The Geneva Papers on Risk and Insurance - Issues and Practice (2023) 48:687–713
https://doi.org/10.1057/s41288-023-00299-5

# Providing pandemic business interruption coverage with double trigger cat bonds

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Received: 30 August 2022 / Accepted: 17 April 2023 / Published online: 30 May 2023


## Abstract

The aim of this paper is to show how qualified investors in cat bonds can offer adequate pandemic business interruption protection in a comprehensive public–private coverage scheme. First, we propose a numerical model to expose how cat bonds can contribute to complement standard re/insurance by improving coverage of cedents even though risks are positively correlated during a pandemic. Second, we introduce double trigger pandemic business interruption cat bonds, which we name PBI bonds, and discuss their precise characteristics to provide efficient coverage. A first trigger should be pulled when the World Health Organization declares a Public Health Emergency of International Concern (PHEIC). The second trigger determines the payout of the bond based on the modelised business interruption losses of an industry in a country. We discuss moral hazard, basis risk, correlation and liquidity issues which are critical in the context of a pandemic. Third, we simulate the life of theoretical PBI bonds in the restaurant industry in France by using data gathered during the COVID-19 pandemic.

**Keywords** Pandemic cat bond · Business interruption losses · Securitisation · Re/insurance

## Introduction

On Friday 29th January 2021, INSEE (the country's national statistics bureau) announced that French GDP shrank by 8.30% in 2020. France's economic downturn followed the closing of non-essential activities during the COVID-19 pandemic.

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Although predictions in the midst of the pandemic were much gloomier, this is the sharpest drop since records began. Private businesses around the world were undergoing systemic and unprecedented disruption. Things got even worse since, in most cases, their insurance policy did not comprise pandemic business interruption coverage.

The restaurant and hospitality industries have been particularly badly hit by decisions of administrative shutdowns due to the pandemic. In France, business interruption losses range from 30% of revenues as estimated by French insurance companies to more than 70% as claimed by the main national organisation of hospitality employers (Poullennec 2021). Under the pressure of political and public opinion, insurance companies have compensated some policyholders as much as 15% of revenues even if contracts explicitly exclude pandemic risk coverage. Furthermore, the OECD estimates that one month of strict confinement leads to USD 1.7 trillion in lost revenue (OECD 2021). Hence losses borne by many industries are huge and threaten the survival of companies of the most exposed sectors.

This paper aims at addressing challenges raised by compensation in the event of a pandemic. In particular, we show how suitable risk securitization can adequately compensate business interruption losses due to a pandemic in a global public/private coverage scheme.

Pandemic risk has a very strong systemic component. Thus, risk mutualisation among policyholders within a given sector or among sectors similarly hit by administrative closure is unworkable. Private (re)insurance capacity limits are rapidly reached and public funding is often presented as the solution to respond to the pandemic business interruption protection gap. Indeed, Germany (German Insurance Association 2020) is considering building a pandemic Re (public) fund while in the United States, legislators propose to establish a federal Pandemic Risk Indemnity Fund (Pandemic Risk Indemnity Act of 2020 or PRIA), quite similar to the Terrorism Risk Insurance Act (TRIA) that was adopted for terrorism risk following the 2001 terrorist attacks (Sclafane 2020). In the meantime, at the end of 2020, the French government introduced the idea of public/private coverage of exceptional catastrophes—including pandemic risk and other systemic risks (Lustman 2020). This scheme was rejected. It was not appropriate to ask additional insurance premia of firms that were already financially destabilised. Furthermore, the so called CATEX system was dedicated to cover future pandemic risks, thus excluding COVID-19.

The common thread between all these national initiatives is the prevalence of a combination of private standard (re)insurance capacity with national public funds. Such a mixed scheme is already in place to cover natural catastrophes in different countries (France, Spain, United States), and has proven its effectiveness. In such schemes, both private (reinsurers) and public bodies (for instance the State of California for earthquake risk coverage) transfer part of the nat cat risk to financial markets. They issue Insurance Linked Securities (ILS), the most popular being cat bonds, in order to increase their capacity to compensate nat cat losses.

Thus, at first sight, the characteristics of existing private/public schemes should be merely extended to economic losses due to a pandemic. Even though some challenges compare with those of structuring traditional catastrophe-linked securities,

significant differences make them much more complex. Indeed pandemic business interruption risk management raises tricky challenges regarding compensation estimation and capacity. Additional capacity shall be provided and an adapted method for evaluating what shall be paid must be implemented. In this paper, we handle both points by implementing a fine-tuned securitization.

Since their inception in the early nineties, ILS have been increasingly issued by reinsurers and/or states to cover major risks such as natural hazards or high mortality risks. Those financial instruments are indeed part of an integrated major risk management process and could also support the coverage of pandemic risk. However, pandemic risk has three distinguishing features that hinder a straightforward transposition of natural catastrophe bonds (nat cat bonds) as they are used today. First, a pandemic hits the world simultaneously. Second, and as a consequence of the first point, stock markets are highly correlated with pandemic risk: recall the huge stock market meltdown in March 2020, following the announcements of lockdowns in different countries. In such a context, purchasing some 'pandemic' cat bonds could undermine investors' strategy of portfolio diversification. And third, the economic consequences of a pandemic are affected by governmental lockdown decisions and by individual hygiene behaviours in response to sanitary measures, and not only by the pandemic itself. Thus the level of business interruption losses depends considerably on human decisions.

In this paper, we show that it is possible to build some specific pandemic business interruption (PBI hereafter) cat bonds, with triggers that deal with moral hazard, basis risk, correlation with other risks and cat bond market liquidity. In that manner, we answer the challenges raised by SCOR's new CEO[1]: "Intuitively and intellectually, yes I would imagine there is a great future for ILS, yes there is a great future for ILS beyond property cat, and yes, there should be ILS for pandemic bonds. [...] Now, how do you price it, how do you structure it, do you make it parametric versus indemnity? The devil is in the details. So what's the future of pandemic bonds?".

A key insight of our proposed scheme rests on coverage of complementary risks by private and public sectors. Whereas pandemic operational losses are compensated by (re)insurers and cat bond holders, wage compensation and an access to zero-free loans are guaranteed by the state.

The precise aim of this paper is to show whether the insurance and reinsurance sectors supplemented by qualified investors in cat bonds can offer business interruption protection due to a pandemic. Hence the new coverage scheme that we present increases protection capacity within and beyond the insurance and reinsurance sectors by combining risk mutualization and securitization on two distinct layers of economic losses.

Our research falls within the scope of the research conducted by Gründl et al. (2021), Richter and Wilson (2020), and Hartwig et al. (2020). Gründl et al. (2021)

[1] The French company SCOR is the world's fourth largest reinsurance company. The interview was published by Artemis on September 15th, 2021: https://www.artemis.bm/news/scor-kicked-itself-for-not-renewing-mortality-bonds-ceo-rousseau/.

focus on corporate pandemic insurance contracts that shall be offered to small and medium–sized firms. They build a specific insurance catastrophe model. Thanks to American data injected in their model, they estimate the parameters of an appropriate pandemic insurance contract. Richter and Wilson (2020) address the question of pandemic risk is insurable. They also propose to build on the lessons from the COVID-19 crisis, by considering both private and public necessary future risk management actions. They evoke 'pandemic' cat bonds and the usefulness of focusing on securitization as a complementary potential coverage tool. Hartwig et al.'s (2020) work is complementary to the last one: it discusses the reasons that made private insurance of business interruption losses very limited during the COVID-19 crisis. The authors are also interested in the various possibilities of complementing private insurance and they discuss, in particular, the important role that governments play, or should play, at different stages of the epidemic.

Schwarcz (2022) suggests explicitly to employ pandemic cat bonds to "utilize deep pockets of the global capital markets". He deals with economic and legal issues to overcome when structuring and issuing those securities. While all these authors focus on the compensation duty of insurance, He et al. (2022) question the role of insurance as governance in risk management and loss reduction. In their concluding remarks they also evoke securitization as a possible tool of an efficient pandemic risk management scheme. They insist on the central role of governments in any public–private solution. Indeed, they can impose mandatory coverage to reduce adverse selection problems. They can provide mutualization through time by issuing debt and hence shift the cost to future taxpayers. Moreover, "governments could promote more robust insurance markets".

