 0            | 0                  | 0       | 0               | 13    |

*“The price is based on experience. So, if climate change brings more natural disasters, the price will go up”* (Perrot, own translation)

The price of ILS is divided into two parts: the risk free and the spread, the latter being directly related to the risk. And it is the spread that will increase due to climate change, while the risk free will be impacted by the monetary policies of the central banks (Hux).

7 interviewees (De Longueville, Herssens, Mérigot, Prechtl, Vanbeneden, Walhin, Wong) explain that ILS prices are directly correlated to reinsurance prices. As the price of reinsurance will increase in the future (cf. section 6.1.1.), ILS prices will follow.

*“If they see the price of reinsurance going up, there is no doubt that the price of ILS will go up”* (Walhin, own translation).

The reason is that exposure will increase for both reinsurance and ILS (De Longueville), and there will be no arbitrage because the market is supposed to be efficient (Mérigot). Thus, small differences apart, prices will likely be dictated by reinsurers (Vanbeneden).

However, not all major perils covered by ILS are due to climate change such as earthquakes (Wong) and prices may differ from one region to another depending on whether such regions are often exposed to catastrophes or not (Vermaas).

Even though the price of ILS may slightly decrease in the short-term due to certain factors such as (i) low interest rates (Kroely); (ii) whether we are in a hard or a soft market (Mulders,

Vermaas); (iii) or an excess of capacity (Mulders), it is certain that in the long run the prices of ILS will increase (Kroely, Mulders).

We will see in the next section that ILS capacity will grow, and one would expect their price to decrease by the law of supply and demand. Nevertheless, the growing numbers of risks would outweigh the increase in capacity resulting in an increase in both capacity and price (De Longueville).

Finally, the speed of this price rise will depend on several factors, such as the capital contribution. The more capital, the more moderate the price increase will be. Other factors like the management of exposures and adaptation measures will moderate this speed of price increase (Kroely). This long-term increase will not be perfectly linear but will evolve gradually, influenced by recent loss experience (De Longueville).

In conclusion, prices of ILS and reinsurance are strongly correlated and are expected to grow in the future due to the impact of climate change.

*“For me, if there is a climate change such that the loss experience increases and the frequency increases, then the cost, whether it is traditional or non-traditional reinsurance, will increase.”* (Herssens, own translation).

### **6.2.3. Future development of ILS**

Concerning the development of ILS, it should be remembered that the ILS market is not a very important market in relation to reinsurance for the moment (Lemonier, Walhin). It is limited to North America (Vanbeneden, Walhin), Japan and only a few European countries (Walhin). Nevertheless, 9 out of 11 interviewees believe that the supply of ILS will grow.

*Statement J: ILS supply will grow.*

|                        | No answer | Do not agree | Partially disagree | Neutral | Partially agree | Agree |
|------------------------|-----------|--------------|--------------------|---------|-----------------|-------|
| Number of interviewees | 3         | 1            | 1                  | 0       | 6               | 3     |

Because the value of the insured possessions is growing (Hux, Mulders) and the number of natural catastrophes is increasing (Savina), reinsurance alone will not suffice (Hux). Hence the capacity will be supplemented by alternative resources (Herssens, Mulders) such as ILS.

The development of the ILS will also be dependent on the evolution of catastrophe modeling (Vanbeneden, Wong), as investors in ILS are much more dependent on modeling than reinsurers who have insight and expertise in understanding risk (Vanbeneden). Moreover, Lemonier predicts that the evolution of ILS will be linked in particular to the increase and better modeling of secondary perils. In addition, this evolution will depend on other investment opportunities in the market (Savina), as it is also the case for reinsurance, as explained previously (cf. section 6.1.1.).

In conclusion, ILS market is expected to grow steadily and gradually over time (Perrot) even at a faster pace than reinsurance. Indeed, because ILS is a small business, its potential for growth is big (Vanbeneden). That said, ILS are not expected to become the predominant instrument over reinsurance (Lemonier).

In summary, ILS will expand in the coming years to insure climate change-related disasters, and the supply will increase.

#### **6.2.4. Private direct investment.**

As we have seen, ILS will grow in the coming years. It is therefore interesting to wonder whether the investors in these products will remain institutional investors, as explained in section 4.2, or whether this base will broaden to include private direct investment in the future. 8 of the 13 interviewees believe that direct private investment in ILS will grow in the coming years.

