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CAT Bonds: A Suitable Systemic Approach for Handling Catastrophic Risks in the Czech Republic?*

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Abstract

Catastrophic natural events in the Czech Republic have always caused a considerable burden on public finance. However, this risk can be transferred to capital market investors through CAT bonds, which have never been used for this purpose in the Czech Republic. The paper deals with the theoretical background of CAT bonds, resulting in a back test simulation of a hypothetical CAT bond issued for the period 1999–2003. As a result, by transferring the risk to the capital market, investors could save a significant part of the Czech Republic's public funds.

Keywords: CAT bonds, insurance, reinsurance, government's expenditures, catastrophic events

JEL Codes: G22, G30, H50, H82, H84

Introduction

Natural catastrophic events seem to be inevitable because they are, for the most part, out of the control of mankind. After they hit, the stricken countries suffer from negative social and economic effects in varying intensity. They differ depending on the force of the disaster and the affected country's risk management.

The financial facilities or the speed of gaining finances used for the recovery process after a catastrophic event are crucial for each country. Fortunately, there are sophisticated ways of transferring the risk outside the government and bringing finances back into the country

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in the case of a loss. The traditional approach of transferring the risk works with insurance and reinsurance respectively. As the traditional re/insurance market showed its own limitation in the 1990s, the financial market has come up to fill the gap. Involvement of financial market investors in a situation is the modern way of transferring the risk. Nowadays, both approaches coexist symbiotically and complete one another.

General theory states that the institute of property insurance is an unbeatable method when loss occurs, because the financial burden is transferred from individuals, entrepreneurs and the public sphere to insurance companies. Furthermore, the global reinsurance market, both traditional or alternative, offers another possibility to handle too big expositions held by insurance companies and export them outside the country of origin. This facility enables increasing the insurance capacity, so that insurers should satisfy better the demand for insurance against catastrophic risks (OECD, 2018).

On the other hand, privately owned insurance companies operating in developed countries can decide freely whether to insure catastrophic risks in specific areas (e.g., based on flood maps). Moreover, insurers stabilize underwriting results by limits fixed in the insurance contract and/or by exclusions stipulated in their terms and conditions. As a result of these two elements, a person with an insurable interest would not be content with the insurance cover.

Continuing on the above point, it should be noted that insurance pricing as a sole form of financial stabilization of insurers is scanty and insufficient. Premium rates applied to catastrophic risks are usually quite high. It is because that it is quite impossible to collect an adequate amount of premium solely from catastrophic risk insurance policies to cover all losses, because the catastrophic risks deal, besides other things, with high severity.

So, the same principles concerning the limits, exclusions and pricing are followed by reinsurers. On top of that, each covered layer is priced differently, while the lower layers are more expensive than the layers at the top of the cover due to principles of probability (Carter, 1995). The obvious ambiguity coming from the contrast between theory and laws of free market practice unlocks the eventuality of government involvement. The engagement of the government varies as each country has its own learned lessons from the past, political background, economical development, and social awareness. As a result, several models have been implemented to cope with the catastrophic risk market gap.

Up to the 1990s, insurance markets used to be more or less enclosed in capital markets, while all risks had been shared inside the insurance community. As a matter of fact, mostly reinsurers had made the rules accepted and followed by insurers, so that they would have obtained reinsurance contracts to stabilize the underwriting results. Due to the expansion of globalization during the last decades and a coincidence of two large disasters (Hurricane Andrew and the Northridge Earthquake), a new opportunity for transferring a risk beyond the frontiers of the insurance market, to deal with catastrophic risks more effectively and broadly, was brought into light. It is called the catastrophic bond but is known simply as the CAT bond.

Although the majority of sponsors are reinsurers or insurers, few governments have been involved in this kind of business until now. Namely, Peru opted for the parametric CAT bond in 2018, triggered by an earthquake and worth USD 200 million; the Philippines issued CAT bonds worth USD 225 million based on modelled loss (Artemis, 2022).

Catastrophic disasters have always caused serious difficulties to every affected economic sector. Their negative social, economic, and political outcomes with other cascade effects are indisputable; therefore, all solutions prepared ad hoc or even ex post seem to be inadequate. Moreover, this way of handling present troubles inflicts other problems, which would have been simply avoided if a reliable arrangement or risk management was adopted.

The objective of this study is to create a procedure leading to the design of a catastrophic bond that could work under the conditions of the Czech Republic and to give an example of its practical implementation. Subsequently, we assess the potential advantages and disadvantages of this investment instrument, not yet used in the Czech Republic, for the country's public finance.

The first part of this paper is a literature review, followed by a section concerning the methodology and results. Finally, the discussion section summarizes the outcomes of this research.

