

Chapter 7.

GREEN AND CAT BONDS AS INSTRUMENTS FOR MANAGING CLIMATE RISKS

Climate change caused by global warming increases the frequency and severity of catastrophic events. In this paper, we will discuss how green projects can be financed by green bonds to mitigate these risks. Before studying green bonds, we should take an outlook on green projects.

Green projects represent initiatives to promote environmental sustainability through renewable energy, conservation efforts, and sustainable development practices. These projects are not mere environmental luxuries but necessities for mitigating the harmful effects of climate change. Climate change, a complex global phenomenon, is intricately linked to our economic models. Predominantly linear economic models, characterised by a “take-make-dispose” approach, have significantly contributed to environmental degradation. In response, the concept of the circular economy emerges as a sustainable alternative, focusing on minimising waste and maximising the reuse and recycling of resources.

Green projects span a wide range of sectors, including but not limited to renewable energy generation (like solar and wind power), sustainable agriculture (focusing on eco-friendly farming practices), and green building designs (which emphasise energy efficiency and minimal environmental impact). The significance of these projects lies in their capacity to reduce greenhouse gas emissions, one of the primary drivers of climate change. Transition to renewable energy sources can significantly diminish our reliance on fossil fuels, reducing carbon emissions. In agriculture, sustainable practices such as crop rotation, organic farming, and efficient water usage help reduce food production’s environmental footprint. These initiatives collectively contribute to a holistic approach to combating climate change.

The circular economy is a regenerative economic model designed to separate economic growth from intensive resource use and degradation of the environment. The circular economy is based on three principles²⁵². First, products are designed and optimised for a cycle of disassembly and reuse,

²⁵² Ellen MacArthur Foundation (2017). *A New Dynamic: Effective Business in a Circular Economy*. Ellen MacArthur Foundation Publishing

substantially minimising waste and resource consumption. Second, products and materials should be used with extended the life cycle through repair, refurbishment, and recycling, thereby maintaining the value of products for as long as possible. Third, the circular economy encourages practices that restore natural systems, such as returning valuable nutrients to the soil through organic farming.²⁵³

Transitioning to a circular economy is a powerful strategy to address climate change. This model significantly lowers greenhouse gas emissions by reducing waste, enhancing resource efficiency, and minimising the exploitation of resources. It also fosters innovation in areas such as material science, renewable energy, and waste management, contributing to the development of sustainable green technologies. For example, in the manufacturing sector, the circular approach can transform waste products into raw materials for other processes, thereby creating closed-loop systems. The energy sector emphasises the use of renewable resources and the efficient use of energy, reducing the carbon footprint of energy production and consumption.

The benefits of the circular economy extend beyond environmental impacts. Economic benefits can lead to substantial cost savings, open new markets, and create job opportunities in recycling and remanufacturing industries. Social benefits are present because this model promotes a more equitable distribution of resources and can potentially reduce the environmental impacts that disproportionately affect lower-income and marginalised communities. Promoting sustainability helps preserve biodiversity, reduce pollution, and combat the adverse effects of climate change, generating environmental benefits.

Integrating green projects with the circular economy is vital to achieving a sustainable future. This synergy can be understood and implemented through several strategies. Green projects, especially in renewable energy and sustainable agriculture, can adopt circular economy principles to enhance resource efficiency. For example, solar panels can be designed for easy recycling at the end of their life cycle, or agricultural waste can be repurposed as organic compost. Companies involved in green technologies can adopt circular business models. It involves leasing products (like energy-efficient appliances) instead of selling them, ensuring that the manufacturer retains responsibility for the product's end-of-life recovery and recycling. Integrating

²⁵³ Geissdoerfer, M., Savaget, P., Bocken, M., & Hultink, J. (2017). The Circular Economy – A New Sustainability Paradigm? *Journal of Cleaner Production*, 143, pp. 757-768.

green projects with innovative recycling and upcycling processes can create a closed-loop system.²⁵⁴ For instance, we can use recycled materials to construct green buildings or upcycling industrial waste into raw materials for renewable energy infrastructure.

Green bonds are issued with the objective to finance ecological projects. These bonds are issued by governments, regional and local authorities, and public and private firms. Green bonds should reduce the amount of pollution and decrease the frequency and severity of catastrophic climate risks such as hurricanes, floods, droughts, storms, and so on. CAT bonds are issued to compensate for losses from catastrophic events, some of which are triggered by climate risks. The issuer of these bonds pays high coupons until the bond's maturity if there is no catastrophic event. Otherwise, the principal is used to cover losses, and coupons are not paid furthermore. Hence, this instrument aims to cover the damage from catastrophic events. Although these two bonds differ, they have the same objective – managing climate risks.

