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Providing Pandemic Business Interruption Coverage with Double Trigger Cat Bonds *

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Abstract

The 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 such as COVID-19 at affordable rates. First, we propose a comprehensive numerical model to show how cat bonds can contribute to complement standard (re)insurance even though risks are positively correlated between different firms or sectors. We present the conditions under which fairer coverage can be provided to insured firms. Second, we discuss the characteristics of the triggers that are needed to provide efficient pandemic business interruption cat bonds (PBI cat bonds), which do not exist yet on the market of insurance-linked securities (ILS). The double trigger pandemic bonds we build are structured on a first trigger which is pulled when the World Health Organization (WHO) declares a Public Health Emergency of International Concern (PHEIC). The second trigger determines the payout of the bond based on the modelized business interruption losses of an industry in a country. In this framework, we discuss moral hazard, basis risk, correlation and liquidity issues. Third, to answer the feasibility of our (two-layer) coverage scheme we simulate the life of theoretical PBI bonds at the height of the pandemic. We apply them to the restaurant industry in France and we use data gathered during the COVID-19 pandemic.

Keywords: pandemic cat bond, business interruption losses, securitization, (re)insurance.

JEL Classification: G11, Q54, G22.

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1 Introduction

On Friday 29th January 2021, the INSEE (the country's national statistics bureau) was announcing that the French GDP shrinked by 8.30% in 2020. France's economic downturn followed the closing of non-essential activities during the COVID-19 pandemic. 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 a systemic and unprecedented disruption. Things got even worse since, in most cases, their insurance policy did not comprise a 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 political and public opinion pressure, insurance companies have compensated some policyholders as high as 15% of revenues even if contracts explicitly exclude pandemic risk coverage. Furthermore, the OECD estimates that one month of strict confinement leads to 1.7 trillion $ in revenues losses (OECD, 2021). Hence losses borne by many industries are huge and threaten business survival of companies of the most exposed sectors.

A pandemic risk has a very strong systemic component. Thus, risk mutualization 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 pandemic business interruption protection gap. Indeed, Germany (German Insurance Association, 2020) is considering the building of 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 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 a public/private coverage of exceptional catastrophes - including pandemic risk and other systemic risks (Lustman, 2020). This scheme was rejected; the government believed it was not appropriate to ask additional insurance premia to firms already financially destabilized by business closures due to the COVID-19 pandemic.

The common point to all these national initiatives is the prevalence of a combination of

private standard (re)insurance capacity with national public funds. More precisely, funds should be accumulated by both taxes and standard insurance premia paid by policyholders.[1] We argue that such a publicly managed pool will not solve the issue of coverage capacity. Additional capacity shall be provided by securitization.

Since their inception in the early nineties, insurance linked securities (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 all 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 behaviors 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 PBI cat bonds, with triggers that permit to 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[2]: "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.

[1] The German Insurance Association proposed to consider cat bonds as possible additional coverage tools.

[2] The French company SCOR is the fourth world's 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/

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 at affordable rates. 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) focus on corporate pandemic insurance contracts that shall be offered to small and medium 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 whether a risk of pandemic is insurable. They also propose to build over 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. (2020)'s 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.

The scheme that we propose is also in line with the discussions conducted by the EIOPA (European Insurance and Occupational Pensions Authority) 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 (2012)'s model developed with independent risks. We introduce correlation between the risks borne by different firms in a given sector as it is typical for a pandemic risk. Despite those correlations, we show that, under some circumstances, adding securitization can lead to fairer compensation.

In section 3, we present a detailed description of pandemic business interruption bonds that will allow to 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 trigger determines the payout of the bond based on the modelized business interruption losses of an industry in a country.

We also 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 loans 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. Finally, we 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[3]. Our purpose is to estimate the maximum amount of coverage that 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.

The remainder of this paper is structured as follows. In the second section, we provide a numerical model that shows under which conditions fairer coverage can be offered to policyholders. In section 3, we propose a precise design of the double-trigger pandemic business interruption bonds and discuss their features in light of moral hazard issues, basis risk and investors' appeal. In section 4, we provide some simulations and empirical data. Section 5 concludes the paper.