1. Literature Review

Financial research has proved a negative connection between property uninsured against catastrophic risks and economic growth of the country. Von Peter et al. (2012) stated that an uninsured part of the losses arising from a catastrophic event eventually leads to appreciable macroeconomic costs. From the economic point of view, Martin and Pindyck (2021) asserted that catastrophes lead to a drop in consumption. On the biggest catastrophes between 1960 and 2016, Horvath (2021) proved that the consequences are significant even a decade afterwards, while the private credit to GDP ratio remains approximately 30% below its predicted potential. Furthermore, Hochrainer (2009) and Thirawat et al. (2017) claimed a direct negative impact of natural catastrophes on GDP depending on the severity of the event.

On the contrary, well insured property generates a positive effect on economic activity. Wasow and Hill (1986) understood insurance as a co-factor of economic development.

Additionally, Pearson (2004) confirmed this statement and emphasized a contribution of insurance to industrialization and urbanization. Another study (Melecky and Raddatz, 2011) showed that countries with higher insurance penetration deal with fewer cuts in state and local government current expenditures due to catastrophic events. Furthermore, their state debt remains almost unchanged.

Standard & Poor's Report (S&P, 2015) states that significant catastrophic disasters may affect economies, resulting in negative effects on their public finance and general credit rating. A considerable rate of property insurance covers against catastrophic risks in a country can mitigate medium-term unfavourable impacts on the economy or even prevent a country's credit rating fall.

Aside from macroeconomic consequences, there is another line which should be taken into account. Without any systemic framework, politicians are those who decide what steps need to be taken in the case of a catastrophe. Based on the phase of the political cycle, the way of their engagement or settlement can vary over time, because politicians may be driven by their own interests (Downs, 1998).

CAT bonds represent a fairly new wave on the insurance market in comparison with traditional reinsurance. However, almost 30 years of their existence have revealed important points regarding their advantages and disadvantages.

As far as the very nature of the CAT bonds is concerned, their main advantage relies on full collateralization (Braun and Kousky, 2021; Cummins, 2012; Carayannopoulos and Perez, 2015; Polacek, 2018). While conventional reinsurance cannot achieve this, because it works on the principle of diversification of risk transfer instead, the CAT bonds seem to be a safe and default-free instrument (Lakdawalla and Zanjani, 2011).

According to Finken and Laux (2009), and Cummins and Dione (2009), CAT bonds are also fully insensitive to asymmetric information, which makes them a perfect tool to settle the equilibrium on the reinsurance market. The contribution of CAT bonds to more efficient reinsurance markets was also confirmed by Lakdawalla and Zanjani (2011) on the basis of a numerical simulation. Besides, Kish (2016) also stated that the opportunity for investors to participate in the field brings many multilateral advantages.

As determined by some authors, due to the high returns uncorrelated with the market, the CAT bonds represent a unique product for investors (Rode et al., 2000; Cummins, 2008; Vivek et al., 2010). On the contrary, Barrieu and Laubergé (2009) argued that the development and world expansion of CAT bonds are limited owing to investors' risk aversion and ambiguity aversion. Furthermore, Gürtler et al. (2014) demonstrated that CAT bonds are zero-beta assets only in times when no crisis appears. As explained on the post-evidence failure of Lehman Brothers, CAT bonds really react (although less than other assets classes) to crises and can be correlated to the market in such tough times.

Recently, Götze and Gürtler (2022) presented a daring study, conducted on the US market, that CAT bonds are able to accomplish insurers' risk management strategies better than reinsurance. They may even substitute the reinsurance model under high default risk of the reinsurance company, low basis risk and in high-risk layers.

Nonetheless, other studies are more conciliatory. Even Trottier and Lai (2017), who validated the advantage of CAT bonds being financial distress costs and default risk-free nature, noted the important point that a combination of reinsurance and CAT bond instruments is optimal. They concluded that small losses should be covered by reinsurance while protection by CAT bonds should be used for excessive losses. Nell and Richter (2004) and Cummins (2008) supported this statement and added that CAT bonds may be able to close the gap in reinsurance supply and proposed their additional risk-bearing capacity.

2. CAT bond design suitable for the Czech Republic

The designing of a CAT bond in this paper is divided into five parts. In the first part, a CAT bond will be described theoretically and the procedure for calculating its parameters will be justified. The second part is focused on a overview of the Czech Republic's situation, and the third and the fourth parts deal with a demonstrative example. The fifth part is devoted to a discussion.

2.1 Theoretical design of a suitable CAT bond

For the purposes of the CAT bond, a bond with a variable coupon is chosen. As maturity respecting a medium-term investment horizon and the issuer's acceptable credit risk compared to a long bond investment is the most popular among bond investors, a 5-year period seems optimal. We have also selected a coupon period, i.e., period for regular coupon payment, of 1 year. When choosing a shorter coupon period, the volatility of the bond price decreases; however, compared to the price volatility during triggering, such consideration is not essential.