Finally, the scheme that we propose is also in line with the discussions conducted by the European Insurance and Occupational Pensions Authority (EIOPA) about options for establishing a European-wide insurance solution to tackle the issue of pandemic business interruption losses. Nevertheless, securitization and ILS products are not yet explicitly considered as part of a European solution.

We start by proposing a comprehensive numerical model that illustrates how a combination of standard (re)insurance and securitization is well-suited to pandemic risk. Our approach is based on Lakdawalla and Zanjani's (2012) model developed with independent risks. The important difference is that we introduce correlation between the risks borne by the firms of a given sector, as is typical for a pandemic risk. Correlation increases the probability of bankruptcy for all firms, as expected. But it also lessens the advantage of partial collateralisation provided by standard insurance since insurers need to immobilise more capital to ensure a given insurance level. We show that the attractiveness of PBI bonds as a complement to standard insurance is even reinforced when risks are correlated by improving individual coverage of some insured firms. In particular, when firms are heterogeneously exposed, PBI bonds contribute to redistributing coverage more harmoneously among them. Besides, we obtain our results without introducing administrative costs, thus in the worst possible situation for the issuance of cat bonds. Indeed, the existence of high administrative costs on standard insurance and reinsurance markets are often presented as an explanation of the relative attractiveness of cat bonds (Froot 2001).

In the "Introducing double trigger PBI cat bonds" section, we present a detailed description of pandemic business interruption bonds that will complement adequately standard insurance. They are devoted to provide additional coverage to private businesses which have subscribed property and casualty insurance. They fit smoothly in the official international alert system that has been implemented by the World Health Organization (WHO). Indeed, the double trigger pandemic bonds we recommend are structured on a first trigger which is pulled when the WHO declares a Public Health Emergency of International Concern (PHEIC); a PHEIC is technically the highest level of alarm. The second sectorial trigger determines the payout of the bond based on the modelized business interruption losses of an industry in a country. The PBI cat bonds that we propose to frame have triggers that differ from those embedded in the so-called pandemic bonds issued by the World Bank in 2017 to fight against Ebola. The latter were based on numbers of deaths in different countries and they were subject to some ethical debates. We evoke this case in the paper.

We then explain why it is important that governments and re/insurers intervene on different types of risks: while (re)insurers shall cover business interruption losses, with the support of the cat bond market, the government must focus on wage compensation and on loan granting. This splitting in the types of losses permits the government to intervene very early in the crisis without being impeded by moral hazard effects. Indeed, private insurers might anticipate the early intervention of the government if it were concerned by the same business interruption losses. We also discuss liquidity issues.

Lastly we run different simulations of global insurance coverage, with standard insurance, public funding and PBI cat bonds, applied to the restaurant industry in France. We build on the experience gathered during the COVID-19 pandemic and by using data provided by UNEDIC.[2] Our purpose is to evaluate how much coverage insurance companies and PBI bonds investors could provide over a policy year. Then we compare these amounts to those paid out in 2020 by insurers, regardless of contractual commitments, and by the French government.

## A two-layer coverage scheme

Some representatives of the insurance and reinsurance industry claim that their industry cannot cover business interruption losses due to a pandemic.[3] Indeed, pandemic risk has its own unique features. We detail them in the next section. In the "A numerical model" section, we propose a numerical model to show how some combination of standard (re)insurance and issuance of some catastrophic bonds can offer a partial solution to the issue of pandemic business interruption losses, even though risks are correlated with each other.

[2] UNEDIC is the French independent association led by social partners whose main mission is to provide social benefits to unemployed people.

[3] In particular, Denis Kessler, CEO of SCOR until recently, states that business interruption clauses cannot cover pandemic perils (Kessler 2021).

## The unique features of pandemic risk

The systemic nature of pandemic risk rules out the implementation of risk-sharing mechanisms through diversification. Furthermore, it does not result from an act of God. Business interruption damages depend largely on political decisions to stem the pandemic, including total or partial closing of non-essential activities. As such, the risk is merely endogenous and can not be easily modelled. The COVID-19 pandemic has hit business sectors heterogeneously. Today, only the most exposed industries would buy coverage, if available, enhancing adverse selection issues. Problems of moral hazard would also arise since a government could shift the burden of indemnification to the insurance sector by prioritising public health at the expense of the economy. Hence offering insurance based on business interruption coverage results in new challenges to overcome.

Meanwhile, the COVID-19 pandemic has forced some businesses into bankruptcy and many others are on the edge of collapsing because of liquidity issues that will become even more critical once public support stops. Getting business interruption compensation is vital for the survival of many of them. However, insureds' claims were met with stiff resistance. About 80% of cases were dismissed in the USA mainly because policies had virus exclusions and typically existing business interruption compensation requires physical damage. Thus, some American states are considering introducing bills to require any commercial property insurance policy to cover business interruption losses due to a future pandemic. Some bills could even require coverage to be applied retroactively (Simpson 2021). In France, 93% of P&C contracts excluded pandemic business interruption losses in 2020 (Lustman 2020).

Another impeding feature of pandemic business interruption risk deals with financial correlation between this risk and capital markets risk of collapse. Indeed, the administrative decisions taken in different countries in 2020 have had an immediate and severe impact on stock markets: on 9 March, they lost 23% of their value, and another collapse of more than 12% was registered on 12 March.

Despite all these a priori blocking points and to mitigate the financial burden carried by private firms and its disastrous social consequences, Spaeter (2023) proposes an integrated pandemic business interruption risk management process, in which three layers of coverage interact. While the first layer is devoted to firms' self-insurance (private saving, diversification on financial markets as also suggested by Louaas and Picard (2020), creation of specific captives), the second one concerns the private (re)insurance sector. On the third layer of coverage, the public sector intervenes as an insurer of last resort of business interruption losses. It is important, at this stage, to notice that the early intervention of governments in subsidising workers' wages[4] and the coverage of sanitary costs remains essential in the risk management process.

[4] Wage subsidies were commonly used by most governments during the COVID-19 pandemic to encourage employers not to lay off employees.

Finally, it is primarily an issue of insurance supply rather than insurance demand.[5] Indeed, since 2020, the vast majority of P&C insurance contracts and reinsurance treaties can only be triggered by physical damage, explicitly excluding administrative business closures due to a pandemic. In what follows, we focus specifically on the layer of coverage that concerns insurers and reinsurers. Financial securitization is at stake with, in particular, the issuance of some specific cat bonds. It plays a central role in the optimal pandemic business interruption risk management.

Cat bonds are regular bonds with an additional covenant which specifies that they are not redeemed if some specified catastrophe occurs. Thanks to the initial formation of a single purpose vehicle (SPR), total collateralization ensures that the capital is secured for indemnification of victims. Cat bonds appeared in the 1990s to provide additional capital and supplement insurance and reinsurance companies to indemnify victims of catastrophic risks like hurricanes or earthquakes. Capital outstanding has developed steadily since then to reach more than USD 46 billion by the end of 2020.[6]

Now, let us show how cat bonds can complement standard insurance even though business interruption risks borne by firms of a given sector or in the same country are correlated with each other.

## A numerical model

We propose a numerical model to show how cat bonds may supplement the standard insurance market when PBI risks are correlated. To do so, we use the formal framework proposed by Lakdawalla and Zanjani (2012) who consider the relationship between two insurers and one reinsurer and who assume that the insurers' portfolios are independent from one another. To be close to our problem, we focus on two non-financial firms and we introduce correlation. Thus we are able to describe the situation of a pandemic during which the firms' risks of business interruption losses are positively correlated with one another. Indeed they depend on the same administrative decision of lockdown within the same country.