*Statement K: Private direct investment in ILS will develop.*

|                        | No answer | Do not agree | Partially disagree | Neutral | Partially agree | Agree |
|------------------------|-----------|--------------|--------------------|---------|-----------------|-------|
| Number of interviewees | 1         | 3            | 1                  | 1       | 2               | 6     |

Currently, several funds allowing private investors<sup>10</sup> to invest directly in ILS already exist (Kroely, Mérigot, Perrot). These funds will particularly develop due to climate change and its consequences on disasters (Lemonier). There is a certain demand in the market from investors (Perrot), and this demand will continue (Prechtel).

The development of such funds will help distribute the risks among investors (Savina) who not only have an appetite for bigger risks (Prechtel) but also have a deep understanding of the ILS mechanism and associated risks (De Longueville, Herssens, Vanbeneden).

That said, some interviewees believe that the capacity of ILS funds will mainly remain in the hands of institutional investors (De Longueville).

*"So, I think there's room for private investment. Now, is it going to represent a lot of capacity? That I'm not sure, so it's probably not going to change the world." (De Longueville, own translation).*

The barriers to the development of these funds are costs and complexity. Investing in an ILS costs several hundred million euros, which means that it would require many small investors (Kroely, Prechtel, Vanbeneden), and it is therefore unlikely that one can invest only €10,000 (Walhin).

ILS are also complex products, and individuals rarely have the expertise and the technological tools to deal with such instruments (Walhin). When reaching out to private investors, issuers must ensure that those private investors are well appraised of the underlying risks and obligations of such investment (Hux, Prechtel). Issuers could face lawsuits if the investors believe they were not sufficiently "equipped" to make an informed decision (De Longueville). Last but not least, there is also the risk that all private investors decide to withdraw after the occurrence of a disaster (Kroely, Vanbeneden), which could be dangerous for the market.

Nevertheless, access to investment in ILS funds for private investors will still be possible indirectly via private banks (Hux, Walhin) for highly wealthy individuals (Walhin).

In short, private investment in ILS will grow according to 8 out of 13 interviewees, although some constraints exist.

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<sup>10</sup> By "private investors" we mean individual investors, as opposed to institutional investors.

### 6.2.5. The most common ILS in the future

Concerning the type of ILS that will be most the used in the future, no consensus really emerged from the interviews. Only 5 out of 8 respondents think that a specific ILS will really emerge in the long run.

*Statement L: One ILS in particular will stand out from the rest.*

|                        | No answer | Do not agree | Partially disagree | Neutral | Partially agree | Agree |
|------------------------|-----------|--------------|--------------------|---------|-----------------|-------|
| Number of interviewees | 6         | 2            | 0                  | 1       | 3               | 2     |

Among them, 4 think that CAT bonds will become the preferred type of ILS (Hux, Perrot, Walhin, Wong) on the market, at least in the short term (Perrot). Indeed, CAT bonds are easy to understand even though they are complex products (Hux, Walhin), they cover well-defined and well-modeled perils (Hux), they are standardized, and they are the ILS with the longest history (Wong). We are currently observing that some money is coming out of collateralized reinsurance, which is the most prominent ILS in the market, and is injected into CAT bonds (Perrot).

Other interviewees do not expect a drastic evolution in the market (Kroely); there is a multitude of different ILS, and none will particularly stand out in the future.

*"What is interesting is to have all these possible formats to allow the ILS investor to diversify his risk and his portfolio" (Mérigot, own translation).*

Thus, it is better to maintain these different ILS because it also allows insurers to cover themselves with various formats and markets to cover their needs (Mérigot). Some will want very simple things, others will want more sophisticated products, and that's why it's important that the ILS product offering remains diverse (Kroely).

Hence, the data collected during the interviews do not enable us to conclude with certainty on the emergence of a specific type of ILS.

### **6.2.6. Creation of new ILS**

New risk transfer tools will likely emerge in the near future to meet the evolving needs and demands of the customers (Savina). One of the major innovations in the field of ILS is that the green component will become much more important, even standard (Vanbeneden). Such ILS will be used to insure green assets, such as solar panels or wind turbines (Savina), or any other initiatives aiming to reduce the greenhouse effect (Herssens). Some ILS will even exclude polluting activities from insurance coverage (Mérigot, Vanbeneden), like coal mines or oil platforms (Mérigot). ILS will eventually become a tool used by insurance and reinsurance companies to fight global warming (Wong).