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

2 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 [4]. Indeed, pandemic risk has its own unique features. We detail them in the next subsection 2.1. In Subsection 2.2, 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.

2.1 The unique features of pandemic risk

The systemic nature of the 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 hardly modelisable. The COVID-19 pandemic has hit heterogeneously business sectors. Today, only most exposed industries would buy a 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 prioritizing public health at the expense of the economy. Hence offering an insurance based on business interruption coverage results in new challenges to get to grips with.

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 will stop. 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 to apply coverage retroactively (Simpson, 2021). In France, almost 93% of P&C contracts were excluding pandemic business interruption losses in 2020 (Lustman, 2020).

[4] Denis Kessler, CEO of SCOR until recently, a major French reinsurance company, states that business interruption clauses cannot cover pandemic perils (Kessler, 2021)

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 of lockdown taken in different countries in 2020 have had an immediate and severe impact stock markets: the 9th of March, they lost 23% of their value, and another collapse of more than 12% was registered the 12th of March.

Despite all these *a priori* blocking points and to mitigate the financial burden carried by private firms and its disastrous social consequences, Spaeter (2021) 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 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 the business interruption losses. It is important, at this stage, to notice that the early intervention of governments in workers' wage subsidizing[5] and in sanitary costs coverage remains essential in the risk management process.

Finally, it is primarily an issue of insurance supply rather than insurance demand. Indeed, since 2020, a vast majority of P&C insurance contracts and reinsurance treaties can only be triggered by a physical damage, explicitly excluding administrative business closures due to a pandemic as a peril to cover business interruption losses. 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 have appeared in the 1990's 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 46 billion $ by the end of 2020 [6].

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

[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 ».

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 a same country are correlated with each other.

2.2 A numerical model

We propose a simple numerical model to show how cat bonds may supplement the standard insurance market when pandemic business interruption risks (PBI risks) are correlated. To do so, we start from Lakdawalla and Zanjani (2012)'s approach dedicated to independent risks 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.

In particular, cat bonds reduce the insurance unfairness arising when firms have different loss probabilities. More precisely, it improves coverage of the least well covered firms compared to the others. This result challenges the well known idea that major risks and insurance coverage do not mix well because of correlation. We also show that assuming that the insurer shall be simultaneously the provider of insurance indemnities and the investor in complementary bonds on behalf of its clients is not ideal. Both activities compete when supported by a given collateralized 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 cat bonds are well designed, as proposed in Section 3, 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 a same macroeconomic situation[7]. This correlation is described by a common parameter ϵ in our model, with $\epsilon > 0$. More precisely, Firm 1 (Firm 2) can lose 100 with a probability of 0.10 (0.01).[8] The upper script 0 (respectively L) designating the no loss state (respectively the loss state), the unconditional risks considered respectively by Firm 1 and by Firm 2 ($i = 1, 2$ in the table) are given in Table 1 hereafter.

Both risks being positively correlated, let us define now the conditional risks. In what follows,

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

[8] We use the initial unconditional probabilities considered by Lakdawalla and Zanjani (2012) in order to be able to compare our results with theirs.

Table 1: Unconditional probabilities

	NO LOSS $x_i^0 = 0$	LOSS $x_i^L = 100$
Firm 1: $\tilde{x}_1$	$0,9$	$0,1$
Firm 2: $\tilde{x}_2$	$0,99$	$0,01$

$x_i(x_j^0)$ (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). Their values are summarized in Table 2 hereafter:

Table 2: Conditional probabilities

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

Hence, Firm i has more chance to bear a loss whenever Firm j also bears one, and symmetrically. To be as simple as possible, we assume that the causality between both firms is symmetric: ϵ impacts identically the probability of loss of Firm 1 and Firm 2. All the results below still hold for asymmetric causalities. Besides, with $\epsilon = 0$, we obtain Lakdawalla and Zanjani (2012)'s model with independent risks.