We show how cat bonds improve the coverage of firms when their risks are positively correlated. To be able to compare our results with those obtained by Lakdawalla and Zanjani (2012), we consider two firms that bear two different levels of risk, one presenting an unconditional probability of loss lower than the other one. Within this framework, we are also able to show how issuing cat bonds can reduce coverage disparity between the insured firms. We still explain why assuming that the insurer shall be simultaneously the provider of insurance indemnities and the investor in complementary bonds on

[5] To our knowledge, only one specific insurance policy has been offered so far. Pathogen RX was developed by the insurance broker Marsh along with Munich Re and tech firm Metabiota in 2018. The product aimed at providing business interruption coverage in case of a pandemic for the sports and event industry. One of the triggers of Pathogen RX is parametric and based on a Pathogen Index Sentiment developed by Metabiota. However, nobody bought this product, most probably because of its price and the unlikeliness of a future pandemic.

[6] Source: https://www.artemis.bm/dashboard/catastrophe-bonds-ils-issued-and-outstanding-by-year/. Artemis is a news, analysis and data media service devoted to the alternative risk transfer, catastrophe bond & insurance linked security. non-traditional reinsurance, insurance linked investments and associated risk transfer markets.

behalf of its clients is not ideal. Both activities compete when supported by a given collateralised capital owned by the insurer, and the cost of this competition increases with correlation. Thus we suggest that the insurer be an intermediary for insured firms on the cat bond markets, and that the pandemic business interruption cat bonds be underwritten by outside investors. When these PBI bonds are well designed, as proposed in the "Introducing double trigger PBI cat bonds" section, such a combination highly contributes to the building of an adequate PBI risk management strategy.

Consider two firms, Firm 1 and Firm 2. The level of their respective gross margin depends on the same macroeconomic situation.[7] This positive correlation is described by a common parameter $\epsilon$ in our model, with $\epsilon > 0$. We assume that each firm can lose 100.

Let us define the conditional probabilities. In Table 1 hereafter, the upper script 0 (respectively $L$) designates the no loss state (respectively the loss state). Then $x_i(x_j^0)$ (respectively $x_i(x_j^L)$), $i = 1, 2$, $j = 1, 2$, $i \neq j$, describes the risk of loss borne by Firm $i$ contingent upon Firm $j$ being in the no loss state (respectively in the loss state).

Firm $i$ has more chance to bear a loss whenever Firm $j$ also bears one, and vice versa. With such a setting, notice that $\epsilon$ must lie between zero and 0.01 in order to guarantee that probabilities lie between 0 and 1. From the properties assigned to unconditional and to conditional probabilities, we obtain the unconditional probabilities displayed in Table 2 hereafter (detailed calculation is available on request).

Hence, Firm 1 bears a higher risk while Firm 2 bears a lower one. Nevertheless, because the letter $L$ is already used for the loss state, we keep continuing to call the firms Firm 1 and Firm 2 (and not Firm H and Firm L for High and Low). If we set $\epsilon$ at 0 we obtain the unconditionnal probabilities considered by Lakdawalla and Zanjani (2012). This permits us to compare our results with theirs. Independency between risks is known as being the ideal situation to benefit from risk mutualization. Thus, the issuance of cat bonds may add limited benefits to a compensation scheme based on standard (re)insurance. In particular, partial collateralization is possible with risk mutualization and standard insurance, while all the funds dedicated to potential future compensation must be locked in a special vehicle on the day of signature of a cat bond contract. Below, we show how this advantage diminishes as risk correlation increases.

**Table 1** Conditional probabilities of cedents' losses

| | $x_2^0 = 0$ | $x_2^L = 100$ |
|---|---|---|
| $x_1^0 = 0$ | $0,99 + \epsilon$ / $0,9 + \epsilon$ | $0,01 - \epsilon$ / $0,9 - \epsilon$ |
| $x_1^L = 100$ | $0,99 - \epsilon$ / $0,1 - \epsilon$ | $0,01 + \epsilon$ / $0,1 + \epsilon$ |

[7] Both firms can belong either to different economic sectors or to the same one for our purpose.

**Table 2** Unconditional probabilities of cedents' losses

| | No loss $x_i^0 = 0$ | Loss $x_i^L = 100$ |
|---|---|---|
| Firm 1: $\tilde{x}_1$ | $\frac{0,9+\epsilon}{1+2\epsilon}$ | $\frac{0,1+\epsilon}{1+2\epsilon}$ |
| Firm 2: $\tilde{x}_2$ | $\frac{0,99+\epsilon}{1+2\epsilon}$ | $\frac{0,01+\epsilon}{1+2\epsilon}$ |

Consider an insurer who issued equity shares for $K = 150$ and offers full insurance to both firms. They will be able to honor each contract only when both firms are not hurt simultaneously, that means when its aggregate loss equals either 0 (no loss at all) or 100 (only one firm bears a loss). Whenever the aggregate loss of the insurer equals 200, it goes bankrupt and each firm receives a percentage of its claim calculated by applying the well-known pro rata rule.

Let us first discuss this assumption. The pro rata rule is well adapted to binary risks borne by both firms when the insurance goes bankrupt. Indeed both become creditors, with equal priority, of the insurance company if they have a claim against it. Each firm receives a percentage of the insurer's equity that is proportional to the level of their respective insured risk.[8] In such a context, the insurer relies on partial collateralization: they own 150, but engage on an amount of insured losses equal to 200.[9]

The aggregate risk of the insurer is denoted $X$, with $p$ indicating the probability. We have:

$$\begin{aligned}
p(X=0) =& p(x_1^0 \cap x_2^0) = p(x_1^0 \mid x_2^0).p(x_2^0) = (0,9+\epsilon).\frac{(0,99+\epsilon)}{(1+2\epsilon)} \\
=& \frac{0,891+1,89\epsilon+\epsilon^2}{1+2\epsilon}, \\
p(X=200) =& p(x_1^L \cap x_2^L) = p(x_1^L \mid x_2^L).p(x_2^L) = (0,1+\epsilon).\frac{(0,01+\epsilon)}{(1+2\epsilon)} \\
=& \frac{0,001+0,11\epsilon+\epsilon^2}{1+2\epsilon}, \\
p(X=100) =& p(x_1^L \cap x_2^0) + p(x_1^0 \cap x_2^L) = p(x_1^L \mid x_2^0).p(x_2^0) + p(x_1^0 \mid x_2^L).p(x_2^L) \\
=& (0,1-\epsilon).\frac{(0,99+\epsilon)}{(1+2\epsilon)} + (0,9-\epsilon).\frac{(0,01+\epsilon)}{(1+2\epsilon)} = \frac{0,108-2\epsilon^2}{1+2\epsilon}.
\end{aligned}$$

The insurer's probability of insolvency is $p(X = 200)$. Not surprisingly, we find that the higher the correlation between individual risks, the higher this insolvency probability.

[8] Mahul and Wright (2004) consider two other rules based on a percentage of the level of insurance that each insured has purchased, not on the available equity as in our model. Another difference deals with the risk of insolvency, assumed to be exogenous and thus not due to insufficient equity of the insurer. Besides, their model considers independent and fully diversifiable individual risks. The context that we are considering is closer to the one studied by Mahul (2003), that is an insurer's insolvency state that is explained by a systemic risk.

[9] This is accepted by international regulations. In particular, the European regulation Solvency II stipulates that the financial reserves of insurers must cover, at least, all the potential losses at 99.5%: the accepted insolvency probability equals 0.5%.