So, ILS will make it possible to insure greener assets and exclude polluting ones, but they will also go one step further, with what are called "green CAT bonds" (Mérigot, Vanbeneden). Thus, not only the insured asset will be a green asset, but also the collateral, the investors' cash, will be directly reinvested in green assets as well (Mérigot, Vanbeneden). Moreover, when the insurer buys a CAT bond, it reduces its risk, which is combined with a reduction in regulatory capital under Solvency II. So, this "saved" capital will also be reinvested in green activities. With this money, the insurer will insure green insurance policies, wind farms, green buildings etc (Mérigot). Thus, this green CAT bond will have a double "green impact", at the level of the insured assets and also at the level of the reinvested money.

Finally, ILS are currently very strongly linked to climatic disasters (Wong), but they will be more and more used for non-climatic events, such as cyber risk (Perrot) or terrorism (Herssens). Nevertheless, these innovations are beyond the scope of this master thesis.

These innovations in the ILS industry are part of the broader framework of insurance and finance, which in their own way support initiatives to address global warming. To the same extent, banks will refuse to finance polluting assets and will offer green funds to their clients to promote ecological transition. Insurance companies, on their side, will create new products that will encourage their clients to become greener. They may, for example, lower the price of insurance for buildings that are energy efficient. Moreover, the new insurance products will foster more and more the circular economy, regenerative agriculture and carbon neutral transport (Herssens).

### 6.2.7. ILS development differs as a function of their size

Among the different types of ILS, some, such as CAT options, are much more accessible than others, such as CAT bonds, because the minimum investment is lower. Paradoxically, 4 out of 5 interviewees believe that the most expensive ILS, which are therefore the least easily accessible, will be the ones developing the most on the market.

*Statement M: Larger ILS will grow the most.*

|                        | No answer | Do not agree | Partially disagree | Neutral | Partially agree | Agree |
|------------------------|-----------|--------------|--------------------|---------|-----------------|-------|
| Number of interviewees | 9         | 0            | 0                  | 1       | 2               | 2     |

This is explained by the fact that the peak risk will increase the most, and therefore the ILS insuring them, like CAT bonds, will grow most strongly (Vanbeneden). Because ILS insuring the lower risks will always be complementary to reinsurance, it will slow down their development (Vanbeneden).

Thus, the results of the interviews indicate that the largest ILS will grow the most.

### 6.2.8. ILS, a safe mechanism?

As we have seen in this thesis, climate change will provoke more climatic catastrophes and ILS are instruments that will develop to insure such catastrophes. This raises the question of their stability as an insurance tool, and we can ask ourselves if ILS are adapted to this climate change or if they can be unstable because they rely on financial markets that are themselves subject to crises. 8 out of 12 respondents believe that the ILS market is a stable market. Some interviewees even argue that ILS are even more stable than reinsurance (Vanbeneden, Savina, Perrot).

*Statement N: ILS are a stable and safe mechanisms.*

|                        | No answer | Do not agree | Partially disagree | Neutral | Partially agree | Agree |
|------------------------|-----------|--------------|--------------------|---------|-----------------|-------|
| Number of interviewees | 2         | 0            | 4                  | 0       | 2               | 6     |

Savina recalls that in the past, reinsurance companies went bankrupt and never paid back their policy holders. ILS contracts are seen as more robust than traditional reinsurance contract

(Perrot) and the financial markets themselves are a token of overall stability (Hux). Hence, there is no doubt that ILS will pay when policyholders face a catastrophe (De Longueville, Perrot).

On the contrary, 4 interviewees, argue that ILS could be unstable (Mulders, Prechtel, Vermaas, Wong) because financial markets are volatile and unstable by definition (Mulders, Vermaas, Wong), and that a crisis could freeze the financial markets thus impacting ILS all the same (Wong). It would then be more prudent not to rely exclusively on ILS, but rather to use them as a complement to reinsurance (Prechtel). Nevertheless, the global ILS market has never really been tested during a major crisis. Some CAT bonds have lost money but the market itself has not (Perrot). Moreover, the continuity risk, i.e. the risk that investors will exit the market after losing money following a catastrophe, is much higher for ILS than for reinsurance (De Longueville), at least in the short term (Perrot).

In conclusion, most of the interviewees believe that ILS are fairly stable insurance tools against climate-related disasters.

#### ***6.2.9. Climate change will not disrupt the reinsurance market.***

According to some critics (cf. section 4.5.), ILS can be compared to mortgage-backed securities, an instrument that participated in the financial crisis of 2007-2008, which, because of their interconnectedness and hidden risks, accentuated the crisis. One would wonder whether it was possible that climate change could provoke a financial catastrophe in the reinsurance market, either directly or via ILS.

7 of the 14 interviewees do not believe that this scenario could ever happen in the reinsurance market and that climate change could disrupt the market and lead to major failures.

