Securitizing Pandemic Risk Insurance

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1 Introduction & Background

The utilization of catastrophe bonds (CAT bonds) as an instrument for securitizing and sharing the economic risks of disasters is not a new idea. Indeed, CAT bonds have been employed for several years for sharing the economic losses resulting from natural disasters including hurricanes, earthquakes, and—more recently, as used by the World Bank—pandemics. The World Bank's attempt to utilize CAT bonds as a public-private partnership to fight pandemic losses became heavily criticized by many academics and policy makers (Insurance Journal, 2020), however, because the amount was too small and the funds were utilized too late to stop the COVID-19 pandemic.[1] Furthermore, because the World-Bank-sponsored pandemic CAT bonds were subsidized by government donations and, absent the occurrence of covered pandemics, were full recourse to the World Bank, this precedent was not market tested and thus provides insufficient applicable insights regarding the commercial viability of such instruments.

This paper examines CAT bonds and other means of risk securitization for pandemics through the dual lenses of the unmet need within the market for risk financing and the requirements for potential viability of a market for pandemic bonds. Unmet capital needs do exist within the risk-financing marketplace – not only for risk capital to protect against pandemic losses but also for the capital to protect against a wide range of disaster losses. Insurance and reinsurance have limited capacity to either absorb or spread the risks of global-level catastrophes, and risk-securitization instruments have proven effective in some cases for layered risk sharing with private and public insurance markets. Having said this, we argue that pandemic exposures can be made insurable by focusing on insuring those pandemics occurring accidentally/ unintentionally, and by increasing reinsurance capacity to handle the associated losses.

1.1 Managing Catastrophe Risk through Insurance

Insurance is the first line of defense strategically for protecting against disaster losses. Insurance provides multiple benefits to individuals, organizations, and society by 1) helping to ameliorate cash-flow uncertainties; 2) promoting the mitigation of the underlying risks; 3) reducing the opportunity cost of allocating financial resources; 4) improving creditworthiness; 5) reducing the frictional costs of

[1] Criticism that the amount was too small certainly does not seem justified, given that the World Bank-sponsored pandemic CAT bonds were intended merely as a pilot project of limited scope. Discussion between Schwarcz and Mukesh Chawla, World Bank Group Senior Adviser to the pandemic CAT-bonds program, Sep. 22, 2020, at a virtual annual meeting of the American Bar Association Section on Business Law.

contracts; and 6) redistributing the financial burden of private losses on society.[2] Insurance markets that include high potential for catastrophic industry losses are nevertheless prone to supply-side problems, predominantly that solvency constraints directly limit the available capacity of the marketplace and competitive insurance market cycles indirectly.[3] The choice by private insurers to limit market exposure, and thus restrict capacity in the face of the highest-risk perils, is of particular relevance to this work. For example, Cummins (2006) states that "*Insurance markets tend to respond adversely to mega-catastrophes. They respond to large events…by restricting the supply of insurance and raising the price of the limited coverage available.*" (pp 338).

Reinsurance – the insurance provided to insurers – provides necessary capital to the private insurance market that helps to alleviate some of the solvency and competitive cycle challenges. By committing substantial capital to share in the catastrophe risk that is accepted by primary insurance contracts, reinsurance benefits primary insurers via 1) reduced likelihood of insolvency; 2) reduced earnings volatility; and 3) increased capacity to write large exposures and contract limits (The Institutes, 2020). Reinsurance is a global business while the primary insurance business is largely a regional or national business; thus, reinsurance serves a critical role in the aggregation and spread of risks internationally (Holzheu and Lechner, 2007).

The importance of available and affordable reinsurance to the smooth functioning of insurance is not easily overstated. The traditional reinsurance market is expected to grow from $402.35 billion in 2020 to just over $435 billion in 2021 worldwide, at a compound annual growth rate of 8.1 percent,[4] and virtually all primary insurance policies are backed by reinsurance contracts (Business Research Company, 2021). Even large government markets for catastrophe risk in the U.S., including the Florida Hurricane

[2] Kousky (2019) provides a comprehensive review of the prior literature on the important role insurance and reinsurance play in disaster recovery and risk reduction.

[3] Klein and Kleindorfer (2003) and Cummins (2006) lay out the capacity issues faced by insurers when considering risk-taking in problematic markets. Salient features of these markets often include relatively low competition, low and/or volatile profitability, high risk of insolvencies for a considerable portion of the market, and regulatory constraints on pricing adequacy and precision. Obviously, insurance companies attempt to maximize profits in the face of these variables. The freedom for insurers to manage risk exposure is critical to maximizing the supply of insurance, yet prohibitively-expensive insurance and/or restrictive insurance contracts may result from such freedom. Suppressive regulation may produce non-optimal market capacity as insurers reduce supply wherever the freedom to charge adequate and precise prices is not possible.

[4] The market is expected to reach approximately $556 billion by the end of 2025 at 6 percent compound annual growth.

Catastrophe Fund (Cat Fund) and the National Flood Insurance Program (NFIP), employ private reinsurance to offload some of their prospective losses.[5]

1.2 Using Risk Securitization to Provide Reinsurance

Risk securitization as referred to in this paper is the use of tradable securities to finance risk, using a risk index to value the security and/or a specified loss event to trigger payment to the insurer. Convergence of the insurance-reinsurance sector with the capital markets has been gaining traction since 2002-2003, when reinsurers reacted to the financial aftermath of Hurricane Andrew, and such risk securitization has taken various forms (Barrieu and Albertini, 2009).[6] The market for these insurance-linked securities (ILS) had grown to approximately $95 billion as of year-end 2018, and has more or less stagnated since, estimated between $95 and $100 billion in size as of early 2021.[7] In context, a $100 billion ILS market represents 20-25 percent of a total $535 billion in reinsurance capital available.[8]

Industry loss warranties (ILWs) comprise the largest share of the ILS marketplace, but to date have been limited in their ability to increase reinsurance market capacity.[9] An ILW is a reinsurance or derivatives contract through which a risk-bearing entity (usually an insurer) can protect against a loss event that reaches an industry-loss threshold. The payment trigger to the insurer is parametric (and based on industry losses), rather than indemnity based (and linked to cumulative losses within a specified period rather than to losses from a single event). The contract specifies the compensation to be paid to the insurer should the ILW be triggered. CAT bonds have some similarities to ILWs (e.g., they only benefit the insurer if a specified loss event occurs), but have shown superior usefulness in reaching investors outside of the traditional reinsurance sector, particularly due to the ease of tradability.[10]

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[5] Medders and Nicholson (2018) outline the Cat Fund's use of reinsurance. Information regarding the NFIP's reinsurance program is available at https://www.fema.gov/flood-insurance/work-with-nfip/reinsurance.
[6] Industry loss warranties, catastrophe bonds, contingent capital, weather derivatives and catastrophe swaps are the best known and most common forms that ILS takes, although reinsurance "sidecars" ebb and flow in use as well.
[7] See: https://www.fitchratings.com/research/insurance/insurance-linked-securities-stagnated-capacity-29-09-2020 and https://www.artemis.bm/news/ils-resilience-reinsurance-capital-grows-renewals-guy-carpenter/.
[8] The total reinsurance capital available was estimated as the simple sum of the $435 billion traditional reinsurance market size and the $100 billion ILS market size.
[9] See Barrieu and Albertini (2009), which details early ILS market development, and https://www.artemis.bm/library/what-are-industry-loss-warranties-ilws/ for more recent indicators of ILW market growth and uses.
[10] Indeed, CAT bonds are arguably the most fitting ILS instrument for novice investors because they are 1) rated and 2) freely tradable by qualified investors. They are also an effective way to enhance the risk-return profile of an investment portfolio.

A CAT bond is a form of ILS wherein a risk-bearing entity (usually an insurer or reinsurer) creates a special purpose vehicle (SPV) to issue the bonds to capital market investors. The SPV invests the proceeds from the CAT-bond sale in a collateral account, generating money market returns. In exchange for consideration (i.e., premiums, or indemnification or guarantee fees), the SPV promises to indemnify or make "payment certain" to the insurer/reinsurer, according to a pre-arranged reinsurance contract should an event of specified severity occur. Repayment of the CAT bonds (including interest payments) are subordinated to the insurer/reinsurer's right to receive that payment, thereby subjecting the investors to a potential loss of principal and/or interest. [Schwarcz, 2022]

Risk securitization via CAT bonds utilizes the global capital markets, thus accessing a far greater capacity than the global insurance and reinsurance markets to absorb catastrophic risks. Polacek (2018) observes that "By attracting alternative sources of capital (e.g., hedge funds, sovereign wealth funds, pension funds, and mutual funds) to compete with traditional reinsurance… CAT bonds exert downward pressure on reinsurance prices (and price volatility) while increasing the total capital available for the transfer of insurance risks."

1.3 Pandemics as a Special-Case Catastrophe Risk

While insurers, reinsurers, and CAT-bond vehicles are important players in the marketplace for catastrophe risk financing, they are reluctant to finance some catastrophe risks. Risks that are subject to catastrophic consequences and/or highly correlated losses are especially difficult to finance in the private market. The potential failure of banks to repay depositors and the exposure to nuclear power accidents are representative of risks that have been considered uninsurable in the private marketplace.[11] Pandemics hold catastrophic global loss potential, solely on the basis of the economic cost of lives lost (Fan, Jamison and Summers, 2017). But pandemics lead to a broader array of economic costs than even this incredible life value loss potential; they may lead to exorbitant health care costs,

[11] The Price-Anderson Nuclear Liability Act of 1957 was enacted to ensure nuclear operators were adequately insured. Pub. L. No. 85-256, 71 Stat. 576. The act required nuclear operators to have the maximum insurance available (then $60 million) and if damages exceeded that level, a second level of government-provided funds was available (up to $500 million). Although the act was subsequently amended to replace the government-funded level with retrospective premiums financed by all American nuclear operators, significant government involvement in the provision of funding to meet the Act's requirements remains. FDIC deposit insurance represents another form of publicly-subsidized insurance. Banks pay the FDIC premiums for government deposit insurance, which protects the banks and their depositors from the risk of "runs." FDIC, *About FDIC: What We Do* (May 2020), https://www.fdic.gov/about/what-we-do/index.html#:~:text=The%20FDIC%20receives%20no%20Congressional,savings%20association%20in%20the%20country.

business interruptions and resultant business income loss, unemployment, and liability losses (primarily in the insurance areas of general liability, marine liability and workers' compensation).[12]

Insurers currently cover certain of the risks associated with pandemics. Standard health insurance policies cover much of the medical costs incurred by employees (and others) who contract diseases, and most life insurance policies cover pandemic-caused deaths (National Association of Insurance Commissioners, 2020). Many pandemic-related risks remain uninsured, though. For example, business-interruption insurance either explicitly excludes pandemic-related disruptions or has been interpreted to condition payments on physical damage causing the disruption. Nor does insurance currently cover all of the increased unemployment or pandemic-related loss-mitigation costs.

1.3.1 Insurability

Risks which are "ideally" insurable possess particular characteristics that dovetail nicely into the comparative advantages provided by the re/insurance industry. Those characteristics include having a large number of exposure units, determinable and measurable losses, and an estimable probability distribution; they also include being subject to fortuitous losses which, if they occur, would be non-catastrophic to the insurer, as well as being insurable at a price that is not prohibitively expensive. Pandemic exposures may not lend themselves ideally to the insurance business model, primarily due to lacking the fortuitous loss and pricing characteristics.[13] Pandemics can occur non-fortuitously—for example, as a tool of bioterrorism—and their losses can be catastrophic, especially if the losses are correlated within and across insurance lines of business, making the insurance price prohibitively expensive.

Insurers do not currently offer insurance that is intended to cover other than the health and life risks associated with a pandemic. The inherent global nature of a pandemic and correlation of losses across insurance accounts and lines of business make pandemics characteristically uninsurable in the private markets (Jaffee and Russell, 1997; Schwarcz and Schwarcz, 2014; The Institutes, 2021). In most cases of uninsurable risks, either the risk-bearing entity retains the risk (albeit typically with some hope of government disaster relief) or governments may provide public insurance programs that either subsidize

[12] See Marsh (March, 2020) "COVID-19: The Impact on the Cargo Industry" available at https://www.marsh.com/ua/en/insights/risk-in-context/covid-19-impact-on-cargo-industry.html.

[13] It also remains questionable whether the probability distributions associated with pandemic risks are reasonably estimable, but this issue is set aside here as a matter of debate among actuaries.

the private insurance marketplace or fully insure the risk as “insurers of last resort” (Skipper and Kwon, 2007).

1.3.1 Market Problems / Externalities

Private insurance markets that include a high potential for catastrophic losses are prone to a variety of problems. Demand-supply inefficiencies are well documented, as are negative market externalities.[14] Combined with the supply-side constraints previously discussed,[15] the individual insurance purchase in the face of disaster potential may be, to some extent, a choice between loss mitigation and insurance.[16] Evidence of an inverse relationship between expectations of government disaster relief and both structural mitigation and insurance demand also have been discovered.[17] The findings of Kaplow (1991), Kelly and Kleffner (2003), and Kunreuther and Pauly (2006) are consistent with the idea that government disaster assistance reduces incentives for individuals to invest in risk reduction or private risk transfer. This demand issue is exacerbated by the inability of many such markets to fully or efficiently price the true cost of the risk within the insurance contract, either due to a suppressive regulatory environment or a prohibitively high premium (Medders, Nyce and Karl, 2014; Klein and Kleindorfer, 2003).