Recall that Firm 2 has the lowest probability of loss. We show below that (i) Firm 2 is also less properly insured whatever the intensity of correlation, and hence is more exposed to the insurer's insolvency risk than Firm 1, and (ii) introducing cat bonds reduces the coverage disparity.[10]

Expected individual losses of Firm 1 are

$$E(\tilde{x}_1) = p(x_1^L).100 = \frac{10 + 100\epsilon}{1 + 2\epsilon} \text{ dollars} \tag{1}$$

and respectively of Firm 2

$$E(\tilde{x}_2) = p(x_2^L).100 = \frac{1 + 100\epsilon}{1 + 2\epsilon} \text{ dollars.} \tag{2}$$

Let us denote as $I(.)$ the individual indemnity function. With a pro rata rule in case of insolvency, expected indemnities for each firm write as follows:

$$\begin{aligned} E(I(\tilde{x}_1)) &= p(x_1^L \cap x_2^0).100 + p(x_1^L \cap x_2^L).\frac{150}{2} \\ &= (0,1-\epsilon).\frac{(0,99+\epsilon)}{(1+2\epsilon)}.100 + \frac{(0,001+0,11\epsilon+\epsilon^2)}{(1+2\epsilon)}.75 \\ &= \frac{9,975 - 80,75\epsilon - 25\epsilon^2}{1+2\epsilon} \end{aligned} \tag{3}$$

And:

$$\begin{aligned} E(I(\tilde{x}_2)) &= p(x_2^L \cap x_1^0).100 + p(x_2^L \cap x_1^L).\frac{150}{2} \\ &= (0,01-\epsilon).\frac{(0,9+\epsilon)}{(1+2\epsilon)}.100 + \frac{(0,001+0,11\epsilon+\epsilon^2)}{(1+2\epsilon)}.75 \\ &= \frac{0,975 - 80,75\epsilon - 25\epsilon^2}{1+2\epsilon} \end{aligned} \tag{4}$$

By dividing (3) by (1), respectively (4) by (2), we obtain the coverage per unit of risk for Firm 1, respectively for Firm 2:

$$E(I(\tilde{x}_1))/E(\tilde{x}_1) = \frac{9,975 - 80,75\epsilon - 25\epsilon^2}{10 + 100\epsilon} \text{ cents per unit of risk} \tag{5}$$

$$E(I(\tilde{x}_2))/E(\tilde{x}_2) = \frac{0,975 - 80,75\epsilon - 25\epsilon^2}{1 + 100\epsilon} \text{ cents per unit of risk} \tag{6}$$

[10] Coverage disparity refers to the difference between the level of insurance per unit of risk without considering preferences. To be complete, one should also consider the risk attitude of each firm. Indeed, it could be optimal for Firm 2 to obtain less coverage per unit of risk than Firm 1 if the former is less risk averse than the latter (Eeckhoudt et al. 2005). For the sake of simplicity, we choose to work as if firms were risk neutral or would have the same risk preferences in our illustrative model.

When risks are positively correlated ($\epsilon > 0$) and only standard insurance is available, we obtain several results. First, by substracting (6) from (5), it can be shown that the coverage per dollar is lower for Firm 2, who bears the smallest risk, than for Firm 1 whatever the degree of correlation, that means for any $\epsilon \geq 0$. Second, as correlation increases, a given level of collateralization (in this model $K = 150$ dollars) offers a lower coverage per dollar for each insured firm compared to a situation with independent risks. Formally, the derivatives of (5) and (6) with respect to $\epsilon$ are strictly negative. Put differently, more collateralized capital is needed to maintain the same level of insurance per unit of risk for each firm compared to a situation without any correlated risk.

Lastly, we obtain that the higher the correlation, the higher the gap between the unit of coverage offered to Firm 1 and to Firm 2. This means that the situation of Firm 2, which is the less covered per unit, is getting worse even more rapidly than the situation of Firm 1. Formally, by substracting (6) from (5) we obtain

$$E(I(\tilde{x}_1))/E(\tilde{x}_1) - E(I(\tilde{x}_2))/E(\tilde{x}_2) = \frac{0,225 + 1626,75\epsilon + 225\epsilon^2}{10 + 1100\epsilon + 10000\epsilon^2}, \tag{7}$$

which is strictly positive and increasing in $\epsilon$. Hence, in the context of correlated risks, one may wonder whether the introduction of cat bonds can improve the distributional property of insurance.

To answer this question, let us assume now that the insurer invests in a PBI bond $B = \text{USD}\,50$ on behalf of Firm 2. We keep assuming zero frictional costs, thus undertaking our analysis in the worst case scenario for the attractiveness of cat bonds compared to standard insurance.

The total available capital is still $K = 150$, but only 100 remains available for standard insurance and 50 is fully collateralized by PBI cat bonds. Assume that Firm 1 does not change anything to its insurance demand: it wishes to be insured (by the standard way) for the whole loss, which is 100 worth, whenever a loss occurs. Firm 2 asks for a standard insurance coverage of 50, and complements it thanks to the PBI bond of 50 offered by the insurer. Hence Firm 2 is also asking for full coverage of its loss. The individual expected losses are still given by (1) and by (2). But now, the respective expected indemnities $E(I(\tilde{x}_1))$ for Firm 1 and $E(I^B(\tilde{x}_2))$ for Firm 2 write, after simplification:

$$\begin{aligned} E(I(\tilde{x}_1)) &= p(x_1^L \cap x_2^0).100 + p(x_1^L \cap x_2^L).\frac{2}{3}.100 \\ &= (0,1-\epsilon).\frac{(0,99+\epsilon)}{(1+2\epsilon)}.100 + \frac{(0,001+0,11\epsilon+\epsilon^2)}{(1+2\epsilon)}.\frac{200}{3} \\ &= \frac{29,9 - 245\epsilon - 100\epsilon^2}{3.(1+2\epsilon)} \end{aligned} \tag{8}$$

And

$$\begin{aligned} E(I^B(\tilde{x}_2)) &= p(x_2^L \cap x_1^0).(50+50) + p(x_2^L \cap x_1^L).(\frac{1}{3}.100+50) \\ &= (0,01-\epsilon).\frac{(0,9+\epsilon)}{(1+2\epsilon)}.100 + \frac{(0,001+0,11\epsilon+\epsilon^2)}{(1+2\epsilon)}.\frac{250}{3} \\ &= \frac{2,95-239,5\epsilon-50\epsilon^2}{3.(1+2\epsilon)} \end{aligned} \tag{9}$$

Let us compare Firm's 2 coverage without and with bonds. By substracting (4) from (9), we obtain, after simplification:

$$E(I(\tilde{x}_2^B)) - E(I(\tilde{x}_2)) = \frac{0,025+2,75\epsilon+25\epsilon^2}{3.(1+2\epsilon)} > 0 \tag{10}$$

Bond issuance on behalf of Firm 2 improves its financial condition whatever the degree of risk correlation. While this improvement for Firm 2 is done at the expense of Firm 1,[11] the gap between the coverage per unit for Firm 1 and for Firm 2 is lessened. Formally, we have after simplification:

$$E(I(\tilde{x}_1))/E(\tilde{x}_1) - E(I^B(\tilde{x}_2))/E(\tilde{x}_2) = \frac{0,4+4845\epsilon-150\epsilon^2-5000\epsilon^3}{3.(10+1100\epsilon+10000\epsilon^2)} \tag{11}$$

It can be shown that the gap given by (11) is lower than the one given by (7). Thus redistribution of compensation between both firms holds when cat bonds are issued.

Finally, our conclusions can be summarised as follows. In our numerical model, Firm 2, who bears a lower risk than Firm 1, has access to a lower level of standard insurance per unit of risk and this coverage disparity is reinforced as risk correlation increases. Introducing cat bonds in the coverage scheme reduces this gap by permitting a redistribution of assets from Firm 1 to Firm 2. Nevertheless, when the standard insurer is also the bondholder, then less capital is still available for standard insurance. Moreover, if correlation is high, then both firms may observe a decrease of their expected indemnities: standard insurance relies more and more on collateralization to maintain a given level of expected compensation.

Finally, the insurer should not simultaneously play the role of the issuer of bonds and of the investor (by collateralising the bond on their own equity). If other investors could invest in cat bonds, then the insurance company would only act as an intermediary for firms on this market. Thus, it would not have to choose between tying up capital either for insurance or for bond investment since bond collateralization would be carried out by outside investors.

The question of administrative costs shall also be discussed. We omitted them, even though standard reinsurance is usually impaired by much higher transaction costs than cat bonds. This gives a comparative advantage to the latter, all other things being equal. Hence, by assuming that administrative costs are equal to zero on both markets (insurance and ILS), we have shown that, even without any comparative

[11] For Firm 1 only $\frac{200}{3}$ is still available in case of the insurer's insolvency, instead of $\frac{150}{2}$ previously.

advantage due to lower administrative costs, cat bonds are useful for complementing standard insurance.