Now consider an insurer who issued equity shares for $K = 150$ and offers full insurance to both firms. He 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 its respective insured risk.[9] In such a context, the insurer relies on partial collateralization: it owns 150, but engages on an amount of insured losses equal to 200.[10]

The aggregate risk of the insurer is denoted X, with p indicating the probability.

$$p(X=0) = p(x_1^0 \cap x_2^0) = p(x_1^0 \mid x_2^0).p(x_2^0) = (0,9+\epsilon).0,99 = 0,891 + 0,99\epsilon,$$

$$p(X=200) = p(x_1^L \cap x_2^L) = p(x_1^L \mid x_2^L).p(x_2^L) = (0,1+\epsilon).0,01 = 0,001 + 0,01\epsilon,$$

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

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

Also notice that ϵ must lie between zero and 0,01 in order to guarantee positive correlation (we must have $p(x_1^L \mid x_2^L) > p(x_1^L \mid x_2^0)$ and symmetrically for Firm 2). This does not permit to consider higher correlation levels. Nevertheless, as already mentioned, the symmetrical impact of ϵ on the probability of loss of both firms permits an easy comparison with Lakdawalla and Zanjani (2012)'s results.[11]

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, ii) this unfair treatment is exacerbated when risks are positively correlated and only standard insurance is available, and iii) introducing cat bonds reduces the unfairness aggravated by correlation.[12]

[9] 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.

[10] 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%.

[11] To work with higher correlation levels, we could choose for instance a conditional probability of loss equal to $0,9 \pm \epsilon$ for Firm 1 and equal to $0,99 \pm 0,1\epsilon$ for Firm 2. With such a setting, ϵ could lie between zero and $0,1$.

[12] With Point i) we generalize the result obtained by Lakdawalla and Zanjani (2012) with independent risks to the case of correlated risks. For points ii) and iii) unfairness 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). In that case, Firm 2 would also pay a lower

Expected individual losses of Firm 1 are

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

and respectively of Firm 2

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

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:

$$\begin{aligned} E(I(\tilde{x}_1)) &= p(x_1^L \cap x_2^0).100 + p(x_1^L \cap x_2^L).\frac{150}{2} \\ &= p(x_1^L \mid x_2^0).p(x_2^0).100 + p(X = 200).75 \\ &= (0,1 - \epsilon).0,99.100 + (0,001 + 0,01\epsilon).75 \\ &= 9,975 - 91,5\epsilon \end{aligned} \tag{3}$$

And:

$$\begin{aligned} E(I(\tilde{x}_2)) &= p(x_2^L \cap x_1^0).100 + p(x_2^L \cap x_1^L).\frac{150}{2} \\ &= p(x_2^L \mid x_1^0).p(x_1^0).100 + p(X = 200).75 \\ &= (0,01 - \epsilon).0,90.100 + (0,001 + 0,01\epsilon).75 \\ &= 0,975 - 82,5\epsilon \end{aligned} \tag{4}$$

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

$$E(I(\tilde{x}_1))/E(\tilde{x}_1) = (0,9975 - 9,15\epsilon) \text{ cents per unit of risk} \tag{5}$$

$$E(I(\tilde{x}_2))/E(\tilde{x}_2) = (0,975 - 82,5\epsilon) \text{ cents per unit of risk} \tag{6}$$

unit insurance premium. However, 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 ($\epsilon > 0$), we obtain two results.[13] First, 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. 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 correlation risk. Formally we have:

$$\frac{\partial E(I(\tilde{x}_1))}{\partial \epsilon} < 0 \text{ and } \frac{\partial E(I(\tilde{x}_2))}{\partial \epsilon} < 0 \tag{7}$$