1.4 Securitization-Reinsurance Vehicles for Pandemic Insurance

Given the inherently uninsurable nature of non-fortuitous pandemic risk in the private market, and the difficult problems found in attempts to develop private markets for catastrophic risks generally (even for those risks otherwise deemed insurable by private market participants), it is questionable whether the responsibility for pandemics should be shared solely among private insurers and reinsurers.

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[14] Medders, Nyce and Karl (2014) document the literature on both the supply- and demand-side market problems, and additionally examines the case of the Florida property insurance market in light of these challenges.

[15] See supra note 3 and accompanying text (observing among other things that solvency constraints directly limit the available capacity of the insurance marketplace).

[16] The findings of research regarding the actual relationship between the availability/pricing of insurance and personal investments in risk-reducing activities are mixed; while insurance transfers risk of financial loss from the individual to the insurance company it inherently creates an incentive for insurance companies to develop a pricing scheme that rewards policyholders who mitigate. While the availability of insurance reduces the incentive to make mitigation expenditures, all else the same, insurance prices can be adequately high to encourage mitigation. See Klein and Kleindorfer (2003) for mathematical illustration and additional literature pertaining to the relationship between insurance and mitigation.

[17] Kunreuther and Pauly (2006) outlines the idea that disaster assistance reduces incentives for individuals to invest in risk reduction or private risk transfer, and contains a thorough review of prior literature on the issue.

Furthermore, the one "experiment" to date with pandemic CAT bonds, by the World Bank, was not a fair market test. The private insurance and reinsurance markets are competitively limited to underwriting the risk of reasonably low likelihood, medium-consequence[18] losses. It is the position of this paper, however, that risk-securitization markets are well positioned to spread the financial impact of high-consequence losses across a large number of investors globally.

While the pandemic exposure is not ideally insurable, it is subject to losses both fortuitous and non-fortuitous. Key examples of non-fortuitous pandemic losses are those caused by bioterrorist or war-based (intentional) pandemics and those losses which are individually predictable and preventable once a fortuitous pandemic is in progress. If these non-fortuitous losses are set aside from coverage, what are left are potentially insurable pandemic losses. The key to improving their private market insurability is market capacity. Although ILS broadly helps to improve capacity, CAT bonds are preferred instruments for enhancing capacity due to their collateralized structure as well as their tradability on the secondary markets. This paper, therefore, explores how CAT bonds may operate in an environment of globally catastrophic risks, such as pandemics.

[18] The definition of "medium consequence" is relative. Suffice to say that for the insurance markets generally this means risks subject to occurrences that cannot singularly produce globally catastrophic results.

2 The General Architecture of Risk Securitization

Conceptually, risk securitization via CAT bonds operates as depicted in Figure 1.

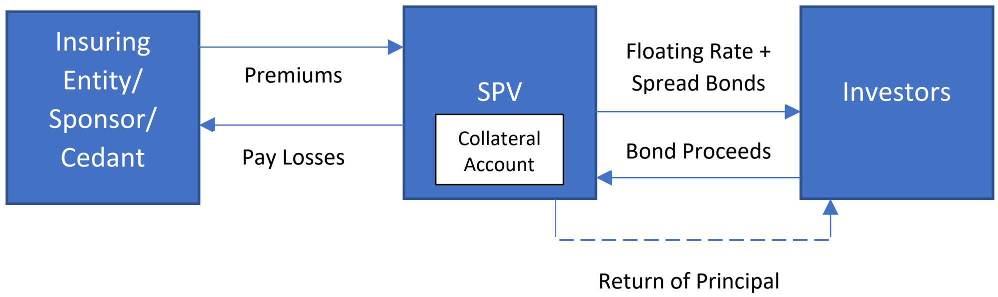

Figure 1. General Structure of a Risk Securitization

An insurance company, reinsurer, government catastrophe fund, or other entity (for simplicity, each a "sponsoring insurer") that wishes to insure parties suffering the catastrophic losses of an extreme event, such as an earthquake or hurricane but potentially including a pandemic, would create an SPV. The SPV enters into a reinsuring agreement with the sponsoring insurer, and issues bonds (or notes) to capital market investors. The bond issue's default provisions would mirror the terms of the reinsurance agreement,[19] and the bond proceeds would be managed in a segregated collateral account within the SPV to generate money market returns.[20] In exchange for premium payments (also known as indemnification or guarantee fees), the SPV—acting effectively as a special purpose reinsurer—would promise to indemnify the sponsoring insurer[21] should the catastrophic event, e.g., a pandemic of

[19] To facilitate such a construction, a nonproportional reinsurance treaty transfers the exposures and the respective premium into the protected collateral account of the SPV. This reinsurance treaty transfers exposure and losses exceeding a specified threshold over a specified period (usually two to four years, and on average three years), and contains detailed clauses regarding the nature of the risk, the responsibilities of the ceding company and the reinsurer, the reporting requirements, etc. (Eves, Fitsch and Müller, 2015). The type of reinsurance contract embedded in the CAT bond can alternatively take the per-occurrence or annual aggregate form. In the per-occurrence case, the CAT bond will only trigger if losses caused by a single CAT event exceed the threshold (or attachment point). In the annual aggregate case, the CAT bond allows for a summation of the insured losses caused by all CAT events in one year that meet the definition of event types that can trigger the CAT bond. (See Beer and Braun, 2021, for more detail.) The CAT bond is valued at the same amount as this agreement when issued, and can only lose money according to the terms of the reinsurance contract. AIR-Worldwide addresses the importance of this relationship between the reinsurance treaty and the CAT-bond terms. See https://www.air-worldwide.com/publications/air-currents/2020/modeling-fundamentals-so-you-want-to-issue-a-cat-bond/.
[20] These money market instruments would be liquid and highly-rated debt securities, including U.S. Treasury money-market instruments.
[21] The operational and legal form of the indemnification could be multifold, including a surety bond or even a credit-default swap (CDS). Generically, however, the indemnification is a basic guarantee. (See Schwarcz, 2020.) If a CDS is used as the indemnification contract, the risk securitization structure would resemble a synthetic

specified magnitude, occur (Polacek, 2018). The CAT bonds would bear interest based not only on the SPV's investment returns but also on its receipt of the premium payments. If no trigger events occur during the risk period, the SPV would repay the principal to investors with the final coupon payment (Polacek, 2018). Repayment of the CAT bonds would be subordinated, however, to the sponsoring insurer's right to indemnification, subjecting the investors to a potential loss of principal and/or interest under those bonds (Polacek, 2018). In this way, risk securitization utilizes the "deep pockets" of the global capital markets, which have a far greater capacity than the global insurance and reinsurance markets, to absorb catastrophic risks (Doherty, 1997a; Doherty, 1997b; Tynes, 2000).

CAT-bond investors are subject to three distinct sources of risk, the first being the insurance risk that, if a covered catastrophic event occurs, they will suffer losses the extent of which are imperfectly known and understood at the time of issuance. The second is the credit risk that the sponsoring insurer may default in paying premiums to the SPV. The third is the investment risk within the collateral account – that the collateral account may produce investment losses or lower-than-expected returns. These risks highlight the importance of data and loss modeling, contract triggers, and credit assessment, which are discussed below.

2.1 Modeled Losses

The insurance risk faced by CAT-bond investors is reduced by understanding the loss potential. Loss potential can be estimated, but of course only with significant residual uncertainty.[22] The insurance risk is comprised of basis risk as well as model risk. The CAT bonds' basis risk is the inherent potential that the CAT bonds are imperfectly matched with the sponsoring insurer's financial loss at stake resulting from the hedged catastrophic event (Barrieu and Albertini, 2009). Unless a CAT bond's indemnity feature pays perfectly according to the sponsoring insurer's incurred and paid losses, a real basis risk is embedded in the bond. The other element of the bond's insurance risk is the model risk, which is separate yet difficult to disentangle from the basis risk (Cummins, 2008; Cummins and Barrieu, 2013). The model risk is the inherent uncertainty associated with the accuracy of modelled losses that are used to price the CAT bond.

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collateralized-debt obligation (CDO) transaction. https://www.investopedia.com/terms/s/syntheticcdo.asp (explaining that transaction).

[22] AIR-Worldwide and RMS, commercial catastrophe modelers having the largest re/insurance market share, acknowledge substantial residual uncertainty: www.air-worldwide.com and www.rms.com, respectively. Numerous academic research papers find wide variations in modeled losses, based on the models used. Iman, Johnson and Watson (2005) and Karl, Medders, and Maroney (2016) provide extensive reviews of this literature.

In the case of rare but severe events, historical loss information has proven unreliable in estimating future loss potential (Rollins, 2005). Stochastic (i.e., probabilistic) catastrophe loss models have been developed that inform insurers and investors about the foreseeable financial impacts of catastrophes and the uncertainty associated with the loss estimates. These models capture how catastrophes behave and impact insurable assets using simulation methods. The model framework primarily includes three components – hazard, vulnerability, and financial (Iman, Johnson and Watson, 2005). The model's hazard component generates events probabilistically in an attempt to capture the frequency, severity, location(s), and other characteristics of catastrophe perils and their occurrences. Exposure data (i.e., characteristics of the properties, people, and/or other elements at risk) are then added to the simulated event output, and the model's vulnerability component estimates the damage to each impacted exposure, based on appropriate scientific assumptions.[23] Insurance policy coverage terms and conditions (such as coverage types, policy limits, deductibles, and other loss-sensitive contract characteristics) are then superimposed onto damage estimates, and the model's financial component estimates the insured losses. The modeled output associated with insured losses typically includes Average Annual Loss (AAL), Exceedance Probability, and Tail Value at Risk (TVaR).[24]

The robustness of the modeling approach, the quality and transparency of the catalog of historic events, exposure data and the underlying modeling assumptions, the ever-evolving technology available to modelers, and the inherent limitations of model validation lead to significant model risk (Barrieu and Albertini, 2009; Karl, Medders and Maroney, 2016). Model risk is difficult to include in insurance and reinsurance pricing, for regulatory and competitive reasons, but may be feasible to incorporate into CAT-bond pricing. CAT bonds are not subject to the stringent regulatory environment that insurance is and, to date, the market for CAT bonds has not reached a competitive level in which adequate pricing is difficult to achieve. Moreover, the utilization of CAT bonds may enhance the ability of insurers to incorporate model risk into their pricing, to the extent the price of the issued CAT bonds is adjusted for model risk and can be passed through to insurance customers.

[23] For natural catastrophes, such as earthquakes, floods, and hurricanes, the sciences used to estimate vulnerability are primarily engineering based. In the case of pandemics, the relevant sciences are certainly more biology based.

[24] AAL is the loss that can be expected to occur per year, on average, over a period of many years; EP is the annual likelihood that a loss of any given size (or greater) will occur in the coming year; TVaR is the expected value (or average) loss beyond a specific exceedance probability. See Karl, Medders and Maroney (2016) for detailed descriptions of these loss outputs and how they are estimated.

Admittedly, the infrequency of pandemics raises doubts about the accuracy of any such risk modeling.[25] The risk modeling of pandemic-related CAT bonds thus may well be as fully informed as possible, but not necessarily fully informed. It therefore is possible that the models overestimate or underestimate pandemic-related risk. In the former case, investors in these CAT bonds may become richer; in the latter case, they may become poorer. If advances in pandemic-loss modeling follow the pattern of the advances made in modeling other perils, pandemic risk models may be better informed in the future than they are today. Nevertheless, they will not necessarily be fully informed.

2.2 Contract Design – The Trigger and Loss Payment Determination

Another factor in the insurance risk inherent in CAT-bond design is the determination of the triggering event and commensurate loss payment (Cummins and Barrieu, 2013; Schwarcz, 2022). The three trigger types commonly used in the CAT-bond market— indemnity, industry loss, and parametric—are described here.[26] There is no consensus as to which is the optimal trigger type; the CAT-bond market swings contingent on whether investor demand or issuer supply is the key market driver. Investors tend to prefer a trigger that provides transparency and does not require re/insurance expertise for bond valuation, while sponsoring insurers benefit more predictably from bonds having payment triggers that are aligned with actual insurer or industry losses. As noted in the discussion below, these preferences can be at odds with one another.

2.2.1 Indemnity Trigger

For an indemnity trigger, the triggering event is an actual loss incurred by the sponsoring insurer following the occurrence of a specified catastrophe event, in a specified geographic region, for a specified line of business (e.g., residential property, business income, commercial general liability). A bond issue of this type requires extensive legal definitions of the key terms, such as the book of business, recognition of loss, and what meets the definition of a catastrophic event (Cummins, 2008). Indemnity transactions and other risk-transfer mechanisms triggered by incurred insurance or reinsurance losses have a clear benefit to the sponsoring insurer. Because the sponsoring insurer's specific loss experience is used as the trigger, the funds recovered from the catastrophe bonds will

[25] See note 21.

[26] A fourth type, modeled loss, is essentially an expansion of the parametric concept and bases the trigger and loss payment on an event (or time period) that reaches a specific modeled loss amount instead of an index function.

match the underlying claims closely, minimizing the insurer's basis risk (the difference between incurred losses and the bond payout).