In the following section, we discuss the characteristics of an ideal PBI bond.

## Introducing double trigger PBI cat bonds

Most cat bonds are "act of God" assets in that they cover damage to property caused by natural forces including hail, rain, tornadoes, floods and hurricanes. However, Artemis also reports the issuance of 27 pandemic cat bonds since 2003 to provide payments in extreme mortality risk scenarios. Some were controversial because of high costs, lack of efficiency and a long and complex list of triggers which made funds arduously available even in the case of a pandemic (Alloway and Vossos 2020).

Hence, we need to carefully take into account the features of pandemic business interruption cat bonds to overcome criticism related to previously issued pandemic cat bonds and to gain the usual benefits such as increased capacity by tapping in to financial markets, reduced default risk and alleviation of moral hazard issues.

The cat bonds we propose would exclusively cover business interruption risk following a pandemic. This means in turn that they are dedicated to private businesses which have subscribed property and casualty insurance.

We explicitly exclude public–private partnerships such as the World Bank pandemic catastrophe bonds issued in 2017 and set to mature in 2020. At issuance, they were viewed as a new way to raise money for public organisations. These bonds would default and the principal would accrue to the World Bank to be distributed to poor countries if some sanitary and death triggers were reached. Thus, it introduced a way to hedge pandemic risk in low income countries through capital markets. Among the many critics addressed to this kind of hedging, the mixture of public and private financing stood out. More specifically, private investors would benefit from the denial or lowering of the disease spread rate or the number of deaths associated with the illness.[12]

To be fair and complete, the cat bonds issued by the World Bank in 2017 together with pandemic risk-linked swaps were ultimately triggered by end of March 2020. They paid out USD 195.84 million. This capital was made available to fund the World Bank's Pandemic Emergency Fund (PEF) and help poorer countries to respond to the COVID-19 pandemic.[13]

[12] The high cost of these bonds for the issuer—the World Bank—was also blamed. The bonds were administered in two tranches A and B. Tranche B bondholders received a yearly coupon rate of 11.5%. The question of elevated costs could be the subject of a lengthy debate since the introduction of a new financial asset needs to attract pioneering investors. When cat bonds were introduced in the 1990s, coupon rates were typically eight times higher than estimated expected losses. This multiplying factor decreased steadily with the market maturity to get close to two, a typical factor required by reinsurance companies for higher layers of risk.

[13] As reported by Artemis on 17 April, 2020 https://www.artemis.bm/news/world-bank-pandemic-bonds-swaps-triggered-will-pay-out-195-84m/. For more details about these pandemic cat bonds, see also World Bank (2020) and Hartwig et al. (2020).

In our mind, pandemic business interruption cat bonds should also have a regional (national) geographic scope. Although the COVID-19 pandemic impacted all countries worldwide, the economic consequences were quite heterogeneous. The world economy contracted by 4.3% in 2020 including a 7.4% average Eurozone decline and a 2% growth in China.

Furthermore, the COVID-19 pandemic revealed huge heterogeneity among sectors. While most of them were negatively and harshly impacted, some of them even expanded, like tech companies, media streaming companies and pharmaceutical companies racing to develop new vaccines. The need for pandemic risk coverage is accordingly contrasted. Hence, if basis risk is a main concern, the cat bond trigger should be built on sectors' aggregate production changes and not GDP growth or decline. In the (re)insurance realm, basis risk refers to the risk of having a difference between the performance of the hedging instruments (cat bonds in our case) and the losses sustained from the hedged position.

In the following section, we consider precisely two main concerns of the issuance of cat bonds, namely moral hazard and basis risk. In the "What relevant triggers?" section, we focus on the trigger that shall compose an efficient PBI cat bond. Finally, the attractiveness of PBI cat bonds for investors, in view of the issue of correlation between pandemic risks and financial risks, is considered in the "Investors appeal" section.

## Moral hazard issues and basis risk

In the PBI risk coverage scheme that we are suggesting, moral hazard issues might appear bilaterally between the three types of concerned stakeholders: investors in cat bonds, (re)insurance companies (the issuers) and the government. Hereafter, we analyse the three relationships and potential conflicting interests.

### Moral hazard

First, as the economic consequences of the pandemic depend largely on governments' decisions on lockdowns, insurance and reinsurance companies' profits are directly impacted if they should offer protection against business interruption loss due to a pandemic. This situation might at first glance introduce moral hazard opportunities. Indeed, the existence of an—hypothetical for the moment—well capitalised PBI risk coverage scheme might induce less public funding support a priori. Actually, this agency issue is reduced to a minimum when both parties cover complementary risks, as the case for the COVID crisis: wages are subsidised by governments whereas business interruption insurance policies typically do not cover them. Furthermore, any decision of a government to reduce non-essential activities would first hit public debt through immediate wages payments before indemnification of business interruption losses paid out by insurance companies. This complementarity is an integral part of the coverage scheme that we propose. We will expand upon it in the "What relevant triggers?" section.

Second, to reduce even further agency costs between governments and cat bond investors, it is essential that both intervene on different layers of losses. Governments act in our scheme as last resort to indemnify part of residual claims. But they also take in charge salaries before cat bonds pay the first dollar of compensation. Hence, cat bond market funds are mobilised for intermediary layers of PBI losses. This is turn implies that the problem of crowding out of private insurance, because of simultaneous governmental disaster relief programmes, is mitigated. This so-called "charity hazard" has been shown to be a concrete issue in other sectors (Raschky et al. 2013).

He et al. (2022) also propose a multi-layered approach in which governments play a key role. In their scheme, they are insurers of last resort. Those authors also suggest that governments should impose mandatory coverage of pandemic risk to private insurers and support them as private risk regulators. Besides the objective of added capacity, it would encourage cedents to follow risk-mitigation activities.

Finally, mitigating moral hazard issues between cedents and investors is a main concern of all investors when they choose between different cat bond features and more specifically between different triggers as explained below. In the double trigger scheme we propose in the "What relevant triggers?" section there is no drawback inherent of an indemnity trigger or a typical reinsurance contract. Even though the insurance company would indemnify too generously and overpay for commercial reasons or under the of public opinion pressure during a pandemic, the value of the second trigger we propose is insensitive to those overestimated cash outflows.

#### Basis risk

The choice of trigger often involves a trade-off between moral hazard risk and basis risk.[14] Our recommended scheme pays close attention to reduce moral hazard costs as suggested above and shown below. It largely conditions the attractiveness to investors for innovative financial assets. However, it should not be done at the expense of basis risk which is a main concern for ceding insurance companies.

(Re)Insurance companies will pass a portion of the risk associated with the business interruption insurance policy to investors of cat bonds. Only this portion is exposed to basis risk which represents the risk of inadequate funds available in case of a pandemic to indemnify client companies as contractually agreed.

If the trigger is finely tuned, basis risk can be reduced to a minimum. Indeed, different parameters can be taken into account in the design of cat bonds. Four types of triggers are considered usually by issuers and investors. The most common is merely the level of losses suffered by the sole issuer, as for standard insurance contracts: indemnities are completely and exclusively dependent on the level of losses suffered by the claimant. In such a scheme, there is no basis risk since the coverage is perfectly correlated with the individual losses. However, this absence of basis risk is obtained at the expense of moral hazard.

[14] Read Cummins and Weiss (2009) for an extensive discussion on cat bond design and the choice of an appropriate trigger.

A second well-known type of trigger is based on some physical parameter. It is used in the securitization of natural catastrophes, for which a given level on the Richter scale, strength of wind, or the intensity of heavy rains can trigger the non-reimbursement of the collateralized capital. In the case of pandemic risks, a parametric trigger could be a number of deaths, as it was considered in the Ebola cat bonds we evoke earlier in the paper, or a level of incidence rate. However, in both cases basis risk holds without moral hazard being controlled. Indeed, the evolution of the level of incidence or of the number of deaths depend strongly on the capacity (and, sometimes, the willingness) of a government to invest consequently in the fight against the pandemic, and also on the population's behaviour.