The second result is more relevant for our issue: 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 is getting worse more rapidly than the situation of Firm 1. Formally, by substracting (6) from (5) we obtain

$$E(I(\tilde{x}_1))/E(\tilde{x}_1) - E(I(\tilde{x}_2))/E(\tilde{x}_2) = 0,0225 + 73,35\epsilon \ , \tag{8}$$

which is strictly positive and increasing in ϵ. 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 and following Lakdawalla and Zanjani (2012)'s framework, let us assume now that the insurer invests in a pandemic business interruption cat bond (PBI cat bond) $B = 50\$$ on behalf of Firm 2. We keep assuming zero frictional costs which is a worst case scenario for the attractiveness of cat bonds compared to standard insurance. Indeed, cat bonds are often considered as useful diversification instruments because their transaction costs are lower than those attached to standard (re)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 it complements it thanks to the PBI cat bond of 50 offered by the insurer. Hence Firm 2 is also asking for full coverage of its loss. We still have $E(\tilde{x}_1) = 10$ and $E(\tilde{x}_2) = 1$. 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,

[13] With no correlation ($\epsilon = 0$), we find Lakdawalla and Zanjani (2012)'s result: Firm 1 obtains 99,75 cents per unit of risk, while Firm 2 obtains only 97,5 cents.

after simplification:

$$\begin{aligned} E(I(\tilde{x}_1)) &= p(x_1^L \cap x_2^0).100 + p(x_1^L \cap x_2^L).\frac{2}{3}.100 \\ &= 9,967 - 98,333\epsilon \end{aligned} \tag{9}$$

And:

$$\begin{aligned} E(I^B(\tilde{x}_2)) &= p(x_2^L \cap x_1^0).(50+50) + p(x_2^L \cap x_1^L).(\frac{1}{3}.100 + 50) \\ &= 0,9833 - 89,167\epsilon \end{aligned} \tag{10}$$

Let us compare Firm's 2 coverage without and with bonds, namely $E(I(\tilde{x}_2))$ obtained with standard insurance (Equ. (4)) with $E(I^B(\tilde{x}_2))$ obtained thanks to a mix of standard insurance and bond issuance (Equ. (10)). By substracting (4) from (10), we have, after simplification:

$$\begin{aligned} 0 &< E(I(\tilde{x}_2^B)) - E(I(\tilde{x}_2)) \\ \epsilon &< 0,001245 \end{aligned} \tag{11}$$

Bond issuance on behalf of Firm 2 improves its financial situation in case of a loss if correlation between its risk and Firm 1's risk is not too high. On the contrary, for levels of ϵ higher than $0,001245$ in our numerical example, the situation for both firms is worsened compared to the one without contingent bonds. More precisely, while more available capital is needed to maintain proper standard insurance coverage when risks are highly correlated, bond issuance is confiscating part of it.

Furthermore, by dividing (9) by (1) and (10) by (2), we obtain also a difference of insurance per unit equal to

$$E(I(\tilde{x}_1))/E(\tilde{x}_1) - E(I^B(\tilde{x}_2))/E(\tilde{x}_2) = (0,0134 + 79,33\epsilon) \ , \tag{12}$$

A comparison of (12) with (8) shows that for levels of ϵ lower than the threshold defined in (11), bond issuance on behalf of Firm 2 lessens the gap between the coverages per unit of

Firm 1 and of Firm 2, thus improving the redistribution of assets between them. Hence, for reasonable correlation levels, investment in contingent bonds by the insurer itself on behalf of its client improves the initial situation of the latter both in absolute and relative terms.

Finally, our conclusions can be summarized as follows. The investment in PBI cat bonds by the insurer on behalf of Firm 2 reduces the gap between both firms in terms of insurance accessibility as correlation increases. More precisely, when correlation is not too high, it improves the situation of the firm in the worst situation when only standard insurance is offered. In our example, Firm 2 plays this role: its risk is lower than Firm 1's risk, but it has access to a lower level of standard insurance per unit of risk. When correlation exceeds a given threshold, the situation of both firms is deteriorated compared to the initial framework in which only standard insurance is available. This is due to the need of more and more capital to ensure a given level of standard insurance when risks are correlated.

Actually, this apparent increase of the opportunity cost of bond issuance emerges because we assume that the insurance company plays simultaneously the role of the issuer of bonds and of the investor (by collateralizing the bond on her own equity). If other investors could invest in PBI 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 frictional costs shall also be discussed. We count them as zero, even though standard reinsurance is usually impaired by much higher transaction costs than cat bonds.