For investors, indemnity risk-transfer mechanisms make the underlying risk less transparent because they cannot access detailed information on every policy or judge the quality of the sponsoring insurer's underwriting or loss adjusting (Barrieu and Albertini, 2009; Cummins and Barrieu, 2013). Also, indemnity-trigger transactions can take a significant amount of time to settle following a catastrophic event, as the sponsoring insurer must first assess and tally all claims. In some cases, the bonds will remain unsettled beyond their scheduled maturity to allow the sponsoring insurer to total all claims. This limbo period can be detrimental to investors, especially if their funds are locked up at significantly lower rates than during the risk period (Cummins and Barrieu, 2013). Any such detriment would depend on the rate of interest contractually payable during the limbo period.

2.2.2 Industry Loss Trigger

CAT bonds using an industry loss-based structure use the indemnity loss experiences of many companies to determine the industry loss estimate. An industry loss trigger is more transparent than a pure indemnity transaction as first industry loss estimates from modeling companies are usually available within a couple of weeks after the catastrophic event.[27] It can take more time, however, for the official loss amount to be released. The risk of the bonds remaining unsettled beyond their scheduled maturity is roughly at the same level as for a pure indemnity bond, and higher than for a parametric trigger (Cummins, 2008).

In the United States and Europe, there are just two commonly accepted providers of insurance industry loss estimates – Property Claims Services (PCS) and PERILS.[28] Both entities provide estimates of the total loss experienced by the insurance industry after a major catastrophe. CAT bonds based on industry loss triggers operate under the assumption that the sponsoring insurer's portfolio is aligned with that of the industry, and therefore the sponsoring insurer recovers a percentage of total industry losses.

[27] See https://www.verisk.com/insurance/products/property-claim-services/pcs-catastrophe-loss-index/ for loss information timing details.
[28] See https://www.verisk.com/insurance/products/property-claim-services/pcs-catastrophe-loss-index/ and https://public.catiq.com/ for details on the quantification of catastrophe loss indices provided by PCS and PERILS, respectively.

2.2.3 Parametric Trigger

Parametrically-triggered CAT bonds use the event characteristics of a catastrophic occurrence as the trigger (e.g., category level and windspeed of hurricanes, location and peak ground acceleration of earthquakes). Most parametric triggers are based on an index of the event parameters whereby appropriate weights are applied to measurements from a larger area, which is designed to match the actual losses expected for the sponsoring insurer's business (Cummins, 2008; Barrieu and Albertini, 2009). Immediately after a catastrophic event, the parameters of the event are entered into an index formula, where the calculated index is a function of

$$Index = f(w_i, v_i),$$

where w_i are predefined weights set at the CAT bonds' time of issuance in line with the distribution of the sponsoring insurer's exposure, and v_i are the values of the relevant event parameters.

Because event parameters are available immediately post event, parametric transactions are settled more quickly than other trigger types, and the risk of the bonds remaining unsettled beyond their scheduled maturity is reduced (Cummins, 2008). However, because parametric triggers are not directly related to insured loss, parametric triggers entail a higher basis risk than do indemnity or industry loss triggers. To ameliorate this risk, the indices used in the bond trigger may be finely tuned to the sponsoring insurer's exposure (Barrieu and Albertini, 2009). For investors, parametric triggers offer much more transparency than indemnity triggers because only the hazard probabilities need to be understood, rather than the hazard, damageability, and financial probabilities.[29]

2.3 Credit Risk, Investment Risk, Credit Ratings, and Pricing

By reducing the assets available to pay the CAT bonds, a sponsoring insurer's default in paying premiums to the SPV would impact the value of the bonds to investors (Liu, Xiao, Yan, Wen, 2014). This risk as well as techniques for mitigating it, are discussed here.

2.3.1 Credit and Investment Risk

As stated previously, CAT-bond insurance risk is accompanied by some amount of credit and investment risk.[30] Credit risk is present because the sponsoring insurer, as counterparty to the SPV, could fail to pay

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[29] These probabilities are calculated and utilized within the hazard, vulnerability, and financial modules of a catastrophe loss model, respectively, to determine the AALs, exceedance probabilities, and TVar.

[30] Documentation and legal risk, also present in CAT-bond transactions, refers to risks associated with the SPV's

its premiums to the SPV when due. This counterparty risk is considered a relatively low risk by rating agencies, however, since insurer solvency is closely monitored and regulated (The Institutes, 2021). Investment risk also exists to the extent that the SPV's investments could lose value. Investors want to be sure that the investment restrictions on the collateral account provide sufficient protection so that they can be reasonably confident in the return of their invested principal absent a bond-triggering event.[31] This risk likewise should be low because the SPV invests to achieve money-market returns. Low expected rates of return accompany a low risk to the principal, and could result in a loss of time value to the principal, particularly in the case of a protracted limbo period. Investors may require a minimum rate of interest to be payable during any post-loss limbo period, to at least match the rate of inflation.

2.3.2 Credit Ratings and Credit Enhancement

A CAT-bond issue's rating is impacted by the bonds' insurance, credit, and investment risk elements. The catastrophic event trigger selected, the likelihood that CAT-bond investors suffer losses,[32] the sponsoring insurer's default (credit) risk, and the riskiness of the collateral account's value (the investment risk) are all key factors supporting the transaction's rating.

The mitigation of the credit risk is achieved primarily through the aforementioned investment restrictions on the collateral. Additionally, credit enhancement, possibly by issuing differing internal-priority classes of CAT bonds under a senior-subordinate structure, could broaden the capital-market investor base by making CAT bonds more appealing to highly risk-averse investors (Schwarcz, 2009; Schwarcz, 2022). To create a senior-subordinate structure to credit enhance CAT bonds, the SPV would issue two or more classes (or "tranches") of CAT bonds, with any reduction of the SPV's assets being absorbed by the different classes in sequence—with the most senior-priority bonds being paid first out of the remaining assets, and the most subordinated-priority (sometimes referred to as "junior") bonds

special purpose organization and bankruptcy remoteness (see Moody's Investor Service, 2020).

[31] The significance of the collateral structures was highlighted by the Lehman Brothers bankruptcy. Originally, the typical CAT-bond structure used a Total Return Swap (TRS) by which the counterparty guaranteed that the SPV would receive a return equivalent to the London Inter-Bank Offered Rate (LIBOR) on its investments in the collateral account. Lehman Brothers was the TRS counterparty for four of 119 active CAT bonds in the market at the time of its collapse; while only a small number of bonds was affected, this caused the market to focus on the safety of underlying assets and design new, more conservative collateral structures that further decreased the counterparty risk. See Barrieu and Albertini (2009) and Cummins and Barrieu (2013).

[32] The more remote the probability of CAT-bond losses (also known as attachment in re/insurance) and exhaustion, the higher the credit rating.

being paid last (Schwarcz, 2009; Schwarcz, 2022). The goal of this structure is to protect payment of—by effectively overcollateralizing—the senior CAT bonds.

Although SPVs issuing CAT bonds sometimes use senior-subordinate structures to provide credit enhancement, they tend to refer to them using insurance industry terminology for allocating insurer risk, typically by assigning different attachment and exhaustion points. Assume, for example, that an SPV issues two classes of bonds to allocate the insurance risk among bondholders, enabling bonds of the less risky class to obtain a higher credit rating than would otherwise be achieved by issuing a single class of bonds. If and when a triggering event occurs, requiring an insurance-indemnification payout, the money used by the SPV to make that payout will first be drawn from the funds allocated to repay the more subordinate class of bonds. That first loss is the attachment point of those bonds. The SPV will continue to make payouts from the funds allocated to repay the more subordinate class of bonds until those funds are exhausted, and thus there is no money left to repay those bonds. That is the exhaustion point for those bonds. Any money thereafter used by the SPV to make insurance-indemnification payouts necessarily will be drawn from the funds allocated to repay the more senior class of bonds—and that is that class's attachment point. All else being equal, rating agencies should assign higher ratings to senior tranches of CAT bonds than to subordinated tranches because the former are less risky (Schwarcz, 2022).

2.3.2 Pricing

From an investor's perspective, the main attraction of CAT bonds is that they provide relatively higher yields on a diversifying asset class (Nowak and Romaniuk, 2013). Unlike traditional reinsurance, catastrophe bonds can be traded on a secondary market, introducing characteristics generally associated with fixed income securities, such as duration, discount margin, and yield to maturity (Cummins, 2008). The yield of a bond can be divided into two components: risk-free interest rate (government bond yield) and credit spread.[33] Credit spread of a corporate bond is affected by the default risk (expected loss of principal) and the risk premium required by investors for taking this risk. Highly leveraged companies are riskier, implying higher probability of default, and therefore their bonds provide higher credit spreads (Liu, Xiao, Yan, Wen, 2014).

The premiums a buyer of reinsurance or sponsoring insurer of a CAT-bond issue must pay are generally fixed; however, the spread achieved by an investor depends on the price as well as the bond's coupon

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[33] The credit spread is the difference between the yield on a bond and the yield on a matched maturity government bond (Cummins, 2008).

payment stream. Specifically, the spread achieved by investors is inversely related to the price of the bond. CAT-bond spread is a function of modeled expected loss (or AALs) and risk premium. The risk premium is the required margin. The risk premium or margin is a function of exposure category or zone and modeled AALs (Barrieu and Albertini, 2009). Additionally, changing perceptions of risk and relative value considerations mean that the risk premium changes over time. Moreover, given comparable loss costs, the market demands a higher margin for complicated, or less homogeneous risks, such as business interruption and income versus direct commercial property risk (Taylor and Weinkle, 2020). Higher uncertainty in estimating expected loss for complex risk results in the market demanding higher margin.

The risk premium (and therefore, spread) is also influenced by the competitive market cycles in re/insurance (Taylor and Weinkle, 2020). In a soft market, the cost of coverage drops, while in a hard market it rises. Historically, hard markets have followed years with significant loss activity resulting in depletion of reinsurance capital. Sometimes this increase is localized to a specific area impacted by loss, while at other times it can raise the cost of reinsurance across the entire market. The spread can also shift due to a change in perception of expected loss. For example, during a very active hurricane season or when a hurricane is approaching the U.S. coastline, the market perceives a higher probability of loss. In these types of scenarios, the spread widens due to increase in expected loss. Finally, in recent years, broader market trends have had a significant influence on the price of risk (risk premium) and consequently catastrophe bond spreads.[34]

3 The Market for Risk Securitization

3.1 Potential Market for CAT Bonds

Re/insurers account for the largest volume of catastrophe bond issuance. Insurance company capital adequacy requirements have overall become more stringent at a time when insurers have faced several years of high claims, and when economic contraction could lead to declining insurance premiums. As a result, a future large catastrophe could result in losses that exceed the current capital capacity of the industry. This provides a market opportunity for significant CAT-bond growth.

[34] Spreads can also widen during periods of extreme economic turmoil, unrelated to natural catastrophes.

Global insured losses have been high in recent years. In 2020, the estimated insured loss from natural disasters worldwide was $30 billion.[35] The aggregated, inflation-adjusted insured losses in 2017 due to Hurricanes Harvey, Irma, and Maria in the U.S. and Caribbean were $92 billion, the most expensive in history.[36] Record insured losses from other 2017 and 2018 natural catastrophe events magnified the impact.[37] As a result of the increased demand, several 2020-21 CAT-bond issues came to market with spreads at all-time highs,[38] and current supply-and-demand dynamics may support even wider CAT-bond spreads.

If the collateral still being held from the last few years' loss events limits the availability of ILS capital needed for retrocession,[39] reinsurers may turn instead to ILWs and CAT bonds. Furthermore, in today's hard insurance market,[40] investors can demand more attractive bond design, which for them means favoring greater transparency and model clarity and refinements in contract language than is attainable in a soft market, without losing attractive pricing. In addition, new perils, regions, and sponsors continue to come to market. During 2020 alone, stand-alone flooding, stand-alone wildfire, and more granular parametric CAT bonds (e.g., California earthquake) were issued. The hard market makes it more likely that maturing CAT bonds will be replaced, potentially at higher pricing, especially given that the market is currently harder than it was in 2017 and earlier.

ILS is one of the very few genuinely, structurally diversifying asset classes, where valuations are determined by the frequency and severity of natural catastrophes rather than by macroeconomic,

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[35] See https://www.statista.com/statistics/612561/natural-disaster-losses-cost-worldwide-by-type-of-loss/ and https://www.munichre.com/en/company/media-relations/media-information-and-corporate-news/media-information/2021/2020-natural-disasters-balance.html for the loss statistics.

[36] To put these losses in perspective, the $92 billion aggregate represents 0.5% of U.S. GDP (see https://www.swissre.com/media/news-releases/2018/nr20180410_sigma_global_insured_loses_highest_ever.html). Domestically in the U.S., Hurricane Katrina in 2005 still stands as the most expensive single natural catastrophe event in history at an inflation-adjusted $41 billion in insured losses (see https://www.statista.com/statistics/612561/natural-disaster-losses-cost-worldwide-by-type-of-loss/ and https://www.swissre.com/dam/jcr:a835acae-c433-4bdb-96d1-a154dd6b88ea/hurrican-katrina-brochure-usletter-web.pdf).

[37] For example, insured losses from wildfires globally were $14 billion in 2017, the highest ever in a single year (Swiss Re Institute, 2018).

[38] By late November the spreads were the highest seen since 2012-13 and by early 2021 had begun to surpass the 2012-13 excess spreads (see https://www.artemis.bm/news/catastrophe-bond-spreads-back-at-their-highest-since-2012-13/).