Third, it is also possible to condition payment on sectorial estimated losses. By doing so, we control for moral hazard since the firm's losses are only imperfectly correlated with those of the sector it belongs to. In the meantime, basis risk is more or less important depending on the level of heterogeneity between the firms within a given sector. Actually, in the "What relevant triggers?" section we propose to build the second trigger on a fourth possibility, namely on some modelled losses: those data are forecasts of business interruption losses that are computed *ex ante* with respect to different lengths of lockdowns that could be decided by the government.

## What relevant triggers?

In what follows, the pandemic business interruption cat bond is structured to pay off on hybrid triggers which blend two triggers in a single bond. The first trigger tests whether there is a pandemic situation. Once this trigger is pulled, the payoff of the second trigger based on industry business interruption losses can be modelled.

### A WHO-based trigger

The purpose of the first trigger is to determine whether the world economy suffers from a pandemic. Indeed, business interruption losses can be attributed to various events. Hence, the suggested cat bond should pay off only on the occurrence of a pandemic. To disentangle the sources, various triggers based on sanitary indicators have been included in previous pandemic cat bonds such as casualty rate. Beyond ethical issues such indicators can raise, they might not be adapted to the financial needs of shaky companies.

We suggest to base the first trigger on the declaration of a PHEIC by the WHO. A PHEIC is defined as "an extraordinary event which is determined to constitute a public health risk to other States through the international spread of disease and to potentially require a coordinated international response". The Director-General of the WHO decides whether to declare a PHEIC based on information received from State Parties and on advice from a committee of experts—the International Health Regulations (IHR) Emergency Committee.[15]

[15] The IHR is the governing framework for health security (WHO 2019).

The IHR came into legal force in June 2007 for 196 states. Since then, there have been six PHEIC declarations, all of them have been for viral emerging infectious diseases, including the ongoing global COVID-19 pandemic.[16] Indeed, the Emergency Committee declared a PHEIC for COVID-19 on 30 January 2020. PHEICs have a major role in the IHR framework: the strength of their declarations is "the ability to rapidly mobilize international coordination, streamline funding and accelerate the advancement of the development of vaccines, therapeutics and diagnostics under emergency use authorization" (Wilder-Smith and Osman 2020).

Nevertheless it should be pointed out that the current IHR framework has been subject to some criticisms. Among them, the binary nature of a declaration of a PHEIC stands out. Indeed, it is ill-suited for diseases which would require a more tiered or graded approach (Durrheim et al. 2020). Hence, a multi-level PHEIC process has been suggested (Wilder-Smith and Osman 2020). However, those limitations are more than counterbalanced by the many advantages of the current health emergency framework, in particular to respond to the needs of business interruption coverage. Indeed, IHR have a nearly universal recognition with 196 State Parties and are legally binding. The declaration of a PHEIC follows a strict process including a notification stage which can only be triggered if any two of four specific questions are affirmed.[17] The declaration of a PHEIC is formulated only when a situation arises that is 'serious, sudden, unusual or unexpected'.[18]

All in all, IHR has gained in the last decade widespread recognition as an efficient framework for global health security without jeopardising unjustifiably economic interests. PHEIC declarations have been triggered cautiously when one considers the many diseases that were eligible since its inception in 2007.

### A modelled business interruption loss trigger

Once the first trigger is pulled, the second trigger determines the payout of the bond based on the estimated business interruption losses of an industry in a country. Because of the heterogeneous economic impact of the pandemic, cat bonds need to be both country and sector specific.

**Risk to cover and first layer component** As cat bonds provide a second-layer protection of business interruption losses, we need first to define precisely the risk covered and the portion borne by the first-layer protection providers, i.e. insurance companies.

Business interruption insurance typically helps to reimburse for lost income and for extra expenses (for instance to relocate a business after fire). Roughly speaking, it covers expected the gross margin which is the difference between revenues and variable costs (including costs of goods sold). Thus, it takes over fixed costs

[16] Read Wilder-Smith and Osman (2020) for an historical account of PHEIC declarations and their effectiveness.

[17] Interestingly, one question has an economic component by asking whether there is a significant risk for international travel or trade restrictions.

[18] Note the strong analogy with the requirements of an event to be covered in the insurance realm.

and expected profit. Business interruption insurance policies are not standardised as there is no agreed upon definition of gross margin and also it might become tricky to disentangle fixed and variable costs. However, cost structures are rather homogeneous within the same industry.

We suggest then that insurance companies could offer business interruption protection due to a pandemic. One key difference with current policies covering perils like fire, theft or wind is that insurers would only cover a pre-specified portion of total losses because of the systemic nature of pandemic risk. In this scheme, client companies file a claim for compensation with their insurance company in the usual way. Indemnifications would be made available by insurance companies through two channels:

- Directly by the reserves built up from the collection of insurance premia.
- Thanks to funds held in the SPV of the cat bond and released for higher levels of compensation.

The first layer is directly linked to insured losses due to the pandemic and hence is essentially free of basis risk. The second layer of coverage is provided by funds of the cat bonds and relies on a modelled loss trigger.

**Choice of a modelled loss trigger for the second layer** As presented in the "Moral hazard issues and basis risk" section, four types of triggers are commonly used in cat bond contracts. The current popularity of indemnity triggers, where losses are based on the size of the sponsoring insurer's actual losses, shows that mastering basis risk is a key priority of ceding companies. However, business interruption protection in a specific sector for a single insurer has too narrow characteristics to induce sufficient demand for this kind of trigger.

For parametric triggers, payouts are based on physical characteristics of the event and constitute a likely candidate. According to Schwarcz (2022), "parametric insurance is especially appropriate for pandemics because payouts need to happen quickly". This type of trigger was actually used by the World Bank in 2017 to finance the Pandemic Emergency Fund (PEF) as developed above. However, the World Bank used casualty rates as the triggering event. We exclude that possibility for ethical reasons and inappropriateness for corporations' protection needs.

An index trigger, where payouts are based on estimates of total loss experienced by all insurance companies, is a more likely candidate. It can, however, take much more time than for traditional cat bonds (where the event has a local scope) for the official amount of losses to be determined.

Instead, we suggest a modelled loss trigger. Business interruption losses due to a pandemic are modelled *ex ante* per industry by plugging in key variables of this industry. This second trigger would be pulled if modelled losses are higher than a threshold mentioned in the issue contract.

The choice of a modelled loss trigger will create several benefits. It would be promptly available and easily updated along with the development of the pandemic. Hence, compensation transactions would be settled more rapidly than with other triggers during a time of dire need. It would be computed by an independent

provider, mitigating moral hazard issues. As the losses are sector specific, characteristics of the trigger could be finely tuned to limit basis risk effects. It is important to notice that the individual risk of lockdown for a given firm is strongly correlated with the risk of the sector since administrative decisions concern sectors as a whole. Whenever cost structures are also homogeneous in a given sector, the basis risk can be put at its minimum.

#### Investors' appeal

Finally, the two triggers employed meet the transparency to investors requirement to reduce agency costs at its minimum. The first trigger is entirely determined by the declaration of a PHEIC by the WHO which has gained credibility since its inception. The second trigger payment calculations are set *ex ante* by an independent agency.

Traditional cat bonds are acknowledged to be attractive to investors, because act of God events like natural disasters have low correlation with returns from other financial markets. They are worthy products for diversification. With betas close to zero, they can reduce substantially the volatility of a portfolio.

This argument does not resist closer examination of stock market behaviour during the COVID-19 pandemic. In the short term at least, investors would lose on both counts: pandemic cat bonds would default and the value of stock market portfolios would plunge. A straightforward decision of simply including those cat bonds in a diversified portfolio seems no longer effective as it would increase the volatility of the portfolio.