1. GREEN BONDS

The first green bond with a nominal value of 600 million euros and a five-year maturity was issued in 2007 by the European Investment Bank (EIB). Countries started to issue sovereign green bonds in 2016. Poland issued green bonds that year, and France the following year. In 2017, the USA also issued a huge amount of green bonds, almost 25 billion USD. In the same year, Indonesia was the first Islamic country that issued green bonds. As an environmentally friendly country, Singapore strongly supports the emission of green bonds.

Supranational institutions like EIB were the first to launch this innovative financial instrument. According to Fatica et al. (2021)²⁵⁵ financial institutions had the dominant share of green bonds in 2018, 46.3% of the total issued amount. Non-financial institutions are in second place with 40% of the total issued amount. The utility and energy sectors are leading within this group, followed by transportation and real estate companies. Supranational institutions issued 13.7% of green bonds. Corporate green bonds were first launched in 2013 by the French public company EDF. In 2014, Unilever issued a green bond of 250 million USD nominal value to reduce pollution in its production

²⁵⁴ Schaltegger, S., & Wagner, M. (Eds.). (2017). *Managing the Business Case for Sustainability: The Integration of Social, Environmental and Economic Performance*. Greenleaf Publishing

²⁵⁵ Fatica, S., Panzica, R., & Rancan, M. (2021). The Pricing of Green Bonds: Are Financial Institutions Special? *Journal of Financial Stability*, 54, 100873

processes, such as waste reduction, water pollution, and CO₂ emission. In 2017, Apple had a significant issue of green bonds with a nominal value of 1 billion USD, and the proceeds from these bonds aimed to increase energy efficiency and enhance the use of renewable energy. According to Falmer (2021)²⁵⁶ the total amount of corporate green bonds issued in 2013 was 5 billion USD; in 2018, the total amount of green bonds was 95.7 billion USD. In 2017, the first investment fund in corporate green bonds was established in the US. Corporate green bonds have a short-term maturity (7.7 years on average), and more than 75% are bonds with fixed coupon rates. Among corporate bonds, those issued by public firms have a longer maturity and a higher share of these bonds with fixed interest rates. Corporate green bonds are used in the US, the EU, and China.

Short-term bonds with a maturity of up to 5 years and bonds with a maturity between 5 and 10 years were dominant in the market, with a market share of 75% in 2018, approximately equally divided between these two maturity groups.

There are two standards for the certification of green bonds (Tang & Zhang, 2020)²⁵⁷. Green bond principles (GBP) were proposed in 2014 by the leading investment banks and the International Capital Market Association. This standard consists of four pillars: the use of funds collected with bond issue, evaluation and selection of green projects, management of the funds collected from bonds, and reporting on the use of these funds). According to GBP, the proceeds from green bonds can be used for renewable energy, green energy and transportation, clean water management, ecological agriculture, pollution reduction, biodiversity preservation, global pollution and climate change, and the production of ecological products. The second standard is the Climate Bond Initiative (CBI), which defines detailed criteria in different sectors for classifying bonds as green. These criteria are used in the process of third-party verification. Concerning corporate green bonds, the criteria for classifying them as green are more evident since these institutions issue green bonds to finance their green projects. On the other hand, financial institutions such as commercial banks and insurance companies issue green bonds to grant green loans to the corporate sector for financing green projects or provide insurance for green projects. The criteria for classifying these bonds into green bonds are

²⁵⁶ Falmer, C. (2021). Corporate Green Bonds. *Journal of financial economics*, 142(2), pp. 499-516.

²⁵⁷ Tang, D. Y., & Zhang, Y. (2020). Do Shareholders Benefit From Green Bonds? *Journal of Corporate Finance*, 61, 101427

more complex than corporate green bonds since the proceeds are indirectly used for green projects.

Third-party verification should reduce asymmetric information between green bond issuers and investors. Some investors prefer green bonds, and their certification convinces them that the funds will be used for the announced purpose. Nevertheless, this external verification is costly for issuers. Some Asian jurisdictions, such as China, Hong Kong, and Singapore, provide subsidies for third-party verification costs. According to Fatica et al. (2021), BIS Bank has established an investment fund for central banks to invest in green bonds.

1.1. The evidence of positive green bond premium

There are three reasons for issuing corporate green bonds, according to Flammer (2021). The first is a signaling motive when a company wants to send a credible signal that it has environmental considerations. The willingness to pay the cost of third-party verification makes the signal credible. This is in accordance with the signaling literature on asymmetric information, where a credible signal should incur a specific cost. There might be other motives, such as “greenwashing,” when a company wants to issue green bonds to make misleading claims about its environmental considerations. The third motive is related to the green premium when a company wants to benefit from lower yields paid on green bonds rather than traditional bonds (so-called brown bonds). In other words, green bonds are sold at a premium (higher price). The higher price of green bonds is reflected in lower yield on these bonds. The author finds a cumulative abnormal return of 0.49% on stocks of green bond issuers after the announcement of a new green bond issue. This effect is more significant for companies that issue first-time green bonds than those that are not first-time issuers.