[39] Retrocession is catastrophe protection for reinsurers. See infra note 44 (and see https://www.artemis.bm/news/trapped-ils-collateral-expectations-rising-with-cat-frequency-covid/ for a discussion of trapped collateral).

[40] A hard insurance market is a recurring part of the competitive insurance cycle found in the property-liability re/insurance market, and is the state of the market today (WillisTowersWatson, 2021).

political, or financial-market events (Cummins and Barrieu, 2013).[41] CAT bonds offer a transparent, liquid way to gain exposure to this diversification potential, along with a history of positive returns. In the near term, the combination of attractive pricing following several years of high insurance losses and structural supply-and-demand dynamics may sustain CAT-bond spreads at attractive levels for investors. Moreover, growing this market offers more scope for diversification and portfolio customization via different exposures (e.g., geographies, perils, and trigger designs) and also enhances market liquidity.

3.2 Realized Market for CAT Bonds

In addition to reasons already given, re/insurers and similar risk-bearing entities have traditionally been attracted to issue catastrophe bonds because of their relatively long-term duration, versus reinsurance and other ILS risk-transfer methods which typically are limited to one-year terms. Also, reinsurance pricing is highly volatile in response to fluctuating losses, while the portion of a CAT bond's pricing that is based on the insurance risk is locked in for multiple years.[42] Insuring entities have overall increased their use of CAT bonds as part of their reinsurance programs. The Texas Windstorm Insurance Association (TWIA), for instance, renewed its reinsurance program in 2021, with three-year CAT-bond coverage now making up $1 billion (approximately 57 percent) of the $1.93 billion overall program.[43]CAT bonds have also traditionally been issued by reinsurers seeking retrocessional protection.[44] Committed reinsurance capital totaled $658 billion in 2020, and is expected to increase in 2021 (WillisRe, 2021). Record-high reinsurance capital at risk, combined with record-high catastrophe losses in recent years, suggests that reinsurers may increasingly look for ways to transfer risk to willing investors. Forty-six new property CAT bonds (those triggered by insured property losses) were issued in 2020, which is double the 23 transactions completed in 2020. The net rise in risk capital outstanding in property CAT bonds was

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[41] See https://www.nb.com/en/global/insights/white-paper-catastrophe-bonds-natural-diversification for recent evidence of CAT bonds as an investor diversification asset class.

[42] Catastrophe bonds are issued as floating rate securities, in which the investor receives an indexed return that is intended to compensate investors for holding their money and is not affected by the insurance risk. It resets periodically based on the prevailing short-term interest rates. The spread of a catastrophe bond is intended to compensate investors for the embedded insurance risk. See Patel (2015) for a detailed treatment of the spread.

[43] TWIA doubled the size of its Alamo Re Ltd. (Series 2021-1) CAT-bond transaction from an initial $250 million to $500 million as part of its 2021 reinsurance renewal. The multi-year, annual aggregate and indemnity-triggered reinsurance protection protects against the potential for one or more losses from named storms and severe thunderstorms in Texas (see https://www.artemis.bm/news/twias-2021-reinsurance-tower-is-57-multi-year-catastrophe-bonds/).

[44] Retrocession is catastrophe protection for reinsurers. There was an uptick in retrocessional CAT-bond issuance in late 2020. Given the complexity and limited transparency of reinsurance risk portfolios, most of these issues utilized parametric triggers. See https://www.artemis.bm/artemis-ils-market-reports/ for the Artemis Q4 2020 Catastrophe Bond and ILS Market Report for market transaction details.

estimated at approximately 2 percent during 2020, with the property CAT-bond market nearing $30 billion in-force at the end of the year.[45]

Over the decades since catastrophe bonds emerged, they have expanded and broadened in their design and use. In recent years, new participants have accessed the market. The World Bank with its developing and emerging markets programs, as well as its more recent (albeit shortlived) PEF program, became an active participant in CAT-bond issuance. Coverage to date has included earthquake and windstorm events in Mexico and the Philippines, earthquakes in Peru, Mexico, Colombia, and Chile,[46] and even the global pandemic bonds that paid out in the second quarter of 2020. The World Bank CAT bonds have interesting implications for the use of catastrophe bonds by government agencies and as a potential component of socially responsible investing. Growth is also coming from more participants seeking to cover entity-specific risks to which they are exposed, including New York's Metropolitan Transportation Authority, Bayview Asset Management, which was hedging its residential mortgage book, and Alphabet, seeking to protect its corporate real estate assets.[47]

3.3 Is There a Market Gap?

The market for CAT bonds is growing, yet the question of whether (and if so, why) there is a market gap remains important. A gap presumes, in this context, that a market need for retrocessional protection exists that is not being met with willing risk capital. This is indeed the case for the CAT-bond market for at least two fundamental reasons. First, on the demand (issuer) side, an insurance market gap persists globally; CAT bond transactions – largely a function of the re/insurance capital at risk – are therefore still smaller in size (possibly less numerous as well) than would be expected from deeper insurance penetration. Second is a supply-side issue: barriers to investor entry are substantial.

Insufficient insurance penetration is no small matter. In 2020 alone, the estimated overall economic loss from natural catastrophes amounted to $75 billion, as compared with the $30 billion in insured losses. Swiss Re estimated in 2018 the global market gap to be a record $1.2 trillion across natural catastrophe,

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[45] See https://www.artemis.bm/news/positive-cat-bond-market-momentum-to-continue-in-2021-aon-securities/ for these statistics and examples of deals transacted.
[46] See https://riskcenter.wharton.upenn.edu/lab-notes/uniting-disaster-risk-transfer-with-sustainable-development/ for details.
[47] See https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/new-york-mta-sponsored-cat-bond-settles-at-top-end-of-price-guidance-8211- artemis-58543485; https://www.swissre.com/media/news-releases/nr-20200113-swiss-re-capital-markets-structures-places-the-first-parametric-earthquake-catastrophebond.html; and https://www.artemis.bm/news/alphabets-googles-first-catastrophe-bond-priced-on-target-at-237-5m/ for more information on each of these recent CAT-bond issuances.

mortality, and healthcare insurance (more than double the gap in premium-equivalent terms in 2000). The biggest gap in financial terms is the healthcare insurance gap, followed by natural catastrophe insurance. But natural catastrophe risk has the lowest level of coverage in percentage terms, at 24% globally.[48] Indeed, the 2011 earthquake and tsunami in Japan caused the most economic damage worldwide during the 1980-2018 period, but its insured losses were dwarfed by Hurricane Katrina in 2005.[49]

Even where alternative risk-finance markets are active, wherein CAT bonds might provide substitute capital to cover insurance risk—and despite the potential demand (whether from insurers or idiosyncratic risk bearers[50])—barriers to entry for CAT-bond investors remain relatively high when compared to investors in other fixed-income securities. CAT bonds sometimes lack the specialized modeling resources that are crucial for portfolio design/ construction and risk management to strike a balance between diversification and compensation.[51]

3.4 A Market for Pandemic CAT Bonds

Given the supply-demand challenges of the CAT-bond market generally, the basic economic hindrance to achieving an effective CAT-bond market for pandemic risk coverage (PCAT market) is developing a sufficiently large investor market for PCAT bonds to enable businesses to purchase adequate pandemic-insurance coverage (Schwarcz, 2022). The CAT-bond market today – despite its growth – is quite small compared to the U.S. government's $2.2 trillion bailout package for COVID-19 or its $750 billion bailout package during the global financial crisis (Schwarcz, 2022). Developing a large enough market for PCAT bonds almost certainly will necessitate that the U.S. government (and possibly other sovereigns) bear some significant portion of the bond risk (Schwarcz, 2022).[52]

[48] This percentage coverage is based on the ratio of insured to economic losses (see https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/protection-gap-persists-across-insurance-world-despite-some-progress-56236161).

[49] See https://www.statista.com/statistics/612561/natural-disaster-losses-cost-worldwide-by-type-of-loss/ for precise figures and comparison.

[50] Given that the catastrophe bond market can be used to structure protection for a range of risks, the demand for such idiosyncratic coverage could grow significantly.

[51] Multi-strategy hedge funds and retail-focused intermediaries, for instance, may find the risk-return features of CAT bonds appealing, although the market presents significant barriers of entry to novice investors.

[52] Insurance Council of Australia's Insuring for Pandemics Study 5 (July, 2020), for example, concludes that because pandemic "risk violates most principles of insurability," especially insofar as the "magnitude of the losses is significant, well in excess of insurance sector capital," global "aggregation of loss means risk cannot be diversified (a key tenet of insurance mathematics)," the "premiums would be high, and most likely unaffordable," and the "losses are hard to define" and "(at least currently) are not calculable prior to a pandemic occurring," a "traditional private sector insurance risk transfer solution to address pandemic risk [is] effectively impossible at this time."

3.4.1 What Level of Pandemic Insurance Should Businesses Purchase?[53]

The amount of liquidity needed to help businesses survive during a pandemic seems like a sensible way to determine the minimum amount of pandemic insurance needed. Assessing that amount of liquidity depends in large part, however, on the length of the pandemic and its impact on the ability of businesses to continue operating during its continuance. As evidenced by COVID-19, it is difficult ex ante to predict the length of a pandemic. Furthermore, the impact on a business's ability to continue operating during a pandemic depends not only on the severity of the pandemic but also on the nature of the firm and applicable government public-safety measures. During the COVID-19 pandemic, for example, pharmacies, grocery stores, and gas stations were deemed essential and allowed to operate whereas restaurants and bars were closed or allowed only limited operations.[54] Even businesses deemed to be essential suffered some interruption due to the need to satisfy government health and safety requirements and customer expectations, including purchasing additional cleaning supplies and sufficient quantities of masks and gloves for employees and providing appropriate store signage.[55]

Given these and other potentially indeterminate variables, this paper does not attempt to calculate the amount of pandemic insurance that should be purchased. Rather, the paper references coverage numbers that have been proposed by others. The most notable example is the $1.150 trillion program of pandemic business-interruption insurance recently proposed by Chubb.[56] Chubb explains this number as the sum of small business liquidity needs, estimated at $750 billion, based on a 14-day waiting period

"Government policy [therefore] plays an important role in structuring solutions" because "principles of insurability are not satisfied." *Id*. *Cf*. Weinberger, *supra* note **Error! Bookmark not defined.** (reporting that the "federal government is likely going to have to provide some sort of global [pandemic risk] coverage, most insurers say" and also observing that both a federal congressperson proposing legislation and a leading private insurer "envision a program where insurers offer pandemic coverage policies to businesses with the federal government bearing most of the coverage costs").

[53] Sections 3.4.1, 3.4.2, and 3.4.3 of this paper are based on Schwarcz, 2022.

[54] *See, e.g.*, N.Y. Exec. Order No. 202.6 (March 7, 2020), https://www.governor.ny.gov/news/no-2026-continuing-temporary-suspension-and-modification-laws-relating-disaster-emergency.

[55] *See, e.g.,* Nathaniel Meyersohn & Sara Ashley O'Brien, *Stores are scrambling to get marks for their workers. It's no easy task*, CNN (last updated April 5, 2020), https://www.cnn.com/2020/04/05/business/masks-workers-amazon-instacart-walmart-lowes/index.html; Daniella Diez et al, *Protective equipment costs increase over 1,000% amid competition and surge in demand*, CNN (last updated April 16, 2020), https://www.cnn.com/2020/04/16/politics/ppe-price-costs-rising-economy-personal-protective-equipment/index.html.

[56] By comparison, the proposed "Black Swan Re" program from Lloyd's of London calls for a broader government and insurance industry reinsurance pool for business interruption insurance that goes beyond pandemics (Lloyd's of London, 2020). It would cover non-damage business interruption arising from a variety of systemic and catastrophic events. Under such a plan, industry pooled capital would cover future systemic events, with government guarantees to pay out if the pool ever had insufficient funds.

and a multiple of three-month payroll expenses, plus large and medium business liquidity needs, estimated at $400 billion (Chubb, 2020). The discussion on market size below begins with that number.

3.4.2 What is the Size of the Market for Pandemic CAT bonds?

Assuming that collectively businesses should be required to purchase at least $1.15 trillion of pandemic insurance, that same order of magnitude of PCAT bonds would need to be issued to indemnify the providers of that insurance. The estimate of the portion of those bonds that can be sold to investors will depend, in part, on their credit rating and their interest rate.[57] The interest rate in turn will depend in part on the premiums that businesses pay to insurers for the pandemic insurance,[58] and thus the premiums that insurers pay to the SPVs for their indemnifications.[59]

Other things being equal, investors naturally will want the most senior priority with respect to other bondholders as well as the highest interest rate. There is a market balance, though: the higher the priority (and thus the higher the credit rating, which should correlate with the priority), the lower the repayment risk and thus the lower the relative interest rate that the bonds need to bear to attract investors (Corporate Finance Institute, 2020).

Because of the inherent uncertainty as to likelihood, severity, and length of future pandemics, some capital market investors may demand a relatively high interest rate—perhaps even compared to similarly rated non-PCAT bonds—to induce them to purchase PCAT bonds. PCAT bonds, on the other hand, would provide investors with a diversified return. Furthermore, investors may discount pandemic-related risk on the basis that society is learning from COVID-19 and thus better prepared to endure the next pandemic with less severe disruption. If so, that might limit the bond payouts and the corresponding loss to PCAT-bond investors.