Actually, this remark needs to be qualified in view of the fast-recovery of stock market indices on hopes of vaccine-led recovery. (Mildly) patient investors would limit their losses to total or partial default of pandemic cat bonds if they (can) hold their portfolio for a few more months or years.[19]

Furthermore, recent empirical studies have shed some new light on cross-correlations among stocks and indices (Gourinchas et al. 2020; Bastidon and Jawadi 2022). Some sectors have recovered quickly or even reacted positively while others are impacted by the COVID-19 shocks in the middle and the long term. Bastidon and Jawadi (2022) analysed the sectoral network structure of the S&P500 using topological indicators of connectivity and distance. They find that the traditional classification of defensive vs cyclical is reinforced while some impacts are specific to the pandemic.

All in all, those empirical studies might provide useful insights to reduce systemic risk of a global portfolio. The question remains about the persistence of those results in case of a new pandemic. However, healthcare stocks returns will most probably remain negatively correlated with pandemic cat bond returns. Hence, investing in those bonds should be counterbalanced by overweighting healthcare stocks to minimise the overall volatility of the portfolio.

[19] This would indeed permit cat bond investors to smooth their profits and losses on the financial markets within a pandemic period.

Hence, from an economic perspective, a pandemic can be characterised by a simultaneous global economic downturn and the expansion of a few industries as witnessed during the COVID-19 pandemic. However, it is difficult to predict all winning sectors of the next pandemic. For instance, information and communication services might reach a maturity level in the future which would leave not much space for further development, even in situations of dire needs for products and services during a lockdown.

Nevertheless, there is one industry—the pharmaceutical sector and more generally the healthcare sector—which will probably benefit from future pandemics. Indeed, a pandemic is characterized in its early and development stages by the non-availability of adequate vaccines or treatments. Pharmaceutical companies jump into fierce competition to discover and develop them and apply rapidly for market authorisation. The COVID-19 pandemic revealed that a global pandemic forces countries to administer doses by the billion generating large-scale pharmaceutical demand.

There is huge uncertainty about the winner of this race. However, the pharmaceutical sector as a whole will experience huge growth in the short term translating into a rise in stock prices. Because of the tremendous needs worldwide, it is much more likely that there will be more than just one winner. Even "losers" of the last vaccine race or pharmaceutical companies which deliberately stayed out of the race might benefit from the pandemic, as they are co-opted to produce vaccines of competitors. For instance, Novartis signed an agreement to support the production of the Pfizer-BioNTech COVID-19 vaccine. Similarly, Sanofi agreed to produce millions of doses of the same vaccine.

To capture the global growth of the pharmaceutical and biotechnology sector, a natural candidate to hedge a global portfolio could be a world stock market index of this sector like MSCI World Pharmaceuticals, Biotechnology and Life Sciences Index. Relying on a world index is crucial since this sector is a global market and it is difficult to predict a single winner and the country it belongs to. Furthermore, a world index has the least potential for market manipulation because of deep market capitalization.

## Examples of amounts of coverage in the French restaurant industry

To assess the feasibility of our two-layer coverage scheme we simulate the life of theoretical PBI bonds in 2020 at the height of the pandemic. We apply them to the restaurant industry in France, where the traffic dropped by around 35% (Terres et territoires 2021). Worldwide, this was one of the most exposed sectors during the COVID-19 pandemic.

The objective of this section is twofold:

(1) The main purpose is to evaluate how much coverage insurance companies and PBI bond investors could provide over a policy year under different scenarios.
(2) As the private sector can not offer alone sufficient coverage of pandemic risk, we compare these amounts with public support under the scheme we propose in

which governments take salaries in charge. We then estimate and compare the weights of both private and public coverage.

We start to estimate aggregate interruption losses for the whole restaurant industry in France in 2020. In a preliminary example in which attachment points are fixed, we provide then an estimation of losses borne by all parties. Finally, we build up different scenarios with varying attachment points.

### Aggregate business interruption losses in the French restaurant industry in 2020

In the restaurant industry, the number of days of administrative closure is key data to estimate industry losses. Combined with the daily revenues of closed restaurants, a daily updated estimate of industry business interruption losses in case of a pandemic is available.

To estimate them, we gathered key information of the French restaurant industry in 2020 (Sanchez 2021). The French government decided to fully close restaurants for seven months and six days. Revenues of the whole sector were close to EUR 57 billion in 2019. If we apply a rule of three to this amount with a zero sector growth rate, we obtain an estimated total sales loss of EUR 34.27 billion in 2020.

However, such a basic model does not account for many other factors impacting revenues of this specific industry, including the seasonal pattern of revenues, decisions of movement restrictions and partial closure, enforcement of curfews or takeaway catering sales increase. A richer model would include those positive and negative factors on sales to fine-tune the overall loss estimation. Thus it would provide a modelized level of losses closer to actual revenue losses observed in France in 2020, which amounted to EUR 21.4 billion (Sancerre 2021). In the simulation exercise below, we use this last amount.

Now we are able to evaluate the business interruption losses of restaurants from their total revenue losses by relying on their cost structure provided by Association Nationale des Permanents et Responsables de Centres de Gestion Agréés (ANPREGECA) (2020).[20] Costs of goods sold represent 31.6% of revenues in France in the restaurant sector. In our scheme, permanent salaries during administrative closure are taken in charge by the state. Salaries and employer social contributions account for 24.80%. External charges represent 30.50% of which we should take into account only variable costs as is typical for indemnification of business interruption loss claims. Variable costs like electricity or temporary contracts account for approximately 50% of external costs.

All in all, maximum business interruption losses borne by the private sector in our scheme can then be estimated at 28.35% of lost revenues (100–31.6–24.80–30.5/2) which would have amounted to EUR 6.067 billion in France in 2020.

[20] ANPREGECA is a national association of accredited professional accounting: centres. It provides key and aggregated statistics to its members.

### A counterfactual scenario of PBI bonds in the midst of the COVID-19 pandemic

Hereafter, we illustrate our modelled index PBI bond calculations by a specific example based on the experience gathered from the COVID-19 crisis. For simplicity, we suppose that PBI bonds have a one year maturity covering the same policy year.[21]

The WHO and its Emergency Committee declared a PHEIC for COVID-19 on 30 January 2020. The first trigger of PBI bonds would have been activated on that day for the 2020 policy year. This ensures eligibility of funds claimed for business interruption losses due to the pandemic.

Let us assume that the first 20% of economic losses are borne by firms thanks to self-insurance. Then if we set at 20% and 30% the upper limits of business interruption losses borne respectively by (re)insurance companies and by cat bondholders, the second trigger of the PBI cat bond would be activated once modelled restaurant losses are higher than 40%.[22] Up to this attachment point of 40%, insurance companies indemnify clients in the usual way by taking into account individual claims. This layer of protection is essentially immune to basis risk for them.

Recalling from the estimations above that maximum business interruption losses borne by the restaurant sector in our scheme amounted to EUR 6.067 billion in France in 2020, we can now apply our arbitrary thresholds of 20%, 20% and 30%: the insured firms bear the first EUR 1.213 billion in economic losses, while insurers compensate for the next EUR 1.213 billion and PBI cat bondholders are requested to compensate the additional EUR 1.82 billion (see Fig. 1).

### Examples with various attachment and exhaustion points

We now simulate how various attachment and exhaustion points impact the maximum amounts of coverage by using the same data sources and methods (Table 3).

To put these figures in perspective, the French government and UNEDIC (the French independent association led by social partners whose main mission is to provide social benefits to unemployed people) spent EUR 26.28 billion in 2020 to assume responsibility for partial unemployment following closure decisions of all sectors. Based on data provided by UNEDIC, we estimate the social benefits for the restaurant sector at EUR 3.719 billion in 2020. These subsidies amount to the smaller part of costs borne by the French state which has also granted public guaranteed loans (PGE) and experienced tax revenue losses. More precisely, aggregated

[21] Actually, longer maturities would be even more appropriate to cover pandemic risk. This would ensure smooth debt servicing costs and reduce estimation errors of expected losses of an uncommon risk. Less interest volatility is also attractive for cat bond investors.