Furthermore, the effect is more substantial for bonds with third-party verification. After the issue of green bonds, companies typically reduce their CO₂ emissions. Moreover, the issuance of green bonds attracts long-term investors and investors with strong environmental preferences, and these investors increase their participation in the ownership of green bond issuing companies. The existence of such preferences in an experimental framework was identified by Martin and Moser (2016)²⁵⁸ who claim that investors are willing to sacrifice a small part of their wealth for environmental benefits.

²⁵⁸ Martin, P. R., & Moser, D. V. (2016). Managers' Green Investment Disclosures and Investors' Reaction. *Journal of Accounting and Economics*, 61(1), pp. 239-254.

By comparing green bonds with brown bonds of the same issuer with similar characteristics, Flammer (2021) does not find a green premium, meaning that investors are not willing to accept lower yields on green bonds than on similar brown bonds, and the author claims that reduction of the cost of capital hypothesis is not verified. Nevertheless, this analysis considers a heterogeneous group of green bonds, which is the drawback of this analysis. More precise results could be obtained by analysing separate groups of corporate bonds according to the issuer's type. It is interesting that Gormley and Matsa (2011)²⁵⁹ find that stocks of companies that are involved in the production of non-healthy products such as alcohol and tobacco have higher returns than other comparable stocks due to the higher risk of litigation. In addition, these stocks are less attractive to institutional investors, such as pension funds and insurance companies. However, they are more attractive for mutual and hedge funds willing to take higher risk.

Fatica et al. (2021) conducted a more detailed desegregated analysis of the green bond premium. Table 1 clearly shows that a green premium (lower yield) exists for green bonds of the non-financial sector and supranational institutions (statistically significant). In contrast, the green bond premium for financial institutions is minimal and statistically non-significant.

Table 1. Green bond premia in different sectors

Issuer	Green bonds (average yield)	Ordinary (average yield)
Supranational institutions	3.52%	5.19%
Financial sector	3.02%	3.18%
Non-financial sector	3.62%	4.73%

Source: Fatica et al. (2021), op. cit.

This phenomenon is based on the indirect link between green bond proceeds and investment in green projects. Non-financial institutions use these proceeds directly, while financial institutions use the proceeds to grant loans to corporations that will eventually use the proceeds for green projects. Hence, the degree of information asymmetry is considerably higher for green bonds in the financial sector. Nevertheless, financial institutions that participate in the United Nations Environment Program Finance Initiative (UNEPFI), which establishes green standards for financial institutions, benefit from lower yields on their green bonds than other financial institutions that do not participate in this initiative. Due to third-party verification, it can also be observed that there

²⁵⁹ Gormley, T. A., & Matsa, D. A. (2011). Growing out of Trouble? Corporate Responses to Liability Risk. *The Review of Financial Studies*, 24(8), pp. 2781-2821.

is a statistically significant lower yield on green bonds of non-financial institutions (Table 2).

Table 2. Green bond yields with and without third-party verification

Issuer	With review (average yield)	Without review (average yield)
Supranational institutions	4.27%	3.09%
Financial sector	2.92%	3.11%
Non-financial sector	3.04%	4.15%

Source: Fatica et al. (2021), op. cit.

In contrast to other papers, Fatica et al. (2021) find that supranational institutions and the financial sector do not benefit from green premiums on the second and further issues of green bonds compared to the first. However, green bonds of non-financial institutions exhibit this effect, and the yield on green bonds is lower for the second issue than for the first issue. This phenomenon stems from the signaling effect, which ensures investors that these firms aim to improve their environmental performance seriously. Finally, this effect exists in developed economies and is not identified in developing economies.

Concerning the financial sector, Fatica et al. (2021) found out that after the issuance of green bonds, banks shift their lending activity to less polluting sectors. Thus, green bonds make banks' asset and liability side of the balance sheet more ecological. The minimum capital requirement in Basel standards could also be tailored to environmental concerns, such that risk weights for green assets are reduced while risk weights for non-green assets are increased.

Zerbib (2019)²⁶⁰ considers factors that affect the green premium and determines that maturity, currency, and issue size do not affect the level of the green premium. In contrast, the green bond's credit rating affects the green bond premium, as shown in Table 3.

Table 3. Green bond premium and credit rating

Credit rating	Mean green premium (in bps)
AAA	-0.01
AA	-0.029
A	-0.018
BBB	-0.021
BB	-0.206
NR	-0.012

²⁶⁰ Zerbib, O. D. (2019). The Effect of Pro-environmental Preferences on Bond Prices: Evidence From Green Bonds. *Journal of Banking & Finance*, 98, pp. 39-60.

Source: Zerbib (2019), *op. cit.*

In the subsequent econometric analysis, Zerbib (2019) finds that green premiums are also higher for green bonds with higher credit ratings. He also determined the existence of green premiums in the secondary bond market.