In the case of a bond with a variable coupon, the sensitivity of the price change with respect to the interest rate change (described in Stádník, 2022) is generally lower in comparison with bonds with a fixed coupon rate. Thus, the price of the bond will be stable, with possible smaller deviations just after the bond issue or after the reset of the next coupon rate, which is in line with classical bond theory. The bond yield will be built only in its variable coupon rate;

therefore, the issue price will be equal to 100% of the bond face value (FV), where FV means the price investors receive at bond maturity together with the last coupon. We will also assume that at the time of resetting the next coupon, the price will also be equal to 100% of the FV and that the reset day is just after the coupon payment. When designing the bond, we expect that investors in CAT bonds want to focus on risk-taking associated primarily with the occurrence of a catastrophic event and not with the risk of interest rate development, so the issue of price volatility is more of a minor issue.

The variable coupon should include:

- a yield premium covering the risk of a catastrophic event by which the bond is triggered. "Triggered" means that if a disaster of a certain magnitude occurs during the lifetime of a CAT bond, the investor receives only a fraction of both the coupon payment and the face value repayment;
- a certain required yield that would be provided by bonds without catastrophic risk but with the same parameters; and
- a premium for the volatility of future cash flows due to the occurrence or non-occurrence of a catastrophic event.

The initial equation for calculating the catastrophic risk yield premium for each coupon (also described in Stádník, 2017) will be Equation (1):

$$P = FV\left(1-q\right) + \omega FVq \tag{1}$$

where P is the current neutral price of a zero-coupon CAT bond with a maturity of 1 year, which is the same time period as the coupon period of the proposed CAT bond with a variable coupon, FV is the face value of zero-coupon CAT bond, q is the probability that a catastrophe after which the bond is triggered occurs during one year, and in that case the investor receives only a fraction of the face value repayment equal to ωFV, where $\omega \in \langle 0,1)$ denotes the received fraction. In our calculations, we use $\omega = 0$. Essentially, the price P is a weighted average of future cash flows, where the weights represent the specific probabilities at which cash flow will occur. The price of P can be interpreted financially as the investment price, where the investor returns the invested amount on average during repeated investments. It meets the requirements of a risk-neutral investor, who is neutral to the volatility of future cash flows.

Since we do not receive any return on average when investing the amount of P, we discount the risk-neutral price P according to Equation (2):

$$P' = \frac{P}{1+i} \tag{2}$$

where P' is the price reflecting both the return for the catastrophe risk and the usual required return. Therefore, i (in p.a. terms) is the required rate for the bond with the same parameters but without catastrophe risk. We decided to opt for 1-year LIBOR rate for the given period.

By using the P' price, we can then calculate the internal rate of return (IRR) of the investment. Subsequently, the IRR acts to construct the value of the coupon of a CAT bond with a variable coupon. We then calculate the *IRR* from Equation (3):

$$P' = \frac{FV}{1+IRR} \tag{3}$$

In the numerical calculations, we will express the price as a percentage of the FV, and the FV will therefore be equal to 100%. The variable coupon rate for each period in decimals is:

$$c_s = IRR + VOLATILITY_{RISK\_PREMIUM} \tag{4}$$

where c_s is the p.a. coupon rate. The coupon rate is a certain percentage of the FV, as opposed to a coupon payment, which is the amount of the payment in units of currency.

To explain it more clearly, the procedure described above transforms the probability of a catastrophic event occurrence by using the scenarios of possible development of future cash flows into the IRR of a zero-coupon bond and further into the coupon rate of a coupon bond at the price of 100% of the FV when IRR is equal to this coupon rate.

Obviously, the IRR contains both the premium for the catastrophic risk and the value of the LIBOR rate. The issue is how to set the volatility value of the risk premium, but it can be resolved by stating that if the probability of a catastrophic event is low, the volatility of the risk premium will be negligible. Coupon interest for a bond-trading investor is included in the accrued interest. Each investor therefore receives a part of the coupon. With regard to the period the investor holds the CAT bond undertaking the risk of its triggering at the same time, which is logically in direct relationship to the holding period, it seems to be fair.

The size of the issue will be chosen to cover a significant part of public expenditures and the trigger will be set so that the probability of an event and thus the risk does not significantly reduce the number of potential investors due to their risk aversion.