To increase the market for PCAT bonds, it could help to implement a senior-subordinate structure to provide credit enhancement. Such a structure would increase investor demand by allocating the senior bonds to more risk-averse investors and the more junior (that is, subordinated) bonds to higher-risk

[57] That, in turn, will depend on whether investors take a first-loss, second-loss, or *pari passu* position with respect to other bondholders, including the government.

[58] It should be noted that small and medium-sized businesses are more subject to pandemic-related risk than large businesses. See Kwak (2020, July 9) arguing that large businesses like Amazon and Walmart have a competitive advantage in pandemics over small businesses, which do not have the resources to build new systems for curbside pick-up and safe delivery of goods.

[59] These amounts are correlated because the premiums are passed through to help pay interest on the SPV's PCAT bonds.

investors. Also, if the U.S. government were to purchase even more deeply subordinated PCAT bonds to make up any investor shortfall, that would create a second senior-subordinate structure—in this case, between the capital market investors and the government—which would further credit enhance those investors and even further raise their willingness to invest.

In theory, capital market investors potentially could purchase a significant portion of the approximately $1.15 trillion of PCAT bonds. The capital markets are estimated at roughly $180 trillion, with the fixed-income portion—the portion representing bonds—estimated at roughly $106 trillion (Lloyd's of London, 2020). PCAT bonds—assuming a market of $1.15 trillion—would represent just one percent of outstanding bond investments and would likely be appealing to a reasonable portion of capital market investors, even if only for diversification purposes. Any estimate of the principal amount of PCAT bonds that capital market investors would be likely to purchase would depend on a range of variables, to be discussed in Section 4.

3.4.3 To What Extent Should Government Share in the Shortfall, and How Should it Share the Risks?

Neither pandemic-risk insurance nor a PCAT-bond market may yet be commercially feasible without the government bearing at least some portion of the risk. To that end, the federal government almost certainly would have to purchase any shortfall between the principal amount of PCAT bonds that would need to be issued to indemnify the insurers and the principal amount of those bonds that could be sold to capital market investors. If insurers were to fully cover pandemic-related risk, the high end of that shortfall might be in the hundreds of billions of dollars, thereby calling for a public-private partnership in which the U.S. government covers the lion's share of the cost.[60] The rationale, according to Chubb, is "that only the federal government has sufficient resources to meet the full extent of pandemic loss, which is not insurable in the private sector."[61]

A more limited version of a public-private partnership could start with lower pandemic-related risk coverage and thus a much lower shortfall that the government would need to cover. If, for example, businesses were required to purchase $10 billion in pandemic insurance (rather than the suggested

[60] Chubb, for instance, proposes that the U.S. government assumes approximately $1 trillion dollars of pandemic-related risk under a public-private partnership, wherein it covers, for small businesses, at least 88 percent of the first $250 billion layer of losses and all of the next $500 billion layer of losses; and, for large and medium businesses, $400 billion of losses less the losses covered by private insurers, which would be limited to $15 billion in the first year and $30 billion by year 10 of the program. That could be as much as 0.88 x $250 billion + $500 billion + $400 billion - $[15/30] = $[220 + 500 + 400 – {15/30}] = between $1.090 trillion and $1.105 trillion (see Chubb, 2020).
[61] Id. at 3.

$1.150 trillion), at most $10 billion principal amount of PCAT bonds would need to be issued to indemnify the providers of that insurance.

An alternative option for federal government participation is that the government might guarantee the PCAT bonds to the extent necessary to motivate capital market investors to purchase all of the bonds, thereby ameliorating the market's exposure to a shortfall. Government risk-sharing through a guarantee might be more politically acceptable because it would not require an initial outflow of funds. Risk-sharing under the Price-Anderson Act, for example, effectively took the form of a federal government guarantee.[62] A guarantee may also be more politically economical because guarantors are influenced by abstraction bias (Schwarcz, 2021). While the business of virtually all financial firms and other investors entails a capital outlay at a project's commencement, such as a bank that makes loans or an investor who buys stocks and bonds, financial guarantors do not actually transfer their property at the time they make a guarantee. This can cause them to view their risk-taking more abstractly and to underestimate the risk, even after discounting for the fact that payment on a guarantee is a contingent obligation (Schwarcz, 2021).

4 Closing the Gap between the Potential & Realized Market for Risk Securitization

4.1 A Market for PCAT Bonds

Today, the market for PCAT bonds is quite limited for several reasons. On the supply side, insurers and reinsurers need to issue CAT bonds for only those risks that they (re)insure. As noted in prior sections, the private insurance market for economic losses due to business interruption from pandemics is sparse; relatively few businesses have coverage, and the amount of coverage that is purchased is low relative to the potential size of losses. Prior to COVID-19, demand for such insurance coverage was limited by widespread underestimation of pandemic risk by businesses, and supply was limited by a hesitation on the part of (re)insurers to commit significant capital to the risk. Few products designed to specifically address the risk of pandemics have ever been brought to market by property-casualty (P&C) (re)insurers. Consequently, a large gap exists between the economic consequences associated with

[62] Risk-sharing under the Price-Anderson Act, for example, effectively took the form of a federal government guarantee, given the government $500 million of protection under the Act for nuclear-reactor accident risk would be payable contingent upon the industry-provided $60 million first-loss position becoming depleted.

pandemics and the immediate ability of the P&C insurance industry to provide products to address those consequences.

Focusing on pandemic-related business continuity (i.e., business interruption) losses alone, Hartwig and Gordon (2020) estimate such losses across all businesses in the U.S. at $1 trillion per month, while at year-end 2019 the total capital resources (measured by policyholder surplus) of the U.S. property–casualty insurance industry were approximately $800 billion, representing a $200 billion hypothetical shortfall in paying for even just one month of these pandemic-related losses. Further bearing in mind that (re)insurance capital must be sufficient to cover all reasonably foreseeable risks – also including those that are unrelated to pandemics – insurance industry strategies aimed at providing business interruption coverage for pandemics would necessarily entail high levels of cost sharing with PCAT bond investors and/ or government.

The finite nature of (re)insurance capital is easily apparent given the large-scale risks to which P&C insurers are already exposed. These include primarily property, commercial liability, and workers' compensation risks. Catastrophic property-loss exposure requires that significant (re)insurance capital be reserved in the event of multiple concurrent natural disasters. Commercial liability loss exposures in the U.S. continue to be problematic for insurers and are considered large in scale because of substantial shifts in the frequency and severity of loss that can occur over a short period of time. Workers' compensation exposure is a large-scale risk due to the federal coverage mandate, and its losses can be expected to correlate with pandemic events.[63] Excess morbidity and mortality associated with a pandemic would further strain reinsurance markets because of reinsurance loss-sharing in the life and health insurance markets.[64]

Setting aside the potential for insurance market problems related to offering pandemic coverage (to be discussed later in this section), the (re)insurance need for capital access provides a risk-securitization demand and opportunity if P&C (re)insurers are to develop a sustainable market for pandemic insurance coverage. For the reasons discussed above, this paper asserts that business interruption insurance coverage is the prime P&C insurance and PCAT bond investment opportunity.

[63] The frequency rate of worker illnesses may increase or decrease during a pandemic. For employers that remain open for business on an "in person" basis during a pandemic, one can easily imagine higher rates of worker illnesses and a resultant higher utilization of workers' compensation insurance. On the other hand, loss "offsets" (inverse loss correlations) may also occur as there will be reduced workplace exposure to illnesses in many industries and jurisdictions due to business shutdowns and/or movement to remote working operations.

[64] Unlike the P&C insurance market, the life-health insurance markets have not historically excluded coverage for losses due to illnesses caused by epidemics or pandemics.

The keys to a future viable and sustainable PCAT bond market are to attract investors, offering expected rates of return that are acceptable, subject to a remote possibility of loss, and to the extent these returns are correlated with those of other assets, also to develop feasible asset-hedge opportunities.

4.1.1 CAT Bond Risk Pricing and Spreads

A starting point for an analysis of the market for PCAT bonds is to consider the market and pricing for CAT bonds more broadly. All else the same, CAT bond prices are lower than those of other government and corporate bonds.[65] The pricing of these securities is generally made up of two components, a spread (or margin) above the risk-free rate to cover the insurance risk and the underlying risk-free rate to compensate investors for the time value of their money. The spread component is equivalent, and directly comparable, to the traditional catastrophe reinsurance layer cost expressed as a "Rate On Line" (ROL).[66]

Formulaically, the CAT-bond spread is derived within a risk-pricing framework that deals with both systematic and non-systematic risk. The formula is as follows: Spread = $(EL)^{(1/\rho)}$, where

EL is the Expected Loss expressed as a percentage, and $\rho \geq 1$, is a Risk Aversion Level (RAL).[67] In practice, the spreads on CAT bonds (and other ILS) issued to date have been significantly higher than similarly rated corporate bonds. Taken at face value, the loss characteristics of CAT bonds are similar to those of corporate bonds; an event triggers a loss that in turn results in a total or partial loss of capital. The only differences are in what causes these events and what determines how much of the capital is actually lost. The simple explanation is that non-CAT bonds investors only risk loss of principal and interest in the event of bond default whereas CAT bond investors technically are subject to losing principal and interest

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[65] Nowak and Romaniuk (2013) provide thorough theoretical and numerical treatment of this price discounting, and show consistency of the discounting across a variety of bond designs, market assumptions, and loss distributions.

[66] ROL is the ratio of premium paid to loss recoverable within reinsurance contracts. A 5% ROL means the insurer must pay 5% of the reinsurer's loss exposure as premium for the reinsurance purchase. Some of the expenses of issuing a CAT bond, such as legal fees, modelling agency fees, etc., are explicit and are not included in the spread. On the other hand, reinsurance/retrocession premiums make implicit allowance for the company expenses.

[67] Wang (2002) presents the risk-pricing formula and develops a robust model for estimation of ρ, the bond's riskiness.

due either to default or a triggering CAT event.[68] This higher investment risk is compensated by a commensurate higher expected rate of return.

Despite the straightforward differences in concept, the historical risk-pricing difference between CAT bonds and non-CAT bonds is not as straightforward as one might think. The spreads for CAT bonds have averaged just over 5% (or 500 basis points), making them appear quite attractive from an investor's perspective, given that the underlying expected losses are less than 1% (equivalent to 5X multiple over expected losses).[69] Over the same 25-30 years, U.S. high-yield corporate bonds have attracted spreads of 3% to 4% (300 to 400 basis points), and have generated losses, as a percentage of capital, of around 3%.[70] While these corporate bond investors have broken even over this period, they have experienced substantial volatility as well. Indeed, 2021 pricing to date indicates that high-yield bond investors are currently willing to accept spreads below 2%.[71] The rationale behind the pricing and spreads of these securities is not explicit, and one can only assume it is what the market is prepared to accept. The spreads for the CAT bonds issued to date are almost indistinguishable from the ROLs for the equivalent catastrophe reinsurance layers. In essence, what has been transferred to the capital markets is the inefficient pricing requirements of insurers and reinsurers, primarily due to their need for capital access rather than to any inability to aggregate risks adequately. Indeed, (re)insurers are the consummate aggregators of risk, as they specialize in bundling and pricing risks that are similarly exposed to loss.

4.1.2 Adjusting CAT Bond Spreads for the Peculiarities of PCAT Risk

The main driver of the risk load of a CAT bond at the time of issue has been the expected loss, while peril-exposure, market cycle, and to a lesser extent the type of trigger have also been important factors affecting the CAT bond price (Braun and Kousky, 2021). In concept, a risk-reducing characteristic of CAT bonds has been the assumed and historical independence (zero or near-zero correlation) of a covered catastrophe's occurrence from the behavior of other catastrophe occurrences, as well as of the financial markets (Tynes, 2000; Vaurigard, 2003; Nowak and Romaniuk, 2013). CAT-bonding pricing, both in theory and in practice, is generally premised on two notions – that the bond-triggering catastrophe's

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[68] The default risk for CAT bonds is much lower than for corporates, though, because an SPV holds cash assets (Liu et. al., 2014). However, CAT bonds have a much higher risk of total loss of capital because investor return is subordinated to insurer reimbursement. Even in a default, it is rare for corporate bonds to lose all value.

[69] See Patel (2015) and https://www.artemis.bm/news/catastrophe-bond-spreads-back-at-their-highest-since-2012-13/ to track the spreads over time.

[70] See https://www.wsj.com/articles/yield-premium-on-riskier-corporate-bonds-nears-all-time-low-11626385329 for historic and current spreads.

[71] See note 68.

direct economic impacts are limited in scope and/ or scale (such as impacting one geographic region, one economic sector, or one business process), and that these economic impacts are largely uncorrelated with other economic processes and their outcomes (namely, those of the financial markets and the values of financial assets). In the case of an asset for risk securitization where either one or both of these notions does not hold, the market risk of the asset is greater than it would otherwise be. In the specific case of PCAT bonds, it should not be assumed that either of these notions holds.

COVID-19 provided an opportunity to observe the business continuity risk resulting from a pandemic; related economic slowdowns/ shutdowns were widespread and felt globally. In the U.S. alone, COVID-19 has led to an unprecedented disruption to the economy and short-term dip in the value of the stock market.[72] Investors suffered heavy losses from a slump in stock prices. A break in the predictability of returns and a shift to greater price volatility of both S&P 500 and DJIA occurred, and volatility significantly increased following the break (Hong, Bian and Lee, 2021). The timing of these changes is consistent with the COVID-19 outbreak. The findings suggest that the pandemic is associated both with market returns and market inefficiency, and thereby defy the assumptions that catastrophic events are necessarily limited in scope and are uncorrelated with financial market behavior.