In the sample of the US data, Baker et al. (2022)²⁶¹ also identify green premium for green bonds over comparable brown bonds. Nevertheless, when the same company issues green and brown bonds with the same characteristics simultaneously, there is no green bond premium in the primary market. However, the green premium appears when these bonds are traded in the secondary market.

Zirek and Unsal (2023)²⁶² analyse green bond premium for different types of bonds based on the level of their external verification. The first category excludes green bonds that are not under GBP standards, and these bonds have the highest greenwashing risk. Bonds with higher certification levels have lower certification risk. Aligned green bonds respect GBP standards but do not have third-party verification. Reviewed green bonds are issued according to GBP standards and have third-party verification. Finally, certified green bonds passed the CBI certification process. The greenwashing risk for this type of bond is almost nonexistent.

Table 4. Green bonds with different types of external verification

Bond type	average maturity	average coupon rate	average credit rating
Total green bonds	5.88	2.25%	AA
Excluded green bonds	5.16	1.99%	AA
Aligned green bonds	7.48	2.45%	AA
Reviewed green bonds	5.64	2.25%	AA
Certified green bonds	6.39	2.31%	A+

Source: Zirek and Unsal (2023)

Zirek and Unsal (2023) determine the green bond premium for aligned, reviewed, and certified bonds (Table 4); the green premium is the highest for certified green bonds. There is no statistically significant green bond premium for excluded bonds. Moreover, certified green bonds have a significantly higher

²⁶¹ Baker, M., Bergstresser, D., Serafeim, G., & Wurgler, J. (2022). The Pricing and Ownership of US Green Bonds. *Annual Review of Financial Economics*, 14, pp. 415-437.

²⁶² Zirek, D., & Unsal, O. (2023). Green Bonds: Do Investors Benefit From Third-party Certification? *Global Finance Journal*, 58, 100872

premium than reviewed green bonds, but there is no significantly higher green bond premium for certified compared to aligned bonds. The author cannot unambiguously conclude that the certification process increases the green bond premium.

Tang and Zhang (2020) analyse the effects of corporate green bond issues on stock prices and identify three channels: investors' attention channel, the fundamental channel and the financing cost channel. Investors' attention channel works in the following way. The issue of green bonds will attract investors' attention, not only of investors interested in green bonds but also of investors interested in stocks of green bond issuers. According to this hypothesis, only the first issue of green bonds attracts investors' attention, and there is no such market reaction for subsequent issues. This will induce investors to buy stocks of environmentally friendly firms, which should increase institutional ownership and liquidity of the stock market. The fundamental channel operates through the reduction of asymmetric information. Namely, the issue of green bonds requires more detailed information on companies' performance than the issue of ordinary bonds. The reduction of information asymmetry increases investors' confidence, leading to higher stock prices. The financing channel is related to the higher interest of environmentally concerned investors who will increase their demand for green bonds and their price, reducing the yield on these bonds and the financing cost of the issuer. The reduction of financing costs will result in a higher company share valuation.

In addition, Tang and Zhang (2020) prove that the stock market positively reacts to green bond announcement in the event window ten days before and after the issue announcement. The cumulative abnormal return in this timeframe is 1.4%, and this effect is more significant for companies that issue green bonds for the first time than for companies that are non-first-time issuers. They also find a green premium of 6.94 basis points on green bonds compared to corporate bonds of similar characteristics. They also find that institutional investors (mainly pension funds) increase their ownership in green bond issuers on average by 7.9% after the issue. On the other hand, hedge funds reduce their ownership in companies that have issued green bonds. The fact that domestic pension funds increase the ownership of environmentally friendly companies confirms the existence of the investor attention channel. Finally, they find that the liquidity of the stock market of green bond issuers increases after the issue of green bonds, and consequently, the bid-ask spread for these stocks decreases. There might be another explanation for reduction of the bid-ask spread related to asymmetric information. Namely, in a famous paper, Glosten and Milgrom

(1985)²⁶³ have shown that when information asymmetry falls (the probability of insider trading), the bid-ask spread should also fall. As we have already discussed, issuing green bonds requires publishing much data on companies' performance, reducing asymmetric information and insiders' informational advantage.

1.2. The evidence of zero green bond premium on the US municipal bonds

In some papers, green premium was not identified, as in Larcker and Watts (2020)²⁶⁴. They claim that Baker et al. (2022) identified the green premium due to methodological misspecification in their estimation. In the sample of US municipal bonds, Larcker and Watts (2020) find a statistically non-significant green premium of 0.4 basis points, mainly due to some outliers. In 85% of cases in the sample, there is no green premium; in the remainder of the sample, it is almost equally likely that there is a positive or negative green premium.

Larcker and Watts (2020) search for explanations for the inexistence of the green bond premium. They found out that there is no difference in the liquidity of green and brown municipal bonds (measured by the price dispersion of bond prices), and the difference in liquidity is not the explanation for the absence of green premium. They find a small green premium of 1.2 bps for CBI-certified green municipal bonds. In 91% of the sample, there is no green premium for CBI-certified green bonds, and the difference exists only for 9% of the bonds.