The CAT bond will be denominated in USD to attract more foreign investors. -

In a case of two catastrophic events, such as a storm and a flood, combined into one catastrophic bond, we could use Equation (5):

$$P' = \frac{FV(1-q_1)(1-q_2) + \omega FV(1-p_1 p_2)}{1+i} \quad (5)$$

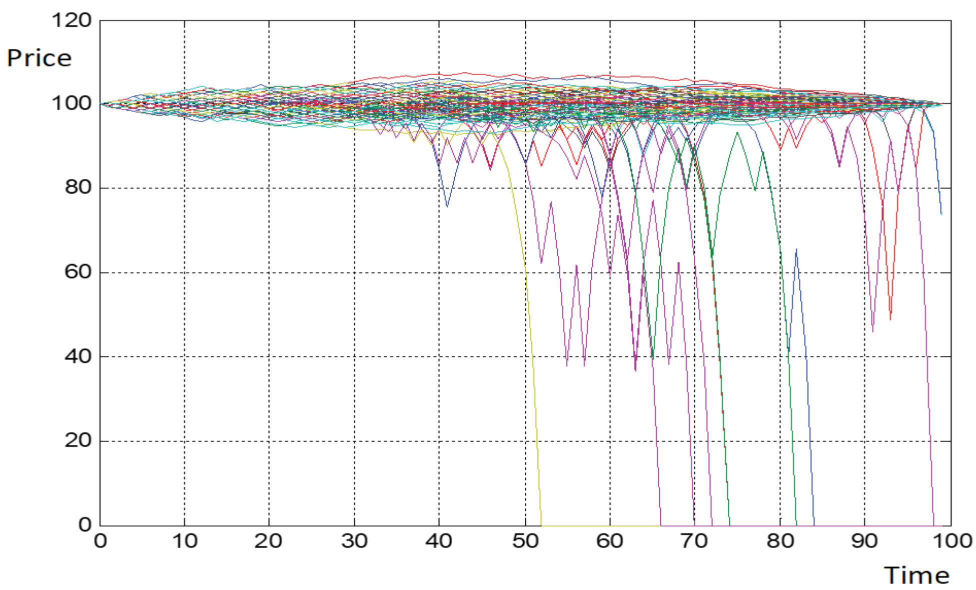
where P_2 is the CAT bond price, q_1, q_2 are the probabilities of the two catastrophe processes having the potential to trigger the bond and $p_1 = 1 - q_1$, $p_2 = 1 - q_2$. The other parameters of the bond are analogous to those in Equation (1). The next calculation procedure, i.e., the determination of the coupon rate, would be analogous to using Equation (1), with one catastrophic event as well.

From the investor's point of view, three main risks are involved: the credit risk associated with the issuer, the risk of catastrophic events and the risk of price volatility. If an investor does not hold a bond until maturity, there is also a risk of selling it at a price significantly lower than the FV.

The price may deviate considerably with the approaching catastrophic event. The sensitivity of the price with respect to the development of the catastrophic event may amount to considerable values, as shown, for example, in Figure 1 (Stádník, 2017). Figure 1 shows a simulation of bond price paths, where sometimes the probability of bond triggering increases significantly. On the other hand, it also captures a situation where the bond is triggered, and its price remains zero. However, quantifying this sensitivity is beyond the scope of this research.

As mentioned above, the sensitivity of the bond price with respect to interest rates is minimized by the use of a variable coupon.

Figure 1: CAT bond price development while a catastrophe is approaching



Source: Stádník (2017)

2.2 Overview of the Czech Republic

The Czech Republic can be characterized as a small open economy in Central Europe that experienced a communist regime in the past. Even though the Iron Curtain fell more than thirty years ago, no systemic framework in terms of catastrophic disasters has been adopted.

From a general point of view, the area in which the Czech Republic lies is certainly not as exposed to catastrophic events of the highest severity in comparison with other stressed countries; in addition, some huge potential disasters can be neglected completely, such as tsunamis or volcanic activity. Despite this, three main destructive groups of catastrophic risks often occur in the Czech Republic: floods, windstorms including tornados, and hailstorms.

Taking a closer look at the rate of private-owned property insurance, according to the Czech Insurance Association uniting the majority of insurers doing business in the Czech Republic, roughly 55% of the properties are insured against catastrophic risks. Table 1 shows the total insured losses (in CZK thousand) during the last five years caused by floods, windstorms including tornados and hailstorms.

Table 1: Insured losses during the past five years (CZK thousand)

Year	Losses, floods	Losses, windstorms	Losses, hailstorms	Total
2017	157,893	1,835,889	697,997	**2,691,779**
2018	186,373	566,631	489,895	**1,242,899**
2019	288,816	1,040,812	1,252,164	**2,581,792**
2020	789,237	1,412,340	572,59	**2,774,169**
2021	558,698	4,076,715	1,469,006	**6,104,419**
TOTAL	**1,981,017**	**8,932,387**	**4,481,654**	**15,395,058**

Source: own processing based on Czech Insurance Association data

Obviously, the rate of insurance of the properties is not sufficient when a catastrophic disaster hits a particular area in the Czech Republic, because the losses are not settled by insurance companies, which are financially well-endowed. The solution for uninsured individuals resides in seeking finance either by their own means or from support provided by the government or charities[2]. As the latter possibility may not be sufficient, people with uninsured properties hit by a catastrophic disaster usually ask for government help.