*Statement O: Climate change could disrupt the reinsurance industry.*

|                        | No answer | Do not agree | Partially disagree | Neutral | Partially agree | Agree |
|------------------------|-----------|--------------|--------------------|---------|-----------------|-------|
| Number of interviewees | 0         | 6            | 1                  | 3       | 2               | 2     |

Indeed, reinsurance is designed to handle extreme events and face disasters that cost millions and even billions (Savina) and the market can absorb such catastrophes, as was the case in 2001 after the September 11 attacks (Prechtel).

Besides, the design of the market itself would make it almost impossible because reinsurers are not as interconnected as banks were in 2007-2008 (Hux, Kroely, Walhin). Indeed, reinsurance companies do not reinsure their competitors (Hux).

*"That would be taking the same risks we can access the market ourselves, it doesn't make sense, and that's supporting a competitor."* (Hux, own translation)

In addition, and contrary to mortgage-backed securities, the reinsurance market is much more transparent (Herssens, Kroely, Lemonier, Mérigot, Vanbeneden, Vermaas) and extremely controlled and regulated (Hux, Lemonier, Mulders, Precht) compared to the banks back in 2007-2008 (Mulders). During this period, some collateralized debt obligations (CDOs) were embedded in each other, and the risk covered by the bank was not precisely known. This is not the case with ILS since this information is available (Mérigot).

As a lesson learned from 2007-2008, finance professionals have developed tools and stress tests that help them anticipate this kind of crisis (Herssens). Progress in risk management has also been made (Mérigot, Walhin), whether in terms of understanding the risks or in terms of compliance (Walhin). Another difference with the subprime crisis is that for mortgage-backed securities, the underlying risk was a systemic and correlated risk, whereas the risk for reinsurers is a diversified and independent one. Besides, the likelihood of several huge catastrophes over the same year is low (Wong). Finally, one last difference with mortgage-backed securities and CDOs is that it is not possible to leverage ILS, because one does not insure more than the amount of the claim, hence limiting the losses. This is the fundamental difference between reinsurance and finance, and it explains why a collapse of this market is very unlikely (Kroely).

This said, the possibility of hidden risks in reinsurance remains (Mérigot, Mulders, Vermaas), as was the case with COVID-19 (Kroely, Perrot), for example, where insurers and reinsurers were taken off guard (Kroely). It is therefore possible that a major catastrophe puts some reinsurers in bad position, and that the bankruptcy of one reinsurer leads to the bankruptcy of others as a domino effect (De Longueville).

Hence, although a single event will most certainly not bankrupt the market (De Longueville), it will still have certain impacts on the players in the sector (Kroely, Perrot, Precht, Vanbeneden). Also, a huge catastrophe, or a series of catastrophes, would have a greater impact on ILS than on traditional reinsurance, even though it would not destroy it because it is already well established (Precht).

In conclusion, a series of disasters would not jeopardize the reinsurance market, according to half of the interviewees, although it could have certain impact on specific players. The biggest threat to the reinsurance sector is not climate change but the financial market itself, in case of very high inflation for example (Hux).

#### **6.2.10. Climate change will not affect the capital market via ILS and reinsurance**

7 out of 11 interviewees don't believe that climate change could have a serious impact on the capital market via the reinsurance or ILS market.

*Statement P: Climate change will influence the capital market via ILS and reinsurance.*

|                        | No answer | Do not agree | Partially disagree | Neutral | Partially agree | Agree |
|------------------------|-----------|--------------|--------------------|---------|-----------------|-------|
| Number of interviewees | 3         | 5            | 2                  | 0       | 4               | 0     |

This is explained, in addition to the reasons cited in the previous section, by the limited weight of ILS and reinsurance compared to the size of the capital market (De Longueville, Hux, Walhin, Wong).

Nevertheless, some believe that it could eventually scratch this capital market (De Longueville, Lemonier, Perrot), in the case of a catastrophic scenario involving several perils (Lemonier), although the role of ILS and reinsurance is not comparable to the role of mortgage-backed securities and CDOs during the 2007-2008 crisis (Mulders).

*"Afterwards, if tomorrow this market should represent 10 times what it represents today, well that means that it can cause the markets to shake a bit, but we are very, very far from that situation in my opinion. Today, it is still a market of specialists that represents, at the level of the total financial markets, not much."* (De Longueville, own translation).

In summary, climate change will not affect the capital market via ILS and reinsurance, although it may scratch it very slightly.