3 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 of those pandemic bonds 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 the pandemic business interruption cat bonds to overcome critics addressed to previously issued pandemic cat bonds and

to gain the usual benefits such as increased capacity by tapping in 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 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 organizations. 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[14].

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 $195.84 millions. 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[15].

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 a 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

[14]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 8 times higher than estimated expected losses. This multiplying factor decreased steadily with the market maturity to get close to 2, a typical factor required by reinsurance companies for higher layers of risk.

[15]As reported by Artemis on April 17th, 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).

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 subsection 3.1, we consider precisely too main concerns of the issuance of cat bonds, namely moral hazard and basis risk. In Subsection 3.2, 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 Subsection 3.2.3.

3.1 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 pandemic economic consequences depend largely on governments' decisions on lockdown, insurance and reinsurance companies' profits are directly impacted if they should offer protection against business interruption loss due to a pandemic which at first glance might introduce moral hazard opportunities. Indeed, the existence of an - hypothetical for the moment - well capitalized 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 it is the case for the COVID crisis: wages are subsidized by governments whereas business interruption insurance policies typically do not cover them. Furthermore, any decision of a government to reduce non-essential activities would hit first public debt through immediate wages payments before indemnification of business interruption losses paid out by insurance companies. This complementary must be an integral part of the coverage scheme that we propose and detail in Subsection 3.2.

Second, to reduce even further agency costs between governments and cat bond investors, it is essential that both intervene on different layers of losses: the cat bond market should be mobilized for higher layers of PBI losses than those covered by public funds.

Third, 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 Subsection 3.2 there is no drawback inherent of an indemnity trigger or a typical reinsurance contract. If the insurance company indemnifies too generously and overpays for commercial reasons or under 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 a trigger often involves a trade-off between moral hazard risk and basis risk. 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.

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, a strength of wind, 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 behavior.

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 Subsection 3.2 we propose to build the second trigger on a fourth possibility, namely on some modeled losses: those data are forcasts of business interruption losses that are computed *ex ante* with respect to different lengths of lockdowns that could be decided by the government.

3.2 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.

3.2.1 A WHO based trigger

The first trigger purpose 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 financial needs of shaky companies.

We suggest to base the first trigger on the declaration of a Public Health Emergency of International Concern (PHEIC) by the World Health Organization (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 IHR Emergency Committee[16].

[16]The International Health Regulations (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 pandemic of coronavirus disease 2019 [17]. 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)).

3.2.2 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, ie., 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 gross margin which is the difference between revenues and variable costs (including costs of goods sold). Thus, it takes over fixed costs and expected profit. Business interruption insurance policies are not standardized as there is no agreed upon definition of gross margin and also it might become tricky to disentangle fixed and variables costs. However, cost structure are rather homogeneous within the same industry.

We suggest then that insurance companies could offer a 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

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

insurance companies through two channels:

- Directly by the premia paid by the insured firms
- 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 the 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 Subsection 3.1, four types of triggers are commonly used in cat bonds 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 which could be casualty rates for pandemic cat bonds. We already excluded 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 losses are higher than a threshold corresponding to business interruption losses borne by insurance companies.

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 a sector as a whole. Whenever

cost structures are also homogeneous in a given sector, the basis risk can be put at its minimum.

3.2.3 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 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 0, they can reduce substantially the volatility of a portfolio.

This argument does not resist closer examination of stock markets 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 into 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 markets indices on hopes of vaccines-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[18].

Additionally, active portfolio management would alleviate the aforementioned correlation risk. Since health care stocks returns are most probably negatively correlated with pandemic cat bonds returns, investing in those bonds should be counterbalanced by overweighting health care stocks to minimize the overall volatility of the portfolio.