2 According to official statements of the largest charities, the contribution can be counted in tens of millions CZK.

Unfortunately, the Ministry of Finance of the Czech Republic has officially stated that it does not have any detailed records related to expenditures on other catastrophes than floods and the 2021 tornado. The fact that expenditures on floods the 2021 tornado alone are monitored, although windstorms and hailstorms have obviously been very costly, is alarming. Expenditures in connection with catastrophic disasters other than floods and the 2021 tornado can therefore be forecast only via governmental statements (which may sometimes be contradictory), expert estimations, or the media. That is why only limited summary official figures (i.e., floods and 2021 tornado) taken from the Government's annual records are demonstrated in Table 2 below.

Table 2: Government expenditures on floods and 2021 tornado in last five years (CZK thousand)[3]

Year	Expenditures on floods and 2021 tornado
2017	900,408
2018	94,752
2019	339,579
2020	904,279
2021	1,344,750
Total	**3,583,768**

Source: own processing based on Ministry of Finance data

To the best of our knowledge, the flood in 2002 was the biggest natural catastrophe of all time in the Czech Republic. The government expenditures reached 73.3 billion CZK, while the insured claims were stated at the amount of 36.7 billion CZK.

When discussing the missing figures on such important expenditures to be stated separately, another concern lies in the fact that there are also no records regarding state-owned property insured or uninsured against catastrophic risks. Nonetheless, there is a strong presumption, based on Czech insurance market experience, that a substantial part of the state-owned property, which could be insured at the total amount of CZK 3,825 billion[4], is just not insured due to the fact that the Czech Republic acts as an insurer on its own (Jedlička, 2022).

3 Announced expenditures shown in Table 3 consist of funds intended for after-flood reconstruction, State Fund for Housing Assistance, the "Flood prevention III" programme, "Floods" programme, reconstruction of the Švihov retention reservoir, initial expenditures on recovery after the 2021 tornado, and expenditures on European Investment Bank's security.

4 According to the balance sheet for 2020 published by the Ministry of Finance of the Czech Republic.

In a nutshell, there is no ex-ante systemic framework in the case of catastrophic events. Furthermore, there is evidence that the governmental recovery steps could depend heavily on populism, which contributes to pointless financial trouble and social dissension. Also, there are no official records whether the state-owned property is insured against catastrophic risks and, on top of that, only figures on expenditures on floods and the 2021 tornado are publicly available from the Ministry of Finance.

2.3 Hypothetical model of Czech CAT bond

This part deals with the hypothetical set of CAT bonds issued by the Czech Republic with the following parameters.

A. Issuer/Cedent/Sponsor

The issuer is the same as the sponsor: the Ministry of Finance of the Czech Republic. This is feasible because the Czech Republic owns a respectable evaluation rating of Aa3 according to Moody's or AA- according to Fitch and Standard & Poor's respectively as of 2022.

B. Term to maturity

Bond maturity: 5 years, issue date on 1 January 1999, maturity on 31 December 2003.

C. Trigger type option

According to a general CAT bond market review, 59.6 trigger types in 100 were historically indemnity ones[5]. In addition, indemnity transactions are more transparent and advantageous for the sponsor, because they reflect the real loss. In our paper, we opt for this type.

D. Risks/perils covered

The three main and costliest catastrophic risks occurring frequently in the Czech Republic are floods, windstorms (including tornados) and hailstorms. However, we take account of floods only in our study.

E. Probability of loss occurrence

Not all the necessary information is available as the Ministry of Finance does not record it properly. Therefore, we can lean only on Czech insurers' expenditures on claim settlement of insured retail and business property.

5 According to Artemis statistics. https://www.artemis.bm/dashboard/cat-bonds-ils-by-trigger/

Table 5: 19 costliest natural disasters in Czech Republic in terms of claim settlement in 1988–2022

No.	Natural catastrophe	Date	Insured claims (CZK bln)
1	**Floods, Czechia**	**August 2002**	**36.700**
2	**Floods, Moravia**	July 1997	10.000
3	**Floods, Czechia**	June 2013	7.538
4	**Tornado, Moravia**	June 2021	3.484
5	**Weight of snow**	Winter 2006	2.500
6	**Hurricane Kyrill**	January 2007	2.225
7	**Storms, hailstorms, floods**	June 2021	2.211
8	**Floods**	June–July 2009	2.068
9	**Hailstorms**	August 2010	1.889
10	**Floods**	May–June 2010	1.844
11	**Summer storms**	July–August 2013	1.561
12	**Floods, Moravia**	August 2010	1.545
13	**Hurricane Herwart**	October 2017	1.444
14	**Windstorm Emma**	March 2008	1.355
15	**Storms, hailstorms, floods**	May–June 2016	1.211
16	**Floods**	March–April 2006	1.000
17	**Floods**	July 2012	0.812
18	**Hurricane Eberhard**	March 2019	0.697
19	**Storm Sabine**	February 2020	0.592

Source: own processing based on Czech Insurers Association data

Data from the Czech Insurers' Association (Table 5) show the 19 costliest natural disasters in the Czech Republic in terms of claim settlement in 1988–2022, which means 35 observations. Since we model a CAT bond for floods only, we can neglect the losses caused by the weight of snow, windstorms (incl. tornados and hurricanes) and hailstorms. Furthermore, we process the probability based on the 35 years of history of natural catastrophes in the Czech Republic (Czechoslovakia respectively).