The authors also compare the issuing costs of green and brown bonds and find that the issuing costs are 12% higher for green than for brown municipal bonds. In 70% of cases, there is no difference in issuing costs, while in 24% of the sample, green bonds have higher issuing costs, and in 6% of the cases, brown bonds are cheaper to issue. Given that the authors do not find evidence of green premiums and that issuing green bonds is more expensive, why municipalities would issue green bonds remains puzzling.

Since green municipal bonds in their sample have slightly higher credit ratings than brown bonds, they infer that wealthier municipalities and municipalities with higher environmental preferences issue green bonds.

²⁶³ Glosten, L., & Milgrom, P. (1985). Bid, Ask, and Transaction Prices in a Specialist Market with Heterogeneously Informed Traders. *Journal of Financial Economics*, 14(1), pp. 71-100.

²⁶⁴ Larcker, D. F., & Watts, E. M. (2020). Where's the Greenium? *Journal of Accounting and Economics*, 69(2-3), 101312.

1.3. Ownership concentration

An interesting analysis conducted by Baker et al. (2022) compares the degree of ownership concentration of green and brown bonds. For this comparison, they use the HHI index, defined as the sum of squares of market shares:

$$HHI = \sum_{i=1}^n s_i^2. \quad (1)$$

They find more concentrated ownership in the sample of US green bonds. Namely, they find that HHI is 0.06 to 0.1 higher for green bonds than for brown bonds, mainly due to the more significant investments of socially responsible funds in green bonds. There is also a difference in the ownership concentration between green bonds of different credit ratings. The highest concentration is identified for green bonds with AAA credit rating. On average, HHI is 0.16 higher than for AAA brown bonds, while for other bonds not in the top credit rating category, HHI is just 0.06 higher than for brown bonds. Finally, CBI-certified green bonds have the highest concentration levels compared to other green bonds with lower certification levels.

Opposite to the previous finding, Larcker and Watts (2020), on the sample of US municipal green bonds, find that these bonds attract a more diverse set of investors. They do not find a statistically significant difference in the institutional ownership between green and brown municipal bonds. The mean HHI for green municipal bonds is 0.573 and for brown municipal bonds 0.646, indicating a higher concentration of ownership for non-green bonds (although statistically nonsignificant).

1.4. Sovereign green bonds

The issuance of sovereign green bonds is still limited compared to municipal and corporate green bonds. According to Ando et al. (2022)²⁶⁵ Only 0.2% of all sovereign bonds in OECD countries are green. In emerging economies, 12% of all new bonds issued in 2021 are green. The advantages of sovereign green bonds over brown bonds are longer maturity and lower cost of debt due to the green bond premium.

²⁶⁵ Sakai, A., Roch, M. F., Wiriadinata, U., & Fu, M. C. (2022). Sovereign Climate Debt Instruments: An Overview of the Green and Catastrophe Bond Markets, *IMF eLibrary*

The first sovereign green bonds were issued by Poland in 2016 and by France in 2017. In 2021, the Central Bank of China published guidelines for issuing green bonds. The market grows steadily, and in 2021, 80 billion USD of green bonds were issued. European countries have the largest stock of outstanding green debt of 161 billion USD in 2021. France has the most significant outstanding debt in green bonds of 48 billion USD (in February 2022), while Chile has the largest outstanding green debt to GDP ratio of 2.37%. The list of the largest issuing countries is shown in Table 5.

Table 5. Sovereign green bonds by jurisdictions in 2021

Jurisdiction	Total outstanding amount of green bonds
France	48 billion USD
Deutschland	27.3 billion USD
The UK	21.9 billion USD
Italy	15.3 billion USD
Netherlands	12.1 billion USD
Belgium	11.8 billion USD
Ireland	7.8 billion USD
Chile	7.5 billion USD
Hong Kong	7.3 billion USD
Spain	5.7 billion USD

Source: Sakai et al. (2022)

The main objectives for issuing sovereign green bonds are investing in less polluting forms of transportation, followed by reduction of CO₂ emission and preservation of biodiversity.

The average maturity of sovereign green bonds is 12.6 years, and the main investors are institutional investors such as pension funds and insurance companies. These investors buy these bonds and aim to hold them until the maturity date. The longer maturity of these bonds reduces the refinancing risk, particularly for emerging economies.

The second advantage of sovereign green bonds is related to the lower cost of the debt due to the green premium. Based on a natural experiment in Germany, Sakai et al. (2022) determined the existence of the green bond premium. Namely, Germany has issued twin bonds since 2020. One issue contains green bonds, and the second one contains brown bonds, and both types have the same coupon and maturity.