The intensity of PCAT-bond triggering events may be relatively high (i.e., unusually large in potential scope and scale relative to other types of CAT bonds) and PCAT-bond returns may be correlated to the riskiness of other financial securities (i.e., may not have zero betas). Nevertheless, adjusting CAT-bond pricing mechanisms to the peculiarities of a PCAT bond's risk appears quite feasible. It is reasonable to expect PCAT returns (especially those directly intended to protect against business interruption and related economic losses) to be correlated to those of other bonds because a pandemic, by definition, is large in relative scope and scale.[73] The PCAT-bond risk, although linked in concept to events of greater scope and scale than that of other CAT bonds, can be linked in practice to 1) more remote probability of a triggering CAT event and 2) prudent selection of loss exposure magnitude, and can be hedged by investors through the prudent utilization of correlated assets. These important PCAT features are developed in Section 4.1.3.

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[72] An important market-wide circuit breaker designed to prevent the stock market from "falling through the floor" was triggered four times in sequence in March 2020, the timing of which is consistent with the COVID-19 outbreak (Hong, Bian and Lee, 2021).

[73] Other perils for which CAT bonds are issued tend to be limited in scope and scale by, at the least, geography (e.g., a CAT bond designed with a hurricane trigger – whether the trigger is defined on a parametric or indemnity basis – will impact one geographic area of an insured risk portfolio).

In theory, CAT bonds should provide investors with a diversified return because natural catastrophes occur randomly and thus are not correlated with standard economic risks. That certainly is true for hurricanes, earthquakes, and other natural disasters that occur within a specific geographical region and within a specific period of time. For example, when stock markets plummeted and corporate bonds defaulted during the 2008 global financial crisis, the Swiss Re CAT bond index rose 2.5%.[74] Even in 2020, when news of the COVID-19 pandemic severely impacted the pricing of several classes of investments, CAT bonds were largely immune to the volatility.[75] Rating agency Standard & Poor's announced that "The COVID-19 pandemic has showcased the value of publicly traded catastrophe bonds (cat bonds) to investors, offering a liquid asset class that was not correlated with the current volatile financial markets."[76]

Logically, the occurrence of a pandemic that is covered by PCAT bonds would negatively impact their value. At the same time, the pandemic could cause a much broader and deeper financial decline than natural disasters such as hurricanes and earthquakes. That does not mean, however, that PCAT bonds cannot provide investors with a diversified return. Like other natural disasters, pandemics occur randomly; they certainly are not caused, for example, by stock-market declines. Therefore, absent a pandemic, there would be no correlation during the normal life of PCAT bonds between their value and financial sector conditions.

If there were a pandemic, there could well be a correlation. However, PCAT investors explicitly bargain to take that risk: they agree to subordinate their right to repayment of the PCAT bonds to the indemnification rights of pandemic insurers. Distinguishing correlation from causation, the important point for PCAT-bond investors is that an economic decline that could impair the value of their traditional investment portfolios would not ordinarily cause a pandemic that could impair the value of their PCAT-bond investment portfolios.

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[74] Steve Johnson, *Catastrophe Bonds Prove Anything But a Disaster*, *Financial Times* (June 2013), available at https://www.ft.com/content/bc897de0-c7a0-11e2-be27-00144feab7de.

[75] Steve Evans, *Covid-19 Pandemic "Showcased" Value of Cat Bonds to Investors: S&P*, Artemis (May 2020), available at https://www.artemis.bm/news/covid-19-pandemic-showcased-value-of-cat-bonds-to-investors-sp/. The series of PEF PCAT bonds that covered coronavirus pandemics was severely impacted, though.

[76] S&P GLOBAL, CREDIT FAQ: IN A CORRELATED MARKET, CATASTROPHE BONDS STAND OUT (May 18, 2020), available at https://www.spglobal.com/ratings/en/research/articles/200518-credit-faq-in-a-correlated-market-catastrophe-bonds-stand-out-11491720.

4.1.3 Market Opportunities for PCAT Bonds

The purpose of this section, and of this paper more broadly, is to consider the role of a future PCAT bond market in financing the economic losses from pandemics, and more specifically the resultant business interruption losses. Recent research has constructed scenarios for insurance pooling, but includes no discussion of the possible capital relief that can be provided by investors via PCAT bonds or other risk-securitization mechanism. Hartwig, Niehaus and Qiu (2020) hint at the market gap that could be filled by PCAT bonds (even though the CAT bond mechanism is not mentioned in their paper) as they estimate the amount of capital needed to provide a credible pandemic-insurance mechanism. They use the aggregate liability for pandemic risk as the expected value of pandemic losses, the assets needed to credibly insure the risk as the 99th percentile value of the distribution of total pandemic losses, and the required capital as the difference between the assets and the liability. Table 1 summarizes the Hartwig et al. pooling examples, indicating for each the hypothetical risk characteristics and probability distributions, as well as the amount of capital each pooled entity must contribute in order to adequately fund the overall capital required to cover claims.[77] We have taken the liberty, for the reader's ease of comparison, to indicate realistic financing markets to which the characteristics may reasonably apply.

Table 1. Illustrative Insurance Pools & their Estimated Capital Requirements as a Percentage of Expected Loss
Adapted from Hartwig, Niehaus and Qiu (2020)

	Example				
Market	1: Cash swap	2: Direct property loss from non-disaster perils	3: Direct and indirect property loss from non-disaster perils	4: Pandemic pool	5: Natural disaster pool
Risk Characteristics	Known likelihood & impact across 1000 pooled entities	Known likelihood Unknown impact across 1000 pooled entities	Known likelihood Uncertain & correlated impact across 1000 pooled entities	Uncertain & correlated likelihood Uncertain & correlated impact across 1000 pooled entities	Uncertain & correlated likelihood & impact across 50 market segments of 20 entities each
Frequency	Bernoulli-probability fixed, independent: (0.02)	Bernoulli-probability fixed, independent: (0.02)	Bernoulli-probability fixed, independent: (0.02)	Binomial-probability uncertain, correlated: (β)	Binomial-probability uncertain, correlated: (β)
Severity	Fixed	Lognormal, uncertain, independent	Lognormal, uncertain, correlated	Lognormal, uncertain, correlated	Lognormal, uncertain, correlated
Req Capital	55%	170%	750%	950%[78]	220%

[77] See Hartwig, Niehaus and Qiu (2020) for detailed market assumptions.
[78] The fourth example (mimicking a pandemic insurance pool with uncertain and correlated likelihood and severity of loss) assumes that the frequency of claims that applies to all entities has a binomial distribution with an

Hartwig, Niehaus and Qiu (2021) do not focus on whether the insurance market is private or public, but rather on the capital hypothetically required to build a credible pooling arrangement. In the fourth example, they show how correlation in the occurrence and magnitude of losses have a significant effect on the amount of required capital. In a mutual pooling arrangement of 1,000 entities for a risk with characteristics similar to a pandemic, they estimate each entity would need to contribute 950% more than its expected loss (i.e., its long-run average loss amount) to constitute a credible pooling arrangement. A fifth example is provided to illustrate how the capital required for natural disasters may differ from that required to insure pandemics, with an assumption that the correlation in losses is limited to segments of the pooled entities instead of all entities' losses being correlated. Although the 220% required in the fifth example is high, it is far smaller than the 950% found for the pandemic risk in Example 4.

The Hartwig, Niehaus and Qiu findings might lead one to conclude that an insurance market for pandemics is not feasible because of an unaffordable insurance premium (i.e., a premium equal to 950% of the entity's expected loss). But this is not necessarily the case, nor do Hartwig, Niehaus and Qiu suggest it is the case. Let's consider first that while an insurance market for pandemic losses may be subject to correlation of losses across all insured entities, and this correlation may be on both the loss likelihood and severity, the likelihood of a pandemic remains lower in reality than that for a loss from natural disaster in many insured geographies. While on one hand, loss correlations raise the level of non-systematic risk that would be found in PCAT bonds over what is found in other CAT bonds, the remoteness of loss possibility simultaneously lowers non-systematic risk. For instance, in any given year, the probability of (business interruption loss due to) hurricanes anywhere in the State of Florida is greater than the probability of (business interruption loss due to) pandemics, yet the Florida property insurance market has found ways to credibly insure the hurricane exposure. Furthermore, as evidenced earlier in this paper, a viable CAT-bond market (in collaboration with public insurance programs) exists

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uncertain probability of a loss. The unknown probability is described by a Beta (β) distribution with parameters 1 and 49, which implies that on average the probability is 0.02, as is the case in all the other examples. The average severity of losses has a lognormal distribution with an expected value equal to $100 and standard deviation equal to $200. Using these assumptions, 5,000 outcomes are simulated for the aggregate loss for all 1000 entities in a risk pooling arrangement, and found the probability distribution that fit these aggregate loss outcomes, using Akaike's information criterion (AIC) statistic to rank the fitted distributions (Saefken et al, 2014). (The distribution with the lowest AIC statistic: lognormal distribution with a mean of $2,650 and a standard deviation of $14,342. The distribution with the second lowest AIC statistic: Inverse Gauss distribution with a mean of $1,946 and standard deviation of $5,050.) Using the fitted distributions, the mean and 99th percentile value of the average loss over a 50-year pooling time frame are simulated, then used to find the amount of capital needed, as the difference between the 99th percentile value and the mean value.

for the Florida hurricane risk capital needed to fund a 99th percentile loss or greater. A PCAT-bond market for business interruption losses from a U.S. or global pandemic may be subject to greater loss scope and scale than a CAT-bond market for business interruption losses from a Florida hurricane, but it is also subject to more remote probabilities of a triggering CAT event.

Second, let's consider that despite the inherently large scope and scale of pandemics and their associated losses, a PCAT-bond market maker can structure deals to reach an acceptable magnitude of loss exposure, and thus to some extent can control the market's non-systematic risk. A viable and useful PCAT-bond market need not be the panacea for pandemic loss exposure, but rather can serve as one element of a larger risk financing system for pandemic losses. Limitation of exposure to loss severity can be achieved in multiple ways. The layer of losses protected by the PCAT bonds can be as small or as large as bond architects determine is viable to attract investors. Moreover, the definition of a triggering event and/ or covered losses can limit the loss exposure (e.g., a minimum requirement related to geographical reach or duration, a limitation of loss types covered to the continuing and extra expenses of affected businesses, an exclusion of intentional/ terrorism-related events).

Third, the systematic risk embedded in PCAT bonds can be adequately hedged by investors via prudent investment in assets whose values and returns are uncorrelated or inversely related to pandemic losses. COVID-19 has revealed some industries that appear to be largely unaffected by pandemic-related economic slowdown/ shutdown, including energy and utilities, financial services[79] and segments of the industrial and materials sectors. The pandemic has also afforded opportunities and favorable financial outcomes to certain industries and companies. Many company stocks within the information technology (e.g., Amazon, Apple, Microsoft, Nvidia and Zoom Video) and communication services (e.g., Alphabet, Facebook and Netflix) sectors have performed particularly well during COVID-19.[80] Despite their exposure to correlated losses, in the case of PCAT bonds, knowledgeable investors can hedge to predictably minimize the downside risk (i.e., adverse financial effects of a triggering event) without minimizing the upside opportunities (because the assets that can be used as hedges do not fall in value in the no-triggering-event state of the world).

[79] It is possible, however, that the financial services sector "dodged a bullet" during the pandemic, as described by Jackson and Schwarcz (2021).
[80] See "Prospering in the Pandemic: The Top 100 Companies," (2020, June 19), *Financial Times*, for more examples of companies and industries that appear to have benefited from the pandemic.

It is noteworthy that most lines of insurance are also prone to both systematic and non-systematic risk, and their pricing needs to take account of both types of risk. For example, liability insurance involving third-party injuries, which may take many years to settle, will be open to market risk on the technical provisions invested over the period and also be exposed to potential claims escalation from changes in the economic, fiscal, and legal environments. Even short-tail property insurance can carry a significant amount of systematic risk as, for example, theft claims tend to increase in times of economic downturns. Insurance related to natural catastrophe exposure and the corresponding CAT-bond market are perhaps the only types of coverage that have little if any exposure to systematic risk.

4.1.4 A PCAT Bond Market for Global Crisis

The Hartwig, Niehaus, and Qiu (2020) work highlights the critical role that capital and surplus relief plays within a healthy insurance market. Reinsurance and CAT-bond capital provides relief to the capital and surplus strain on the primary insurance market by providing additional capital for large losses. In so doing, it also serves an implicit capital relief role for insured policyholders. Without a reinsurance backstop or built-up capital and surplus, an insurance pooling arrangement would need to obtain all of the worst-case capital directly from its insureds in the form of insurance premiums.

Hartwig et. al. (2020) find that the premium for pandemic insurance, in the absence of capital and surplus relief, may equal 950% of the expected loss amount, at a 2% event probability.[81] Although only intended as a simple market illustration, the example they provide does not appear to be unrealistic. Assume for discussion that $1 trillion per month is needed to pay for business interruption losses resulting from an economic disruption with characteristics similar to the COVID-19 pandemic, and further assume that a 2.5-month disruption represents an equivalent 99th percentile (worst probable case) loss event. Thus, the event reaches $2.5 billion or greater in business interruption losses with a 1% probability. In such a case, losses from the event exceed 950% of the expected loss amount illustrated by Hartwig et. al. (2020).