As the CAT bond serves as a financial instrument covering the biggest losses, the trigger should match accordingly. Therefore, we set the trigger at 5.000 billion CZK. There were three natural catastrophes larger than 5.000 billion CZK in the 35-year period. For such a ratio, the frequency of the occurrence of a natural catastrophe exceeding the trigger equals 3/35 = 8.57% per year. The value can be understood as a synonym for the probability, denoted as *q* in Equation (1). The frequency of occurrence is over a relatively short time period; therefore, the probability value should rather be considered indicative only.

F. Coupon payments

In chapter 2.1 we decided that the coupon period would be 1 year. The calculation of the coupon payments is divided into two consequent steps:

1. Risk-neutral prices of investment discounted by LIBOR interest rates for the given year (according to Equation 2) can be formulated as follows:

$$P'_{Year}'\% = \frac{8.57\% \times 0\% + 91.43\% \times 100\%}{1 + 1Y\,USD\,LIBOR_{Year}} \tag{6}$$

The subscript *Year* in the formula corresponds to the calculation of coupon rates consequently for individual years.

Table 6: 1-year LIBOR (values used in calculations shown in bold)

Year	Average yield	Year open	Year close
2003	1.36%	**1.46%**	1.46%
2002	2.20%	**2.40%**	1.45%
2001	3.85%	**5.94%**	2.44%
2000	6.87%	**6.60%**	6.00%
1999	5.72%	**5.09%**	6.50%

Source: Reuters Eikon, 2022

2. Interest rate later used in the calculation of the coupon payments can be calculated as follows (according to Equation 3):

$$IRR_{Year} = \frac{100\%}{P'_{Year}\%} - 1 \tag{7}$$

G. Currency exchange risk

Given the fact that the CAT bond is denominated in USD, the issuer in the Czech Republic takes the market risk of unfavourable development of the CZK/USD currency pair. It is necessary to realize that the issuer will pay coupon pay-outs of the nominal value on certain dates in USD and receive the amount from the investor when buying a CAT bond in USD. The issuer may have a USD position, may acquire USD by converting on the spot, and may also hedge against negative fluctuations of the exchange rate using currency forwards or options.

In our case, we will back-test in USD for covering the damage in 2002. The CNB spot rate as of 1 July 2002 (29.514 CZK/USD) will be used. Damages worth CZK 36.7 billion in 2002 will therefore represent USD 1.24 billion.

H. FACE values

We design face values FV1, FV2 and FV3 of three different sizes matching USD 0.17 billion, USD 1 billion and USD 2 billion. USD 0.17 billion corresponds to the value of CZK 5 billion, which is the minimum damage at which the bond is triggered. We use the exchange rate at the time just before the issue as of 31 December 1998, which was 29.855 CZK/USD.

2.4 Example of back testing of hypothetical CAT bond

Based on the methodological steps described above, we perform back testing on historical data in a period that is consistent with the lifetime of the proposed bond. A coupon payment is always set at the start of the year using 1-year USD LIBOR at the probability of 8.57%.

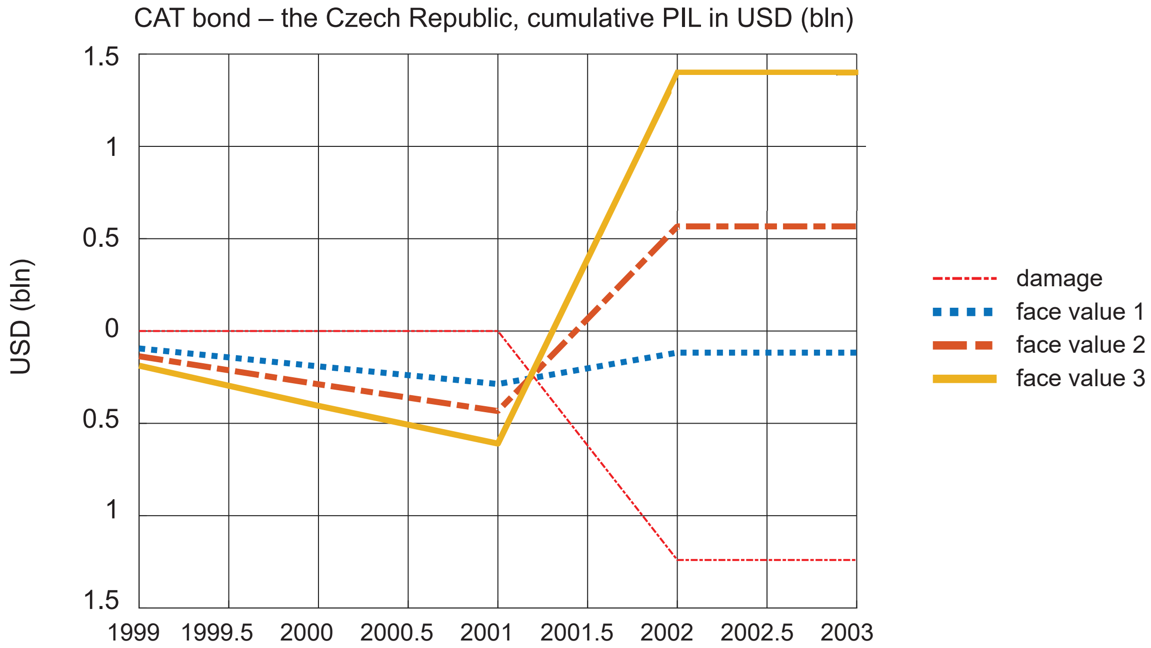
Table 7: Simulated development of cumulative costs and revenues of issuer of CAT bond triggered in 2002