2. CAT BONDS

The event that was crucial for the launch of an innovative financial instrument, such as the CAT bond, was the damage caused by Hurricane Andrew in 1992 in Florida. Insurance companies were exposed to total losses of 15.5 billion USD, and eight insurers went bankrupt, while others faced enormous solvency problems. To remedy this problem, first CAT bonds were issued as a substitute for reinsurance. The first CAT bond was issued in 1994 by Hannover Re. CAT bond offers relatively high coupon payments to investors, but they risk losing the principal if a predefined catastrophic event occurs. For example, if an earthquake is stronger than 7.2 on the Richter scale, the insurer can use the principal of the bonds to cover the losses.

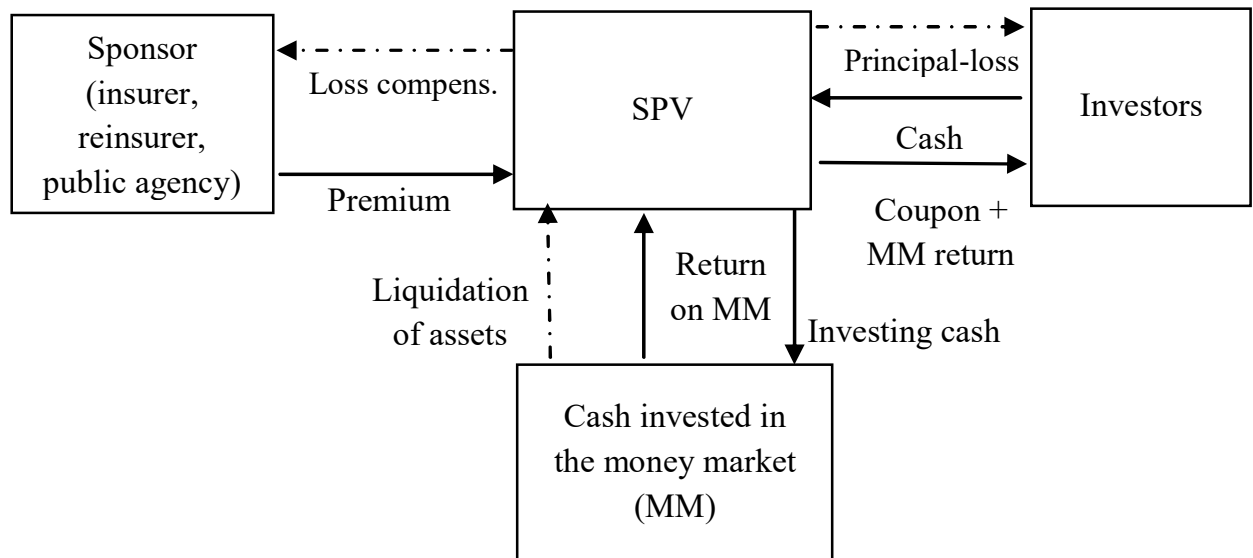
The mechanism of CAT bonds is well explained in one example from Polacek (2018)²⁶⁶. The CAT bonds in the example were issued by Mariah RE Ltd as the special purpose vehicle (SPV) in November 2010 for the insurance company American Family Mutual Insurance (AFMI), called the sponsor of the CAT bonds. Mariah RE Ltd acted as the middleman between investors and AFMI. CAT bonds covered the risk of hurricanes and tornados and transferred the risk from the sponsor to the investors in CAT bonds. The trigger point was the insurance industry losses of 825 million USD caused by the covered risks. When total industry losses achieve this level, AFMI was entitled to retain 1 USD of bond principal for 1 USD of covered losses, up to the total amount of the CAT bond issue of 100 million USD. For example, suppose total insurance industry losses in the US caused by hurricanes and tornados were 850 million USD. In that case, AFMI is entitled to use 25 million USD of the bonds principals to cover the losses of insured agents. If the total amount of insurance industry losses in the US were 925 million USD, AFMI could keep all 100 million USD to cover losses.

The role of the middleman (special purpose vehicle-SPV) in the CAT bond issue is crucial to diminish investors' concerns about the sponsor's (insurer, reinsurer, or public agency) credit rating and how sponsors will use the proceeds. The SPV issues CAT bonds for sponsors, collects the money from investors, and invests the proceeds in safe assets such as the US treasury money market. Typically, CAT bonds have a maturity of three years. SPV transfers the proceeds to the sponsor if the trigger point is reached. Otherwise, the sponsor transfers the premium (for example, coupon rate of 6.5%) to the SPV, and SPV pays the premium along with the interest earned in the money market to

²⁶⁶ Polacek, A. (2018). Catastrophe Bonds: A Primer and Retrospective. *Chicago Fed Letter*, 405, pp. 1-7.

investors. The principal is returned to investors at the maturity date. This can be illustrated in Figure 1, where dotted arrows show the contingent payments based on reaching or not reaching the trigger point.