Suppose a future PCAT-bond market exists that is triggered by an event or at a loss level having a 0.4% probability (i.e., a 1-in-250-year loss exceedance amount). The amount of capital this PCAT-bond market must provide for it to make a significant and meaningful contribution to the risk-financing system in the case of a global crisis depends upon how the system itself is designed. Discussion of the architecture for the full system of pandemic risk financing and its implications for PCAT-bond viability is provided in

[81] See the illustration in section 4.1.3.

Section 4.2. For now, we assert a back-of-envelope solution based on $1 trillion in loss exposure for every month of business interruption: $3 trillion (equivalent to three months of loss) of PCAT-bond capital at a 0.4% probability of trigger (implying $1.2 billion in expected losses) would be needed to achieve a viable private market for pandemic insurance.

4.2 Building a Healthy Risk-Financing System for Pandemic Business Interruption Losses

For several reasons, the structure of the broader risk-financing system should matter to prospective PCAT-bond investors. First, the riskiness of a PCAT bond (particularly the non-systematic risk) is determined in large part by the expected losses, and the structure of the larger system within which the PCAT bond operates has a bearing on expected losses, both in their likelihood and magnitude. Second, the market problems associated with the risk-financing structure to which PCAT bonds would provide capital relief would increase the model risk, thereby making the expected losses less credible.

A private insurance market is preferable to a public market as a basis for insurance, to the extent feasible and practicable. Catastrophe risks have tested the private market capacity and ability to maintain a healthy marketplace, particularly during periods of short-term shocks and stresses. Research on the financing of risks having disaster-loss potential, over multiple markets and time, consistently support the following observations:[82]

- Public-private partnerships, at least in concept, can provide catastrophe protection more efficiently than public or private markets alone.
- Partial insurance is preferable to full insurance.
- A risk-based premium is important to promote mitigation of the underlying risk.
- Internal risk reduction via investments in risk knowledge and modeling are valuable in overcoming market challenges.
- Fully public (social) insurance markets are best when limited to markets where severe availability problems are present.
- Government pre-event aid is valuable.
- Government post-event aid is best when limited to unmitigable losses.

[82] Doherty (1997a and 1997b); Klein and Kleindorfer (2003); Cummins (2006); Kunreuther, H., Pauly, M. (2006); Medders, Karl and Nyce (2014); Medders and Nicholson (2018); Kousky, C. (2019); and Hartwig, Niehaus and Qiu (2020) for the wealth of literature that has been done on these topics.

For virtually all industries in the U.S., P&C insurance is available and can be written to cover net income losses, plus continuing expenses, plus extra expenses during a period of restoration after a direct property loss occurs (The Institutes, 2020). Making a market for pandemic-induced business interruption, however, means creating business interruption coverage for losses due to a specified loss of use without requiring direct (physical) property damage. Traditionally, business interruption coverages have excluded losses that did not result from "physical damage and/ or physical loss of use," and further explicitly excluded losses arising from pathogens (The Institutes, 2020). Few purely pandemic-insurance-related products have ever been brought to market by insurers. This likely reflects a traditional perception that pandemics are largely uninsurable, or at least not efficiently insurable.

4.2.1 Problems within Markets for Catastrophe (including Pandemic) Risk

Notwithstanding the support in the literature for a private insurance market, pandemics present risk characteristics that make the provision of private insurance challenging and insufficient. Section 1.3.1 discusses the characteristics of privately-insurable risk, and highlights the importance of limiting the insurer's catastrophic exposure and probability of ruin while also providing the insurance at a fair and not prohibitively expensive premium. A problem with private insurance pooling is finding a way to implement the arrangement so that sufficient funds are available each year that a large loss could occur (Doherty, 1997a, 1997b; Cummins, 2006). To illustrate, suppose in each year an insurance arrangement receives 125% more in premium inflows than its expected loss amount of $2,000. The $4,500 ($2000 × (1+1.25)) in premiums exceeds the expected annual payout of $2,000, but a larger loss could occur in one of the early years before a sufficient buffer has been accumulated. Indeed, in the case of right-skewed loss severity distributions such as those associated with catastrophes, there may be a significant probability that a loss larger than $2,000, and indeed even much larger than $4,500, occurs. Given the recent economic experience with COVID-19, understanding whether and how this problem might present in a market for pandemic-business interruption insurance requires little or no imagination.

Exacerbating the capital-inadequacy problem is that insurers and reinsurers face systematic risk as institutional investors because their underwriting (insurance) and investment (market) risks may be correlated. (Re)insurers are expected to hold assets in excess of their expected loss liabilities (reserves). These assets typically are invested in investment-grade financial securities for the purpose of earning investment income. Because of the investment-grade requirement, the returns on those financial securities are on average safer than what is typical of institutional investors. Nonetheless, they are still uncertain (The Institutes, 2020). Combined with the uncertainty associated with pooled insurance capital, this systematic risk to asset values can adversely impact the ability of the re(insurer) to pay all losses.

There are also informational challenges[83] that private insurance markets face, not the least of which is adverse selection that can result in market instability over time. In a pool of business entities subject to pandemic risk, between-firm differences may exist in their frequency and/ or severity characteristics which, unless price-differentiated appropriately, could result in entities opting to move to another pool or to retain more of their risk internally. Another challenge tangential to adverse selection is that of moral hazard, which describes a situation in which actions (or lack thereof) by insureds can change the likelihood or severity of losses. A requirement for businesses to purchase pandemic-risk insurance might inadvertently foster some moral hazard by making businesses less motivated to take the proper precautions to halt the spread of the disease. Virtually all insurance, however, creates this type of inadvertent moral hazard risk, which the industry controls by setting appropriate deductibles and/or other loss sharing.[84] Pandemic-risk insurance likewise should be subject to loss sharing. Uncertainty over whether a business's pandemic insurance will be high enough to cover all pandemic-related losses also should help to control this moral hazard.[85]

The requirement for businesses to purchase pandemic-risk insurance might also inadvertently foster governmental moral hazard by making governments less likely to mandate protections. For example, a government might be less likely to issue politically difficult stay-at-home orders, to require residents to wear face masks, or to close borders. A government might even have an incentive to let a pandemic worsen to trigger insurance payouts. The World Bank's PEF insurance mitigates governmental moral hazard by having the cash window make funds accessible for countries combating pandemics that are

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[83] Klein and Kleindorfer (2003) and Medders, Nyce and Karl (2014) spend considerable time discussing these informational problems.

[84] Car insurance deductibles provide a familiar example. If a driver purchases comprehensive car insurance and has no deductible, he has relatively little reason to drive carefully because any damage resulting from an accident will totally covered by the insurance company. However, if the insurance policy has a $2,000 deductible, then the driver will have to pay for a portion of his car accidents and is thereby incentivized to drive more carefully. The deductible realigns the interests of the driver and the insurance company and therefore mitigates moral hazard.

[85] Pandemic costs can be huge. Some estimate, for example, that the long-term economic impact of COVID-19 could be as high as $15.7 trillion dollars. Letter from Phillip L. Swagel, Dir., Congressional Budget Office, to Charles Schumer, Senate Minority Leader, U.S. Senate, Comparison of CBO's May 2020 Interim Projections of Gross Domestic Product and Its January 2020 Baseline Projections, 2 (June 1, 2020) available at https://www.cbo.gov/system/files/2020-06/56376-GDP.pdf. The risk of illness or death provides another brake on moral hazard; businesses should have an incentive to make their workplaces safe for their employees and customers. *Cf*. CENTERS FOR DISEASE CONTROL AND PREVENTION, *Cases in the U.S.*, https://www.cdc.gov/coronavirus/2019-ncov/cases-updates/cases-in-us.html (discussing the risk of illness or death).

not yet sufficiently severe to trigger the insurance window.[86] Governmental moral hazard is also limited by the significant backlash that a government could face by mishandling an epidemic.[87] The presence of insurance itself may feed moral hazard, as insurance converts what would otherwise be a private cost into a cost borne by the pool. While an inability to adequately differentiate by pricing between insureds according to risk may lead some "low-risk" insureds to leave the pool, it may lead others to remain but fail to mitigate, counting on getting a return their insurance "investment" in the form of loss payments. Both exacerbating and exacerbated by the adverse selection and moral hazard problems is the problem of the "free rider," the case of the insured whose losses are chronically subsidized by the rest of the pool. We have discussed earlier in Section 4 that even during a pandemic, the potential for economic loss/ profit can differ by entity and industry-sector. It may differ as well by location, since forced shutdowns have not been enacted or enforced equally across jurisdictions doing COVID-19. Catastrophe loss modeling has become the standard for pricing and differentiating the basis risk faced by insurers of catastrophe perils and exposures. Pandemic loss modeling, however, is still in its infancy and may not yet provide adequate information for optimal pricing. Even if it could, price differentiation among disaster perils and insured characteristics can prove difficult, for both competitive and regulatory reasons.

Given the problems associated with arranging a private market pool over time, it is reasonable to ask whether a government could arrange such a pooling arrangement. One big advantage of a government arranging the pooling arrangement over time is that it has the ability to borrow funds and then tax future cohorts, which helps reduce the capital problem (see e.g., Gordon and Varian 1988). In addition, a government has fat power to force participation, which could help reduce adverse selection. On the other hand, pooling over time requires a long-term commitment, and governments will be tempted to react to short-term political developments.

4.2.2 A Basic Pandemic Risk-Financing System Design that includes PCAT Bonds

We recommend in this section the skeleton of a public-private risk-financing system that would provide catastrophe protection for periods of pandemic-related business interruptions. Our discussion of the

[86] PEF Operational Brief for Eligible Counties, *supra* note **Error! Bookmark not defined.**, at 5.
[87] *Cf.* Justin Sink, *President Obama's Ebola Problem*, THE HILL, Oct. 16, 2014, available at https://thehill.com/news/administration/220922-president-obamas-ebola-problem (criticizing the Obama administration for its alleged mishandling of the Ebola outbreak in West Africa); Jessie Hellmann, *Trump Downplaying Sparks New Criticism of COVID-19 Response*, July 6, 2020, https://thehill.com/policy/healthcare/506075-trump-downplaying-sparks-new-criticism-of-covid-19-response (criticizing the Trump administration for its mishandling of Covid-19).

proposed system assumes some growth within the private insurance-reinsurance market in the near term to accommodate pandemic risk. It also assumes the creation of a PCAT-bond market that may be subsidized by government funding in the near term and that grows significantly over a longer term.

Private insurance-reinsurance as its basis. Private insurers and reinsurers can find the capital-loss layers and pandemic-associated loss types where they are willing to "play" based on their individual and collective risk appetites. These pooling institutions are experienced risk aggregators, and have the existing infrastructure to appropriately and efficiently service, price, and allocate capital to these risks.

Partial insurance for business entities during short period of restoration. Partially-insured business-interruption risks leave the insured entity with incentives to mitigate against losses (and thereby inherently mitigate against moral hazard), and place less strain on insurer capital than would fully-insured business interruption risks. Partial insurance can be achieved by choice of loss type(s), plus start and duration of coverage, including a dollar maximum if desired.[88] One possible design of a basic contract for partial insurance protection is this: coverage that begins after 45 days and ends after 90 days from the start of a forced shutdown and pays 50% of the ALS for continuing expenses only,[89] with an option to purchase additional cover for a portion of the ALS for extra expenses.[90] Note that the first 45 days of a forced shutdown is uninsured. Business entities that cannot economically withstand a 45-day break in operations would need to rethink their financial strategy and risk appetite. Note that we also do not recommend protection of business profits, first because of the often-protracted process of calculating and verifying the ALS with respect to profits, and second because of heightened moral hazard associated with lost profitability as an insured risk.

A risk-based premium. The pricing of the basic contract would be based on an entity's actual exposure as well as loss estimates generated by pandemic loss models (in the long term) and/ or a combination of these models and actuarial loss analysis of prior pandemic events (in the shorter term).

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[88] Business interruption insurance is a time-element coverage. Although the amount purchased is sometimes written on a dollar-of-coverage basis, it is often written (or the nominal dollar-coverage amount derived directly from) as a formulaic time period, such as the actual loss sustained (ALS) up to X maximum period of restoration. The period of restoration is typically written as days, weeks or months. (See The Institutes, 2020) for details of how business interruption coverage generally operates.

[89] Continuing expenses are those costs that must be paid during a period of restoration, either for legal (e.g. some or all of payroll; mortgage payments owed to mortgagee) or other compelling business (e.g. payments for electricity to remain on to allow for productivity or property protection; some or all of payroll) reasons.

[90] Extra expenses are generally the costs of modifying or moving the operations and possibly the costs of expediting these activities in order to reduce the duration/ severity of the business interruption.