Indeed, from an economic perspective, a pandemic can be characterized by a simultaneous global economy downturn and the expansion of a few industries as witnessed by the COVID-19 pandemic. However, it is difficult to predict all winning sectors of the next pandemic. For instances, information and communication services might reach a maturity level in the future

[18]This would indeed permit cat bond investors to smooth their profits and losses on the financial markets within a pandemic period. For the COVID-19, the last forecasts of the OECD announce 2023 as the year of the return to the pre-COVID economic situation in the world: a cycle of three years.

which would leave not much space for further development, even in situation of dire needs for their products and services during a lockdown.

Nevertheless, there is one industry – the pharmaceutical sector and more generally the health care sectors - 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. Pharmaceuticals jump into a fierce competition to discover and develop them and apply rapidly for market authorization. The COVID-19 pandemic revealed that a world pandemic forces countries to administer doses by billions generating a large scale pharmaceutical demand.

There is a huge uncertainty about the winner's name of this race. However, the pharmaceutical sector as a whole will experience a huge growth in the short term translating into stock prices rise. 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. To rely 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.

Since the purpose of the pandemic business interruption cat bonds that we propose is to supplement insurance companies for higher layers of protection, the most obvious choice of period of coverage would be one year, the same as in a typical insurance policy.

4 Simulations and discussion

To answer 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 sector during the COVID-19 pandemic.

* *An introductory example*

Hereafter, we illustrate our modelled index PBI bonds calculations by a simplified example based on the experience gathered from the COVID-19 crisis. The main purpose is to estimate the maximum amount of coverage insurance companies and PBI bonds investors can provide over a policy year. As a matter of simplicity, we suppose that PBI bonds have a one year maturity covering the same policy year.[19]

In the restaurant industry, the number of days of administrative closure is a key data to estimate the 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. 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 pulled once modelled restaurant losses are higher than 40%.[20]

The WHO and its Emergency Committee declared a Public Health Emergency of International Concern (PHEIC) for COVID-19 on 30 January 2020. The first trigger of PBI bonds would have been pulled on that day for the 2020 policy year. This ensures eligibility of funds claimed for business interruption losses due to the pandemic. Up to the 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 of basis risk for them.

To compute estimated losses by the modelled loss trigger, we gathered several key informations of the French restaurant industry in 2020 (Sanchez, 2021). The French Government decided to fully close restaurants during 7 months and 6 days. Revenues of the whole sector were €57 billion in 2019. Those figures yield an estimated total sales loss of €34.27 billion in 2020 by applying a zero sector growth rate to the rule of three.

However, this simple model does not account for many other factors impacting revenues of this specific industry, including seasonal pattern of revenues, decisions of movement restrictions

[19] 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.

[20] 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%.

and partial closure, enforcement of curfews or take-away catering sales increase. A richer model would include those positive and negative factors on sales to fine-tune the overall loss estimation. Indeed, actual revenue losses observed in France in 2020 have amounted to €21.4 billion (Sancerre, 2021).

To estimate losses taken in charge by the private sector, we use the cost structure of restaurants provided by ANPREGECA (2019)[21].Costs of good 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% among which we should take into account only variable costs as is typical for indemnification of business interruption losses 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 €6.067 billions in France in 2020. With our arbitrary thresholds of 20%, 20% and 30%, the firms bear the first €1.213 billions of economic losses, while insurers compensate for the next €1.213 billions and PBI cat bondholders are requested to compensate for additional €1,82 billions (see Figure 1).

[21] ANPREGECA (Association Nationale des Permanents et Responsables de Centres de Gestion Agréés.) is a national association of accredited professional accounting centers. They provide key and aggregated statistics to its members.