Figure 1. CAT bond mechanism



Source: Polacek (2018), *op. cit.*

In the case of AFMI, as early as April and May 2011, many tornados across the US caused considerable losses to insurance companies. The third-party expert, AIR Worldwide, was in charge of verifying total insurance industry losses. AIR Worldwide estimated total insurance industry losses at 954.6 million USD, 129.6 million USD larger than the trigger point. AFMI was entitled to use the whole amount of proceeds from CAT bonds of 100 million USD to cover losses.

CAT bonds can be based on four types of triggers: indemnity, insurance industry loss, parametric, and hybrid (combination of triggers). The indemnity trigger is based on the insurer's actual losses, and the insurance industry loss trigger is based on total insurance industry losses, as in the previously described case. Both types of triggers require third-party verification from expert companies, such as AIR Worldwide. Nevertheless, the verification process is much faster for total insurance industry losses, and the insurance company can obtain the proceeds from CAT bonds in 3 months. In the case of an indemnity trigger, the verification process is much longer, and it can take up to two years due to the moral hazard problem for the insurance company that has an incentive to exaggerate losses. The parametric trigger is based on the easily verifiable strength of earthquake or wind, and these bonds do not need third-party verification. The insurer can claim the proceeds within three months.

From an insurer's point of view, there is a trade-off between moral hazard behavior and basis risk, according to Cummins (2008)²⁶⁷. The indemnity trigger is closely related to the insurer's losses, and basis risk is minimised. On the other hand, moral hazard may induce insurers to exaggerate losses. There are also two disadvantages for an insurer: it should disclose more information about its business, and the period of loss verification is more extended. Parametric triggers do not involve moral hazard, but there might be substantial basis risk for insurers. The basis risk can be minimised if the parametric trigger is closely related to the area with the highest insurer's exposure to catastrophic risks. The advantage of this trigger for the insurer is that it can receive the CAT bond proceeds without delay. The trigger based on insurance industry losses minimises the moral hazard problem and exposes the insurer to the basis risk. Suppose the insurer is particularly exposed to high risk in a small geographic area adversely affected by catastrophic risks while other areas of the country are unaffected. In that case, the trigger point might not be reached. In order to minimise the basis risk with this trigger, the insurance industry losses should be defined on a regional level rather than a country level. Hybrid triggers are based on the combination of the previous three triggers.

According to Polacek (2018), insurance companies are the largest issuers of CAT bonds, with 60% of total outstanding CAT bonds. Insurers' CAT bonds often have an indemnity trigger, followed by an insurance industry loss trigger, while parametric and hybrid triggers are rarely used. Reinsurers are the second most crucial group of issuers of CAT bonds, with a market share of 25%. Reinsurers must wait for insurers to determine their losses and claim compensation for reinsurers. Hence, the indemnity loss trigger would take too long for the reinsurer to receive compensation from the CAT bond proceeds.

Moreover, reinsurers receive transferred risk from insurers from the whole country, not from a particular region, and for this reason, the insurance industry loss trigger is more appropriate. This is the most common trigger for reinsurers' CAT bonds, followed by parametric triggers. Hybrid and indemnity triggers are far behind and almost equally used. State catastrophe funds are the third most crucial group of CAT bond issuers. In the US, two federal states most exposed to catastrophe risks, Florida and California, have their catastrophe funds. Florida is exposed to hurricanes, and California to earthquakes. These funds take on themselves catastrophic risks that private insurers previously insured. Private insurers in these two federal states are exposed to higher risks than in

²⁶⁷ Cummins, J. (2008). Cat Bonds and Other Risk-linked Securities: State of the Market and Recent Developments. *Risk Management and Insurance Review*, 11(1), pp. 23-47.

other federal states, and public catastrophe funds are a better option. These funds also issue CAT bonds and dominantly use indemnity triggers.

Some previously issued CAT bonds had the option of delayed payment of the principal if the trigger point was reached and there was no further payment of the coupon and return from the money market. For example, a CAT bond with a three-year maturity period and a 6.5% premium + return from the money market might be converted into a ten-year zero-coupon bond after the catastrophic event. This CAT bond type is no longer the standard since it offers much smaller protection for insurers than CAT bonds where the principal is at risk.

CAT bonds have several advantages over reinsurance. First, they transfer the catastrophic risk to a wide range of investors. Second, they offer multi-year reinsurance protection (typically three years). In contrast, the reinsurance contract lasts one year, and insurers are exposed to the risk of an increase in the reinsurance premium. Third, as a substitute for reinsurance, CAT bonds can reduce reinsurance premia. Fourth, fixed costs of issuance of CAT bonds can be amortised within the period of CAT bond maturity.

CAT bonds also have several advantages for investors. Since SPV holds collateral in the money market, there is no concern about the issuer's credit risk. CAT bonds typically have a credit rating of BBB or lower, unrelated to the sponsor's credit risk. A CAT bond's credit rating is related to the probability of catastrophic event. The higher the risk, the lower the credit rating of a CAT bond. Second, the return on these bonds is uncorrelated with the return on other financial assets, and CAT bonds are a good instrument for diversification. Investors can reduce their risk if they invest in CAT bonds in different geographic areas, since it is unlikely that all these remote areas could be hit simultaneously by catastrophic risks. According to Barrieu and Loubergé (2009)²⁶⁸, the main disadvantage that inhibits even faster development of the CAT bond market is the possibility of simultaneous realisation of a catastrophic risk and stock market crash, when CAT bonds do not offer diversification opportunity.