### 6.2.11. Impacts of climate change on the pricing of ILS

As we have seen in section 6.1.4, climate change is significantly complicating natural catastrophes' modeling. Despite a bigger volume of available data (De Longueville) uncertainty is increasing (Herssens) and disasters evolve rapidly (De Longueville). We also know that modeling is an essential component of ILS pricing (Mérigot) therefore climate change will also impact the pricing of these ILS making it more complex in the future, according to 6 out of 11 interviewees.

*Statement Q: Climate change will complicate ILS pricing.*

|                        | No answer | Do not agree | Partially disagree | Neutral | Partially agree | Agree |
|------------------------|-----------|--------------|--------------------|---------|-----------------|-------|
| Number of interviewees | 3         | 0            | 0                  | 5       | 1               | 5     |

Pricing of ILS will have to continuously adapt to the development of climate change (De Longueville), by increasing the margin of error for example (Herssens).

*"As for any type of risk mitigation, investors do not like uncertainty. If one of the parameters start to go crazy, such as the frequency of claims because of climate change, it will complicate the pricing and as soon as the pricing is complicated, a loading for the margin of error is generally added"* (Herssens, own translation)

### 6.2.12. Impacts of climate change on the regulation

The question of the climate change impact on regulation is debated among the interviewees. On the one hand, 3 out of 13 do not think that regulation will be modified due to climate change. On the other hand, 9 interviewees believe that climate change will influence regulation, in particular Solvency II (Herssens, Lemonier).

*Statement R: Climate change will influence the regulation of reinsurance and ILS.*

|                        | No answer | Do not agree | Partially disagree | Neutral | Partially agree | Agree |
|------------------------|-----------|--------------|--------------------|---------|-----------------|-------|
| Number of interviewees | 1         | 3            | 0                  | 0       | 3               | 6     |

Awareness of climate change is growing (Hux) resulting in an increasing demand for stress-tests on climate change (Herssens, Hux, Savina, Vanbeneden) and a continuous evaluation of

reinsurers' resilience (Savina) against various natural catastrophes' case scenarios (Vanbeneden). In addition, the reporting of catastrophe risks will be more demanding (PrechtI).

Regulation and stakeholders, whether they are reinsurers or investors in ILS, are pushing for (i) more transparency (Vanbeneden), (ii) a reduction of underwriting in polluting assets (Perrot, Vanbeneden), (iii) a standardization of the assessment of future risks related to climate change (Herssens), and (iv) the use of TCFD<sup>11</sup> type of documentation for example (Vanbeneden).

Also, we will see a convergence of global regulation, encouraged by the TCFD standards, knowing that the implementation of these standards may differ from one country to another because not all countries are subject to the same climate risks and because not all countries have a market pool (cf. section 1.2.2.). Such country-specific differences may slightly influence the implementation of the regulation (Vanbeneden).

Certain interviewees do not believe that these changes in regulation will impact ILS (Perrot, Walhin) because ILS mostly deal with private investors (Walhin). Vanbeneden on the contrary thinks that reinsurance and ILS will be treated the same way in particular with respect to the demand for stress tests. In his view, ILS are even more advanced than reinsurance in terms of regulation because ILS investors, being primarily financiers, have already been exposed to TCFD requirements and are more appraised of the regulation. Nevertheless, the demands in terms of regulation will be identical for reinsurance and ILS.

*"But regulation is still regulation. Everyone is subject to the same regulation, but they may have anticipation that is better and proactivity that is better."* (Vanbeneden, own translation)

One of the major consequences of climate change on regulation will be the development of climate projections (Vanbeneden, Walhin), which do not only concern the coming years but also the next 10, 20 or 30 years (Vanbeneden, Walhin), and even up to 80 years (PrechtI, Vanbeneden). These changes will occur in the next 2 years for all actors in the sector (Vanbeneden). Climate projections are already in place for the large ILS investors and reinsurers, but not necessarily for the smaller ones (Vanbeneden).

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<sup>11</sup> TCFD: Task Force on Climate-related Financial Disclosures. The goal is to improve reporting concerning climate-related financial information (Fsb-Tcfd, n.d.).

Finally, another important impact will be the increase in the need for capital of reinsurance companies as a consequence of the increase in expected risks (Mulders, Perrot, Vanbeneden), which will result in an increase in the price of the reinsurance premium (Vanbeneden).

In a nutshell, 9 out of 13 interviewees believe that climate change will have an impact on the regulation of ILS and reinsurance.