[22] The threshold of 40% of business interruption losses is called the attachment point of the PBI cat bond, while the threshold of 70% is its exhaustion point. In other words, the bondholder is requested to intervene on the layer 40–70% of total business interruption losses. An exhaustion point of 100% would provide full coverage of business interruption risk to firms beyond a self-insurance deductible of 20%.

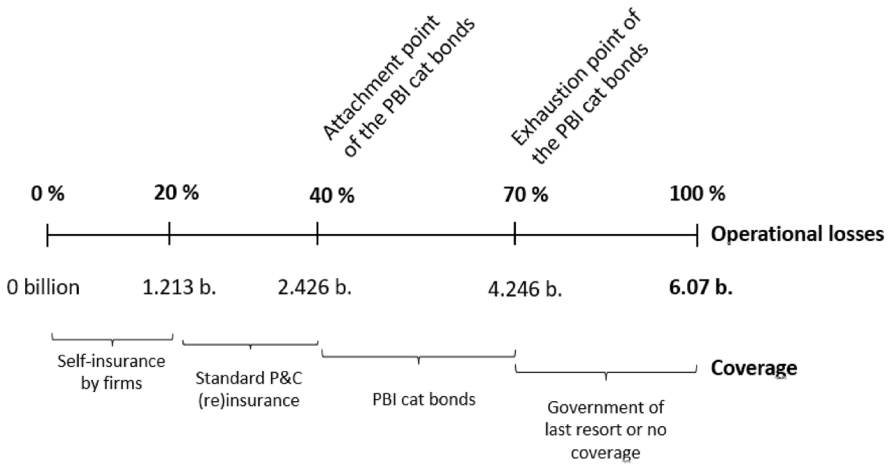


**Fig. 1** Attachment point, exhaustion point and levels of coverage for the restaurant industry in France

**Table 3** Limits of coverage of business interruption losses in the French restaurant industry in 2020 (EUR billion)

| | | **Weight limits of (re)insurance** | | |
|---|---|---|---|---|
| | | 10% | 20% | 50% |
| **Weight limits of PBI bonds** | 10% | 0.61 / 0.61 | 1.21 / 0.61 | 3.03 / 0.61 |
| | 30% | 0.61 / 1.82 | 1.21 / 1.82 | 3.03 / 1.82 |
| | 50% | 0.61 / 3.03 | 1.21 / 3.03 | 3.03 / 3.03 |

social benefits for partial employment for all sectors represent about one sixth of the EUR 160 billion estimated losses borne by the French state in 2020.

Hence, if we extrapolate using the same ratio of 1 to 6, total public costs for the restaurant industry convert into EUR 22.314 billion (EUR 3.719 billion x 6). This means in turn that whatever the hypothetical business interruption coverage scheme considered in Table 3, the bulk of coverage is carried by the public sector. Even if we consider full coverage of business interruption risk by the private sector (lower right box of Table 3), which is certainly not desirable for obvious moral hazard issues, the insurance sector and PBI bondholders would contribute only 10.67% each to the overall financial effort compared to 78.64% by the public sector.

If insurance companies and PBI bondholders would cover 50% of business interruption losses, according to the table (middle box in Table 3), they would bear respectively 4.77% and 7.16% of the total effort in favour of the restaurants compared to 88.04% for the public sector.

While not trivial, claims paid by the private sector under the new proposed scheme entail significant benefits for (re)insurance companies. Indeed, the whole sector has been put under harsh media pressure during the pandemic for failing to cover pandemic risk. The French Insurance Federation (France Assureurs) estimates that the whole sector has contributed EUR 2.6 billion to directly support companies and individuals. Additionally, EUR 2 billion has been invested to sustain French economic recovery. Those figures do not encompass brand deterioration costs nor litigation costs following the unprecedented wave of lawsuits.

## Conclusion

The COVID-19 pandemic hit the world economy severely in 2020 and 2021. The most directly exposed sectors were in dire need of protection following prolonged economic shutdowns. Worldwide, governments did their share of direct contributions by implementing job retention schemes in addition to more general measures to boost economic recovery. However, they proved insufficient to avoid liquidity cash shortfalls and bankruptcy in extreme cases, not counting escalating public debt. As pandemics will most probably recur at higher frequency, additional capacity is needed to mitigate ruinous repercussions in the future.

Most firms were not protected against business interruption losses due to a pandemic. The (re)insurance industry will most reasonably find it difficult to fill this protection gap alone. In this paper, we focused on how the financial capacities of (re)insurers can be increased via public–private cooperation.

The proposed scheme fits smoothly into the prevailing health and economic recovery mechanisms to combat pandemics. Two points constitute the cornerstones of our scheme. First, standard (re)insurance cannot mobilize sufficient capital to cover adequately, even partly, business interruption losses borne by firms when governments decide to implement lockdowns, curfews, and other administrative safety measures. Hence securitization, with the building of specific PBI bonds, is needed. Second, in order to overcome moral hazard issues and to permit the government to intervene at different stages of the crisis, and not only as a saviour of last resort, private insurers and governments must cover different types of losses. While private insurers must bear business interruption variable losses (excluding wages), the government must take in charge wages of people working in the most impacted sectors, zero, or very low, interests loans to firms, and the sanitary costs of the pandemic. In that way, no substitution effect between the government and private insurance coverage strategies emerges. Both actors adopt complementary loss coverage actions.

In the paper, we proposed a numerical model that shows how issuing PBI bonds that complement standard insurance improves the efficiency of compensation in an environment of correlated risks. Then we described more specifically the desirable features of these financial instruments. We argue that they must rely on a double trigger mechanism to ensure justified eligibility for compensation. The first trigger is pulled once the WHO declares an outbreak of a pandemic through a PHEIC which is essentially immune to state intervention. The payoff of the second trigger based on modelled business interruption losses ensures swift and indisputable compensation.

Furthermore, basis risk is firmly controlled when the scope of coverage is simultaneously national and sector specific. Lastly, we also discussed the issue of liquidity. The value of those PBI cat bonds are correlated with macroeconomic risk in the real economy, which is not the case for conventional cat bonds. Thus the diversification property of the 'pandemic' bonds may be challenged.

Finally, we proposed some simulations of coverage of the restaurant industry based on data gathered during the COVID-19 pandemic in France. They provide insights on how different parties could commonly face the impact of a pandemic on business interruption losses. We put the simulated amounts of coverage into perspective with what was paid by insurers in 2020 independently of pandemic contractual clauses, which were almost always absent in P&C insurance contracts. We are aware that we focused on one specific economic sector. Nevertheless, the catering sector was one of the most impacted during the pandemic. It also encompasses a very high number of small and medium-sized firms, which do not have enough financial reserves to mitigate the impact of a crisis like COVID-19. Moreover, the catering sector is also one that employs a large number of people in proportion of their commercial revenues. Besides, very large firms benefit already from their own insurance captives. They are also able to issue PBI bonds on their own on the ILS market. Thus, they could be considered as non-recipients of our insurance scheme during its first stage of development.

Further research shall still consider all the positive externalities provided by a future well capitalised public–private 'pandemic' insurance system as evoked by Hartwig et al. (2020). Indeed, none of the benefits or cost savings induced by such a system are currently evaluated. For instance, well insured firms lessen the probability of observing high levels of insolvencies. Insurance would also mitigate the risk of some healthy firms having to stop their production because some of their suppliers encounter financial difficulties.

**Acknowledgements** We are grateful to Lucas Bauer, Claude Casterot, Isabelle Joulin, Pierre Picard and Olivier Sonntag for insightful discussions on this topic. We would also like to thank Christophe Courbage, Michael Faure, Ernst Karner, and all participants at the 2022 Joint Seminar of the European Association of Law and Economics and The Geneva Association on Pandemics—Liability and Insurance in Vienna for their insightful comments. We would also like to show our gratitude to participants at the 2022 'Journées Internationales du Risque' at IRIAF-Niort and at the 2022 Applied Microeconomics Days in Rennes. Finally, we acknowledge UNEDIC for providing useful data from pandemic business interruption losses in France.

**Data availability** No database was used for this manuscript.

## Declarations

**Conflict of interest** On behalf of all authors, the corresponding author states that there is no conflict of interest.

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