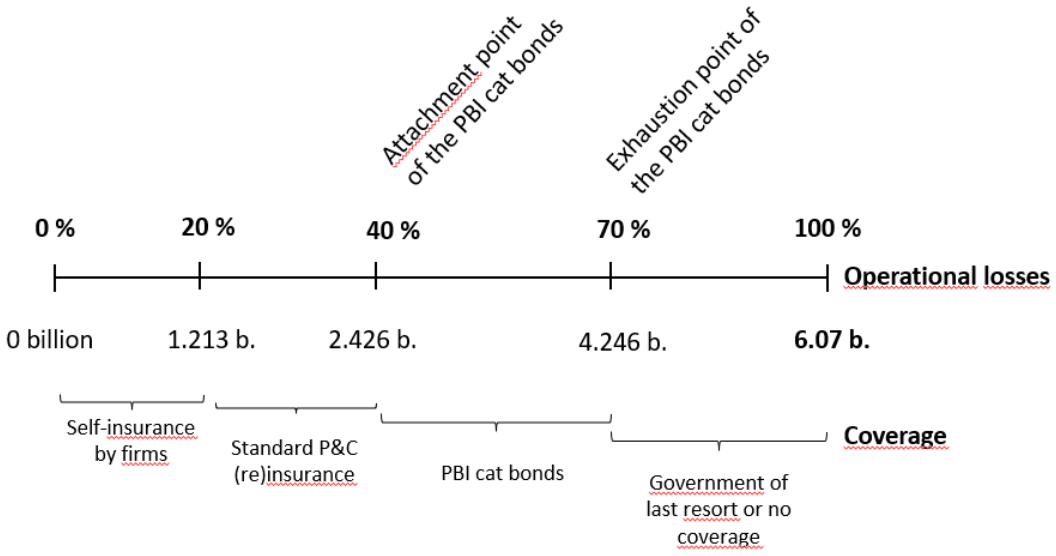

Figure 1: Attachment point, exhaustion point and levels of coverage for the catering sector

* *Simulations 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).

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

		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

To put these figures in perspective, the French government and UNEDIC (the French independent association led by social partners which main mission is to provide social benefits to unemployed people) spent €26.28 billion in 2020 to assume responsibility for partial unemployment following closure decisions of all sectors. We estimate the social benefits for the restaurant sector at €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 revenues losses. More precisely, aggregated social benefits for partial employment for all sectors represent about one sixth of the €160 billion estimated losses borne by the French State in 2020.

Hence, if we extrapolate using the same ratio 1 to 6, total public costs for the restaurant industry convert into €22.314 billion (€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 both indemnify 10.67% of the sum of losses and public effort compared to 78.64% by the public sector.

If the whole private sector would cover 50% of business interruption losses, according to the table (middle box in Table 3), insurance companies, PBI bondholders and the public sector would bear respectively 4.77%, 7.16% and 88.04% of the total effort to combat the economic consequences of the pandemic. If we stick to the direct support to the restaurant industry, we get respectively 17.92%, 26.89% and 55.10%.

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 hash media pressure during the pandemic for failing to cover pandemic risk. The French Insurance Federation (France Assureurs) estimates that the whole sector has contributed €2.6 billion to support directly companies and individuals. Additionally, €2.0 billion have been invested to sustain the French economic recovery. Those figures do not encompass brand deterioration costs nor litigation costs following the unprecedented wave of lawsuits.

5 Conclusion

The COVID-19 pandemic hit severely the world economy 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 contribution by implementing job retention schemes in addition to more general measures to boost economy recovery. However, they proved insufficient to avoid liquidity cash shortfall 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 increasing the financial capacities of (re)insurers which are embedded in a public-private cooperation that fights pandemic and its economic consequences.

The proposed scheme fits smoothly into the prevailing health and economic recovery mechanisms to combat pandemics. Two points constitute the cornestones 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 lockdowns, curfews, and other administrative safety measures. Hence securitization, with the building of specific pandemic business interruption cat bonds (PBI cat 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 savior on last resort, private insurers and governments must cover different types of losses. While private insurers focus on 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, no substitution effect between the government and the 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 cat bonds that complements standard insurance improves 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 a Public Health Emergency of International Concern (PHEIC) which is essentially immune to States 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 those '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 from pandemic contractual clauses, which were almost always absent in the Property&Casualty insurance contracts. We are aware that we focused on one specific economic sector. Nevertheless, the catering sector is one of the most impacted during the pandemic. It encompasses also a very high number of small and medium 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 cat 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 capitalized 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 to be obliged to stop their production because some of their suppliers encounter financial difficulties.

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