### **6.3. Impacts of climate change on the society**

#### **6.3.1. The role of the State**

The premiums charged by insurance companies will increase as a result of climate change (Herssens, Prechtel, Walhin) to such an extent that in some parts of the world they might become unaffordable for individuals (Prechtel). This raises the question of the role of the State in dealing with climatic disasters. Climate change will definitely affect the way society organizes solidarity around natural catastrophes (Lemonier, Mériqot). States are facing two options: either they opt for a purely capitalist choice and exclusively leave to the private sector the management of climate change disasters, with the risk that some people living in high-risk areas would no longer be insured and/or that premiums would increase unreasonably, or they opt for a rather mutualistic approach where the State ensures minimum protection by spreading the cost over the entire population. It is almost a philosophical question that is being discussed right now (Lemonier). If private sector alone insures climate change catastrophes, insurers may elect to cover only certain risks thus leaving people without proper insurance coverage (Mériqot).

Again, the national policies vary from one country to another and depends on the systems already in place. France for example operates through its Nat CAT pool while The Netherlands operates differently (cf. section 1.2.2.) (Mulders, Vermaas).

Although all the interviewees work in private companies, all the respondents believe that the State should play the role of insurer of last resort in the event of a major climatic shock.

*Statement S: The State should act as the insurer of last resort.*

|                        | No answer | Do not agree | Partially disagree | Neutral | Partially agree | Agree |
|------------------------|-----------|--------------|--------------------|---------|-----------------|-------|
| Number of interviewees | 3         | 0            | 0                  | 0       | 3               | 8     |

The role of the State must remain limited to exceptional disaster (Precht), and it should not necessarily be the richest who are able to insure themselves, but the whole population (Lemonier). This is the direction France is heading to for instance, encompassing natural risks as a matter of national security (Lemonier).

Thus, the interviewees advocate the development of public-private partnerships (PPP) to insure these disasters (Hux, Mériqot, Perrot, Vanbeneden), particularly for perils such as floods (Vanbeneden). These partnerships are likely to grow in the future, according to the 11 interviewees that answered the question.

*Statement T: There will be more public-private partnerships in the future.*

|                        | No answer | Do not agree | Partially disagree | Neutral | Partially agree | Agree |
|------------------------|-----------|--------------|--------------------|---------|-----------------|-------|
| Number of interviewees | 3         | 0            | 0                  | 0       | 5               | 6     |

*"Public-private partnerships are likely to increase due to global warming as the State has to protect itself from the risk of bankruptcy of the insurance sector."* (Herssens, own translation).

Catastrophic risks will therefore be mutualized through the intervention of various actors (Herssens, Walhin): (i) insurers will focus on the bottom of the program, (ii) reinsurers will take care of the middle and top of the curve, depending on the market cycle in which they operate, and (iii) the State will cover the amounts that are higher than the reinsurance management capital via public-private partnerships and will take the role of insurer of last resort for perils such as, for example, floods with return periods of more than 250 or 500 years (Vanbeneden).

It is key that State intervention does not compete with the private market and only comes into play where there is no private offer (Hux, Vanbeneden), and only for major catastrophes that the private market could not manage (Vanbeneden).

This said, State intervention should not take place when too excessive amounts are at stake otherwise even the State will not be able to pay out (Mériqot, Walhin).

Besides, the creation of these PPPs is quite complex and requires a long-term view of the management of the natural disaster from political leaders. Indeed, PPP usually consume the

short-term budget and, even if these solutions are much more cost-effective in the long term, the fact that some politicians are limited to the next election may hinder the development of PPPs (Hux)

A concrete example of PPP is the Belgian Nat CAT system (cf. section 1.2.3.) (Herssens). Although it is very poorly calibrated (Walhin) and some aspects need to be modified, such as (i) more clarity on the responsibilities of the regions and the private sector, (ii) more adequate intervention limits and, above all, (iii) that money is invested by the regions in these funds (Herssens), the general idea seems to be very efficient for managing disasters (Walhin).

Another major role of the State will be its investment in the various adaptation measures in order to avoid the disaster beforehand, and not only to play the role of insurer of last resort after the disaster (Vanbeneden), which is much less expensive for society (Perrot). Indeed, this investment in infrastructure will allow the private sector to play its role at affordable prices, and the State to intervene only as insurer of last resort (Vanbeneden). If this investment is not done properly, it will become very difficult to insure against disasters, even for the States (Vanbeneden). These investments are a long-term strategy, and include, among many others, the construction of river defenses or carbon reduction through the adaptation of renewable energy production means (Savina). Also, it is important that the State does prevention in addition to adaptation, notably through risk mapping, for example by classifying certain flood-prone areas as red zones (Mérigot), and by not granting urban planning permits in these risk zones (Walhin).