First, CAT bonds were issued with a ten-year maturity, but investors do not prefer CAT bonds with long maturity since they are exposed to higher risk. In addition, investors would like to reprice catastrophic risks based on the updated frequency and intensity of these events. Sponsors do not prefer CAT bonds with

²⁶⁸ Barrieu, P., & Loubergé, H. (2009). Hybrid CAT Bonds. *Journal of Risk and Insurance*, 76(3), pp. 547-578.

maturity shorter than three years since they cannot amortise issuing costs over several years, have unstable sources for covering losses, and are exposed to reinsurance price changes.

At the onset of the CAT bond market, the leading investors were insurers and reinsurers, and there was no influx of capital outside of the insurance sector. However, as soon as 2007, the share of insurers and reinsurers in total demand for CAT bonds fell to 7%, and institutional investors became the primary buyers of CAT bonds, such as CAT bond funds or hedge funds. The CAT bond market diminished in 2008 after the bankruptcy of the Lehman Brothers, which was SPV for some CAT bonds, but the market recovered in 2009. There was a constant growth of the CAT bond market from 2010 to 2017 that was driven by low yields on other assets, and investors have found an alternative with higher yields. The second factor was the development of catastrophe risk modeling, which enabled investors to better estimate the risk of investing in CAT bonds.²⁶⁹

The ratio of yields (coupon rate + return from MM) to expected loss shows the cost of reinsurance in the CAT bond market. In the first years of the CAT bond market, this ratio was around six, indicating relatively high costs of this type of reinsurance, but then fell to 2.1 in 2005. After Hurricane Katrina in 2005, it increased to 3.7, but then it fell again to 2.3. The yield on CAT bonds is higher than on corporate bonds classified with BB credit risk.²⁷⁰

Since CAT bonds have full collateral in the form of high-quality money market instruments, sponsor characteristics should not affect the premium they pay to investors. Nevertheless, Götze and Gürtler (2020)²⁷¹ determine inefficiencies in the CAT bond market, meaning that sponsor-related characteristics affect the premium. They find that sponsors with more experience in the CAT bond market, such as Swiss Re, issue CAT bonds with lower premium payments to investors. This fact represents a barrier to entry for new sponsors in the CAT bond market since they should pay higher premiums than well-established sponsors. Second, sponsors with more extensive market coverage in the CAT bond market also pay lower premium to investors. Third, new issues of CAT bonds are sold at lower premium, implying that investors highly value innovative CAT bonds. Finally, the premium increases when the sponsor's credit rating falls.

²⁶⁹ Polacek (2018), op. cit.

²⁷⁰ Cummins (2008), op. cit.

²⁷¹ Götze, T., & Gürtler, M. (2020). Hard Markets, Hard Times: On the Inefficiency of the CAT Bond Market. *Journal of Corporate Finance*, 62, 101553.

2.1. Sovereign CAT bonds

The first sovereign CAT bond was issued by the Mexican Natural Disaster Fund in 2006 to cover earthquake risk. The bonds had a parametric trigger related to the magnitude of the earthquake and a nominal value of 160 million USD. The yearly expected loss was 0.96 percent.

The US is the largest issuer of CAT bonds, with 5.6 billion USD of outstanding earthquake CAT bonds in 2021. Mexico is the second largest issuer of CAT bonds, with 845 million USD and 420 million USD of outstanding CAT bonds against storms and earthquakes, respectively. Mexico has also issued 290 million USD of CAT bonds covering earthquake and storm risks. Turkey and Chile both have around 500 million CAT bonds against earthquakes, while Colombia has 400 million USD CAT bonds against the same peril, and so on. World Bank has issued 320 million USD CAT bonds against epidemic risks. In some cases, the sponsors of these bonds are regional agencies, and in some cases, the sponsor is the central government.²⁷²

The World Bank facilitates the issuance of CAT bonds for some developing countries by serving as the SPV, gaining investors' confidence in these bonds and reducing the required yield. The leading investors in sovereign CAT bonds are insurance-linked security funds, asset management companies, insurers, reinsurers, and pension funds.

Global warming increases the frequency and severity of climate risks. The possibility of reducing pollution *ex-ante* is to issue green bonds at the corporate, regional, and national levels. As we have explained, there are also some benefits of green bonds for issuers, apart from the benefits for society. The other instrument for *ex-post* managing climate risks is the CAT bond. It offers an attractive form of reinsurance and has several advantages over classical reinsurance. It also offers benefits to investors for obtaining high yields and achieving diversification.

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²⁷² Sakai et al. (2022), op. cit.