Year	Catastrophe damage (USD bln)	Face value 1 cash flow (USD bln)	Face value 2 cash flow (USD bln)	Face value 3 cash flow (USD bln)
1999	0.000	−0.094	−0.137	−0.188
2000	0.000	−0.097	−0.152	−0.218
2001	0.000	−0.096	−0.145	−0.205
2002	−1.240	0.170	1.000	2.000
2003	0.000	0.000	0.000	0.000

Source: authors' calculations

Simulated development of cumulative costs and revenues of the issuer of a CAT bond triggered in 2002 is illustrated in Figure 2.

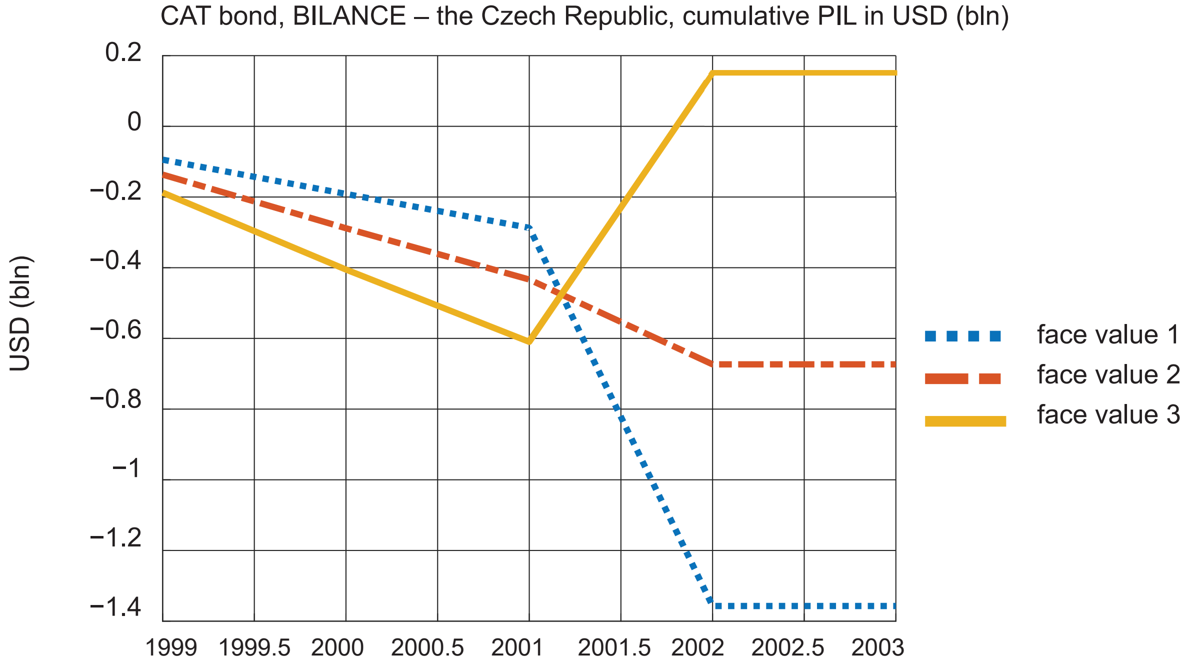
Figure 2: Simulated development of cumulative costs and revenues of issuer of CAT bond triggered in 2002



Notes: catastrophic damage represented by thin line; thick lines correspond to 3 sizes of CAT bond face value
Source: own processing based on data shown in Tables 5, 6, 7

The cumulative loss history from 1999 to 2003 is drawn with the thin red line. Obviously, the biggest rise in the losses appeared in 2002, when the gigantic flood occurred in the Czech Republic. The three other lines reflect the issuer's gains/losses resulting from the different face values (USD 0.17 bln, USD 1 bln and USD 2 bln). The considerably high coupon payments are paid first, but once the trigger occurs in 2002, the investor is supposed to pay the face value.