In summary, the State must play the role of insurer of last resort and step in when there is no private offer through PPPs, as well as invest in adaptation and disaster prevention. Also, the State can use private solutions to insure extreme catastrophes.

One possible way for a State to cover itself is to purchase a reinsurance contract on the private market (Lemonier). Several States already do it (Herssens), such as Turkey, for example, which insure its earthquake risk. This risk is therefore spread globally thanks to reinsurance (Lemonier).

*"So, there we have a system that is both organized by the State but where most of the risk is clearly transferred to the open market, but through reinsurance." (Lemonier, own translation).*

In addition, some States, with the support of the World Bank (Hux, Mérigot, Perrot), issue CAT bonds or other ILS in order to insure themselves against certain natural disasters (De Longueville, Hux, Perrot, Savina, Vanbeneden), especially developing countries (Hux), such as Mexico for its earthquake risk (De Longueville), or certain Latin American countries (Perrot, Vanbeneden), like Peru for example (Perrot).

These CAT bonds are often parametric, which has the advantage that payment is very fast once the trigger is reached (Herssens, Hux, Vanbeneden), usually within 24-48 hours (Hux). The State can thus use it for urgent actions such as first aid and rescue of survivors (Hux) or the immediate reconstruction of damages, instead of waiting for long periods to be insured (Herssens, Hux, Vanbeneden), as it is the case with classic insurance (Savina). Hence, the country impacted is no longer dependent on international aid (Hux). These initiatives will be developed in the future by the States (Vanbeneden).

Finally, it is important to recall that the cost of these natural disasters, which will increase in frequency and intensity as a result of climate change, will ultimately be borne by consumers (De Longueville, Savina, Walhin), whether through the increase in the price charged by the private sector (De Longueville, Savina) or through the taxes charged by the public sector (De Longueville).

In conclusion, the State will always have a primordial role in the insurance of natural disasters. It will always be the insurer of last resort and will have a major role when the private sector can no longer assume certain extreme catastrophes. In order to play its role correctly, the States will develop more and more public-private partnerships with the insurance and reinsurance sector, not only to finance the damages after the disaster, but also to carry out prevention and adaptation upstream, in order to better anticipate the consequences of climatic disasters. In addition, we have seen that some States, particularly those in the developing world, cover themselves via the purchase of reinsurance policies or the issuance of ILS, and that these practices will also develop in the future following climate change. Finally, it should be noted that the increasing cost of these disasters will be passed on to consumers.

## Conclusion

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In this thesis, we have examined one of the major financial issues facing the insurance industry as it confronts the evolving threat of climate change at the beginning of the 21<sup>st</sup> century, namely the financing of natural catastrophes. More specifically, the objective of this thesis was to review and understand the impacts of climate change on the financial instruments used by insurance companies to manage these extraordinary risks, including through reinsurance and insurance-linked securities. To carry out this research project, we have sought the views of a broad array of experts and interviewed a total of fourteen professionals from twelve different companies, in seven different countries.

What emerges clearly from this work is the upward direction of the long-term trend for premiums, the price of reinsurance. It has now become very clear that climate change will cause a significant increase in these prices in the long term. Indeed, the increase in both the number and the intensity of climate catastrophes themselves will require insurers to pay out ever larger amounts to cover damages, which in turn must inevitably be reflected in higher premiums. This rising trend will be very clear in the long term, even as prices might fluctuate from one year to the next, going up or down depending on interest rates and on whether the market is soft or hard.

In turn, the increases in demand and in prices are expected to lead to an increase in supply. Thus, despite the higher and more frequent payments of damages that insurers will have to bear, the overall breadth and depth of the reinsurance market are expected to rise, with new players entering the market to respond to the higher demand and take advantage of higher prices. In the same spirit, a small majority of interviewees also believe that climate change is a source of opportunities for the industry to innovate and generate new long-term revenues. In addition, it is expected that the largest reinsurers will grow the most in the coming years compared to reinsurers of more modest size.

Overall, looking at future trends for the catastrophe reinsurance market, there is clearly a tension between, on the one hand, the negative (the higher burden from more frequent and expensive damages), and, on the other, the positive (the business opportunities). Our view, drawing from the analysis reported in this thesis, is that the positive will dominate the negative, that this

market will expand and thrive into the 21st century, and that reinsurance will remain a crucial mechanism for insuring catastrophes.