Figure 3: Simulated development of cumulative costs and revenues of issuer of CAT bond triggered in 2002



Notes: revenues are used to compensate for catastrophic damage, represented by thin line in Figure 2 (example uses 3 sizes of CAT bond face value)

Source: own processing

2.5. Discussion and policy recommendations

A hypothetical bond with 5-year maturity which would have been issued by the Ministry of Finance of the Czech Republic was set starting in 1999. As the biggest ever recorded floods hit the Czech Republic in the summer of 2002, the hypothetical CAT bond would have covered the losses.

This model shows that while the parameters of the CAT bonds are set correctly, the government expenses may approach very low amounts to cover the impacts of the natural catastrophes. Instead of government expenses, investors' money would be used to finance the consequences of the disaster; therefore, the coupon payments are definitively worth the payment.

For demonstration purposes, the simulation was done intentionally for a period when a large-scale catastrophic event occurred, and the bond was triggered. It is obvious that there are also periods when the bond would not be triggered during its lifetime and would only mean high interest costs for the issuer. However, over a long period of time, given a reasonably determined probability of a catastrophic event, the bond should be beneficial for the public finance of the Czech Republic.

Conclusion

Catastrophic risks represent events which are supposed to negatively affect all the spheres of economic and social life. As these disasters tend to either occur repeatedly or appear quite unexpectedly, there should be a general appeal among the public for before-the-catastrophic-event functional solution under the patronage of the Government of the Czech Republic.

The Czech Republic faces two other big issues with the potential to harm the domestic economics. The first one rests in the fact that the percentage of the property insurance cover in the Czech Republic is very low. Only 55% percent of the private property is insured against the perils of natural catastrophes. Primarily, uninsured people in trouble after a natural disaster seek resolution with their own financial funds. As they are mostly insufficient, they turn to the Government or charities. Help is unguaranteed as it depends on the political cycle and the governing political orientation. Obviously, left-wing parties would be more likely to help than right-wing ones.

On the other hand, how motivating is government aid in natural disaster cases for those who pay the policy premium regularly as these people are responsible for their own property? The fact is that government aid to uninsured people who need financial help must be paid somehow. The easiest way to collect money is via taxes. Therefore, the naked truth is that responsible people pay twice: once for themselves and another time for their irresponsible fellow citizens.

Generally, many important questions arose during the writing of this paper. Firstly, why is it so difficult for the Government to adopt the idea of supporting and encouraging people's own personal responsibility? Why does the Government not stimulate people by complex tax reliefs, which would be efficient? Alternatively, why does the Government not cooperate with insurance companies, so that public education and deterrent examples could take place constantly? It could even try to discuss compulsory insurance against catastrophic risks.

Maybe the best way to enlighten the public lies in self-example. As mentioned above, the state-owned property is supposed to be uninsured, because the Government acts as an insurer to itself. It is comprehensible to a certain extent, because the insurance rates can be high, especially for risks such as theft, business interruption or liability. Fortunately, these risks are frequent, but evince low severity. On the contrary, natural catastrophes possess the potential to cause considerable increases in government expenditures; therefore, this issue deserves deep contemplation, because all citizens are involved as taxpayers.

A test for the modern approach for the Czech Republic was made, calculating a hypothetical five-year CAT bond starting from 1999 issued by the Czech Republic. The model convincingly showed that the CAT bond issuance is worth considering, because the investors' payments would complement the government expenses on consequences of natural disasters.

One way or another, in terms of traditional or modern methods of handling catastrophic risks in advance, the Czech Republic decidedly has to have a reliable ex-ante solution. To rely on own depletable financial sources coming from elevated taxes imposed on citizens or companies, on help from the European Union or on charity aid is short-sighted and unworthy of a developed country trying to become one of the first-league countries.

Besides the issues mentioned above, there is another reproach, aimed directly at the Ministry of Finance of the Czech Republic. Its statistics about natural disaster expenditures are totally insufficient and contain only data on the foods and the 2021 tornado. They need to be more detailed and easily accessible to each person interested in the question. The same applies to facts and figures on state property insurance, which must not be hidden anymore.

For further research, we see it as relevant and desirable to continue with the question whether CAT bond issuance in the Czech Republic or even in Central Europe is feasible and if so, in which form. As of today, CAT bonds in Central Europe are mainly in a hypothetical stage except Germany, where a CAT bond has been issued to cover the storm risk (Jackman, 2021). On top of that, from the point of view of the potential natural catastrophes, the areas of the neighbouring countries, i.e., Austria, Slovakia, Poland and Germany (especially Bavaria) are similar to the Czech Republic. On that account, the statistics used in these countries can lead to improvements in the accuracy of predicting catastrophic risk occurrence in the Czech Republic.

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