At a more technical level, it is clear as well that climate change will complicate modeling due to the increasing frequency and variance of shocks. The data from the past is of little use to understand a future with more frequent and more severe catastrophes. Overall, however, it is expected that the models will improve greatly, specifically those concerning secondary perils, thanks in part to the increasing use of bigdata and other technological advances.

In this context, insurance-linked securities (ILS) are expected to continue to play an important role. Most interviewees do not consider ILS as a threat to reinsurance, but rather as a useful complementary instrument. The demand for coverage will increase and both instruments will continue to exist without competing head-on.

Having said this, the fact is that it is mainly the reinsurers themselves that need ILS and have developed its market in recent years. Looking forward, this will remain even more true, and the complementarity between reinsurance and ILS is therefore expected to remain strong, driving up the demand for both.

By the same token, just as climate change will undoubtedly lead to a long-term increase in insurance and reinsurance prices, the prices of ILS are expected to increase. Indeed, ILS prices and reinsurance premiums are strongly correlated, and there is every indication that this pattern will be sustained in the future.

With these trends in demand and in prices, the supply of ILS itself is projected to grow slowly and gradually in the future. In parallel, the ILS investor base is also expected to broaden in the coming decades, and an increasing number of private investors will be able to invest directly in these instruments, although private investment will remain a fraction of the investment by institutional investors. This said, ILS are not expected to become the primary instrument for insuring the insurers, a role that is expected to continue to be played by traditional reinsurance.

Within the broad market for ILS, experts believe that there will be different trends for different segments. Specifically, though the whole market will grow, experts expect the larger and less accessible ILS to grow the most since they cover the perils most prone to climate change.

The development of ILS broadly speaking is also expected to foster the spread of “greener” ILS, such as Green CAT Bonds. These bonds, in addition to insuring green assets, will invest the collateral directly in other green assets as well as the capital saved under Solvency II.

The interviews also reveal that the majority of respondents believe that ILS, which are based on financial markets, are a stable instrument for insuring against climate catastrophes as opposed to certain reproaches made.

In addition, a slight majority of respondents do not believe that insurance-linked securities could disrupt the whole reinsurance market, causing one large climate shock to a single ILS to snowball into a full market-wide collapse. The reason is that, unlike mortgage-backed securities (MBS), ILS are less interconnected. In particular, reinsurers do not take on the risks of their competitors, so that, if one reinsurer is hit by a large shock, it does not pass it on to another. Moreover, the ILS market is much more transparent than the MBS market was, and, unlike MBS, there is no way to leverage. There is also, at the current juncture, a very limited scope for climate shocks to impact, via ILS, not only the reinsurance market, but the broader capital market, given the extremely small size of these markets compared to the capital market.

Furthermore, climate change will have an impact on regulation, with more demanding reporting, climate projections, increased transparency and more stress tests.

Finally, another significant impact of climate change will be to intensify the role of the State, not only as a regulator but, most likely, in its role as insurer of last resort. This is also expected to translate into a growing number of public-private partnerships, both to cover the damage caused by disasters, but, pre-emptively, to foster prevention of these disasters.

Although this exploratory research was done in the most rigorous way possible, a series of limitations must be mentioned.

First of all, as in all exploratory research, this study reflects its author's subjective views. Indeed, the selection of the areas of focus, their description, and their classification all reflect our sensitivity and interpretation. It is possible that another author, drawing on the same inputs from the literature and the interviews, would have provided a slightly different summary. Second, it is worth noting that the impacts of climate change on reinsurance and ILS are multiple, and many of them could not be explored in detail due to time and space constraints. Finally, our main findings are based on a limited panel of 14 interviewees. Although the companies for

which these interviewees work and the countries in which they work are varied, it is possible that a different panel of interviewees would have provided alternative views that changed the final conclusions of this thesis.

Finally, the field of ILS is vast and can also be extended to other sectors than climate disasters. Some researchers could examine their development on disasters related to cyber-crime or terrorism for example. Moreover, it could be interesting to investigate the recent development of blockchain technology in parametric ILS.

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## Abstract:

Climate change has many consequences on the society in which we live. In particular, one of its effects is the increase in intensity and frequency of natural disasters. Therefore, it constitutes a significant threat for insurance companies. In order to insure their policyholders against these climatic catastrophes, insurance companies mainly use two financial mechanisms, namely reinsurance and insurance-linked securities. The first mechanism consists in insuring themselves with private companies. The second mechanism provides insurers with access to financing from investors in the capital markets. The objective of my thesis is to understand how climate change will impact reinsurance and insurance-linked securities in the coming years. Among the most significant results of my research, we note a long-term growth in price and capacity for these two instruments.

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