Compulsory coverage for business entities to protect against short period of restoration. Given that short-term pandemic business interruption insurance would likely not be inexpensive, many businesses might choose to retain all or a portion of the risk unless required by government mandate to purchase the insurance. A government requirement for businesses to purchase pandemic-risk insurance, as this Article proposes, should reduce moral hazard.[91] Absent such a requirement, businesses that otherwise view pandemic insurance as economically desirable might forgo paying for such insurance because they expect federal bailouts in the event of a major pandemic.[92] There is much precedence for business insurance coverage mandates, including workers' compensation insurance, unemployment insurance, the social security insurance system, health insurance, and even auto insurance. A mandate reduces the risk of adverse selection and guarantees adequate levels of participation in the insurance market.[93]

Enhanced coverage for business entities during longer periods of restoration. Loss events that necessitate forced shutdowns that extend beyond 90 days may be covered on an enhanced basis, such as with higher coinsurance percentages and/ or a broader array of loss types in cover. Complementing the basic contract for the first 90 days from the start of a forced shutdown that is outlined above, this coverage could begin after 90 days and end after 180 days from the start of a forced shutdown and pay 75% of the ALS for continuing expenses and extra expenses.

The participation of PCAT bonds, with a parametric (primarily duration-based) trigger and loss payment. Loss events having forced shutdowns that extend beyond 90 days would be (re)insured, with capital and surplus relief provided by triggered PCAT bonds up to a maximum of $2.5 trillion. At this level of loss and the remoteness of the likelihood of the bonds being triggered, a PCAT-bond market could reasonably

[91] Moral hazard generally refers to "loss-increasing behavior that arises under insurance." David Rowell & Luke B. Connelly, *A History of the Term "Moral Hazard"*, 79 J. RISK & INS. 1051, 1051 (2012). Moral Hazard can arise *ex ante* as when an insured engages in risky behavior or fails to take precautions because he knows any loss will be covered by insurance. *Id.* Moral hazard also can arise *ex post* as when an insured exaggerates her losses to receive a higher insurance payout. *Id.* at 1052.

[92] *Cf*. Veronique Bruggeman *et al*., *Insurance Against Catastrophe: Government Stimulation of Insurance Markets for Catastrophic Events*, 23 DUKE ENVTL. L. & POL'Y F. 185, 208-209 (2012) (discussing the propensity for private actors to forgo insurance counting on government compensation). Furthermore, if a significant percentage of businesses fail to purchase pandemic-risk insurance, in hopes of free riding on future bailouts, risk-securitization transactions may be too small to statistically diversify pandemic-related risks.

[93] Adequate insurance participation in catastrophe insurance markets cannot be assumed. Both the NFIP and the California Earthquake Authority (CEA), for instance, suffers from very low take-up rates by property owners who are at moderate-to-high risk. Cf. supra note 92 (observing that if a significant percentage of businesses fail to purchase pandemic-risk insurance, in hopes of free riding on future bailouts, risk-securitization transactions may be too small to statistically diversify pandemic-related risks).

grow over time. To the extent it limited investors' expected losses to sufficiently low values, the suggested structure would provide insurers and reinsurers with sufficient access to needed capital.[94]

Limited government assistance pre- and post-event. Government assistance on a post-event basis has proven inefficient during COVID-19 and worse, potentially in conflict with meeting other economic goals, such as jobs creation.[95] Moreover, the expectation of government aid may result in some businesses shirking the insurance mandate described above.[96] This is not to say that post-event government relief not be used, but rather to encourage the restriction of its use to unmitigable losses. Pre-event loss mitigation may be especially valuable, however. [Perhaps provide examples to show why it may be especially valuable.] [Also, should we discuss *how* businesses should be incentivized, pre-event, to mitigate potential pandemic-related losses?] For small and/or struggling businesses that lack the competitive and financial capacity to absorb or pass on the costs of pre-event mitigation to their customers, the government might consider providing limited financial assistance.

4.2.3 Stress Testing the System

Clearly, the risk-financing system outlined here is overly simplistic, lacking the details required to ”make” either a market for pandemic insurance or for PCAT bonds. It is for policymakers and leaders in financial services to properly design the detailed mechanisms these markets will need to run smoothly. What we can do is to stress test the suggested basic market mechanism. We can do a relatively credible job of stress testing by using our current pandemic to calibrate needs. Let's consider a risk market having a risk-financing system that operates like the one suggested in Section 4.2.2. Let's assume that a pandemic loss event such as COVID-19 or worse would result in $1 trillion in monthly ALS for continuing expenses.[97] Let's further suppose that a pandemic loss event occurs and forces nationwide business shutdowns that last 180 days (or approximately 6 months). The subsequent business interruption losses would have worst-case financial impacts, as provided below.

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[94] The provision of pandemic-related business interruption insurance by private insurance markets would also help governments to focus social insurance pooling to meet other pandemic-related needs, where severe insurance availability problems are present and/or existing government insurance should be enhanced during a crisis.

[95] See, e.g., Brad Polumbo, How massive expansion of coronavirus unemployment benefits could backfire, Washington Examiner, Apr. 8, 2020, available at https://www.washingtonexaminer.com/opinion/how-the-cares-acts-massive-coronavirus-unemployment-benefits-could-backfire.

[96] See supra notes 91-92 and accompanying text.

[97] The federal government's PPP paid approximately $525 billion for three months of payroll protection, so the actual number could be lower than $1 trillion (Kunreuther and Schupp, 2021). $1 trillion is intended to err on the side of overestimating the loss exposure, given it is being used here for the purpose of stress testing the system.

Retained by business entities

1st 45 days:	1.5 months X $1 trillion monthly X 100% retention =	$1.5 trillion
46th-90th days:	1.5 months X $1 trillion monthly X 0.50 coinsurance portion =	$0.75 trillion
91st-180th days:	3.0 months X $1 trillion monthly X 0.25 coinsurance portion =	$0.75 trillion
Total:		$3.00 trillion

Absorbed by (re)insurers

1st 45 days:	1.5 months X $1 trillion monthly X 0.00 coverage =	$0.00 trillion
46th-90th days:	1.5 months X $1 trillion monthly X 0.50 coinsurance portion =	$0.75 trillion
91st-180th days:	3.0 months X $1 trillion monthly X 0.75 coinsurance portion =	$2.25 trillion
91st-180th days:	- 2.5 trillion triggered =	- $2.50 trillion
Total:		$0.50 trillion

Relief from PCAT bonds, absorbed by investors

1st 45 days:	1.5 months X $1 trillion monthly X 0.00 relief =	$0.00 trillion
46th-90th days:	1.5 months X $1 trillion monthly X 0.00 relief =	$0.00 trillion
91st-180th days:	$2.5 trillion triggered =	$2.50 trillion
Total:		$2.50 trillion

In this stressed scenario, more of the losses are borne by the business entities than by the risk pooling or financial markets. Although the businesses suffer under such a scenario, they only absorb half of the cost of continuing expenses they would have borne under a status-quo system (i.e., one in which there is no pandemic insurance). The (re)insurers, in absorbing $0.50 trillion, provide a buffer between insured businesses and the capital markets and serve to aggregate the risks for investors.[98] The $0.50 trillion, although the smallest allocation, would indeed be catastrophic to today's P&C (re)insurance market given the $800 billion total market size and the fact that the market cannot afford to tie up most of its capital and surplus (in this case, 5/8th, in one line of business).

[98] In this sense, risk aggregation means the process of combining (or bundling) risks and their value measurements to obtain more comprehensive views of risk and measures. In the context of pandemic insurance, (re)insurers play an important role in bundling risks arising from exposure to the threat of pandemics in order to arrive at a total risk exposure that can then be efficiently spread across willing investors.

The PCAT-bond market is allocated $2.5 trillion of losses within the scenario. A cursory view of this might lead to the conclusion that a PCAT market is an unrealistic notion. After all, the entire CAT-bond issuances in 2021 are expected to reach only $12 billion, and PCAT bonds would constitute only a portion of the future CAT-bond market. Notwithstanding the limitations of the CAT-bond market, the entire bond market is valued in the range of $106 to $119 trillion, and the U.S. bond market in the range of $41 to $46 trillion, making our hypothetical PCAT-bond market appear quite small in comparison. In theory, capital market investors potentially could purchase a significant portion of the approximately $1.150 trillion of the contemplated PCAT bonds. The capital markets are estimated at roughly $180 trillion,[99] with the "fixed income" portion—the portion representing bonds[100]—estimated at nearly two-thirds of this market value.[101] The contemplated PCAT bonds would represent just one percent of outstanding bond investments. It appears that investors in a post COVID-19 world would be interested in purchasing PCAT bonds.[102] Rating agency Standard & Poor's observes, for example, that "The COVID-19 pandemic has showcased the value of publicly traded catastrophe bonds (cat bonds) to investors, offering a liquid asset class that was not correlated with the current volatile financial markets."[103] Even if capital market investors fail to purchase a significant portion of the $1.150 trillion of the contemplated PCAT bonds, any portion they purchase would contribute, pro tanto, to reducing the government's share of risk in controlling pandemic-related harm.

Moreover, our scenario involves a $2.5 trillion PCAT-bond market whose economic plausibility can be illustrated simply. Let's suppose a pandemic in the scale of COVID-19 were subject to a 0.02 Poisson-distributed probability of occurrence.[104] Using a compound Poisson process, with a mean of 50%, to derive the probability that the event would extend to 45 days results in a 0.01 probability. The same compound Poisson process associates a < 0.004 probability of such an event having a duration of 90 days or more, and thereby triggering the PCAT bonds. The majority of CAT bonds issued to date have estimated annual trigger probabilities of around 1% (1 in 100 years) and exhaustion (total loss) probabilities of around 0.4% (1 in 250 years). The 0.4% (or less) probability in this case is consistent with

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[99] Lloyd's of London (2020).
[100] Bonds are "the most common type of fixed-income security." *See* https://www.investopedia.com/terms/f/fixed-incomesecurity.asp.
[101] SIFMA, available at https://www.sifma.org/resources/research/research-quarterly-fixed-income-issuance-and-trading-second-quarter-2020/. The U.S. fixed-income portion alone was estimated as $41 trillion. *Id*.
[102] Evans, *supra* note 75.
[103] *Id.*
[104] A probability of 0.02 implies a 1-in-50-year loss event, which is intended to overestimate the risk for stress-testing purposes.

the loss probabilities associated with CAT bonds more generally. When multiplied by the $2.5 trillion PCAT bond exposure, the 0.4% probability indicates $10 billion in expected losses. Even if bond investors continue to demand a premium to invest in CAT bonds, such a PCAT bond should be attractive to investors at the time of issue, based on risk pricing. Consider the CAT-bond spread from earlier in Section 4:

Spread = $(EL)^{(1/\rho)}$, where EL=$10 billion/$2.5 trillion (or 0.4%) and the required spread = 2%. Solving for ρ, we find it approximates 1.32192, which suggests a risk aversion level (RAL) that is consistent with CAT bonds on the market.

In other words, according to the risk aversion levels and commensurate spreads required by actual CAT-bond investors today, the numbers support the viability of PCAT bonds. The illustration above indicates that our hypothetical PCAT-bond market could plausibly produce spreads at or exceeding those required by CAT-bond investors.

4.3 Economic, Legal, and Policy Implications

Movement from the status quo to some sort of risk-financing system for insuring pandemic risks has myriad implications. This section attempts to address the most fundamental and pressing of these. An all-important consideration is that of the potential benefits that society receives as a result of having a functional and feasible risk-transfer system that compensates entities for some sizable portion of their economic losses from a pandemic. These include reduced magnitude and duration of a related recessionary economic period, a reduced likelihood that business relationships among contracting parties or between the business and its employees will be damaged or disrupted, a reduction in the risk placed on lending institutions, and a reduced likelihood that failing financial institutions might have a cascading effect on the solvency of other institutions. As discussed, however, no risk-transfer system comes without market problems of its own. The obstacles to developing a sufficient PCAT-bond market can have repercussions on the overall system as well.

4.2.2 Overcoming Market Problems

Despite the economic benefits, in order to build and maintain a robust pandemic risk-transfer system and a parallel PCAT-bond market, several market challenges must be overcome. Earlier discussions considered solutions for some of the key (re)insurance market problems. Caution in the design of the pooling mechanism and in contracting the risk transfer can minimize informational problems, such as the aforementioned adverse selection and moral hazard. Additional insurance-market problems that are unique (or almost so) to pandemic risk must be considered as well. Should a market for pandemic insurance pay for intentional (e.g., manmade, bioterrorism-induced) pandemics? Should there be tort limitations on pandemic-related liability for businesses (wherein liability exists only in cases of gross negligence)?

On the PCAT-bond market front, challenges can be mitigated to some extent by design. For instance, PCAT bonds that are triggered by event parameters (parametric bonds) should have lower associated levels of uncertainty than those that are triggered by actual damage costs (indemnity bonds) because the former's loss amounts will be determined by a formula rather than requiring detailed claims and verification of actual losses. That reduced uncertainty will enable parametric bond issues to attract lower ρ's and spreads compared to non-parametric bond issues with the same expected loss estimates. These lower spreads would reduce the premiums that would need to be payable on the pandemic insurance.

Concerns that CAT-bond (including PCAT-bond) issuers may experience bond market clashes, wherein multiple issuers are simultaneously "courting" the same available and wiling capital, are legitimate (Medders and Nicholson, 2018), yet the reality is that the number of independent catastrophe exposures that are likely to be covered by risk securitization and PCAT bonds is no more than 10 to perhaps 15 on a global basis.

The limited number of independent exposures available to investors of PCAT bonds reduces the scope for risk diversification (due to the high correlation of losses across exposures inherent to PCAT bonds); and even with spreads at 5% for an underlying loss rate of 1%, there is scope for losses to exceed the sum of spreads from an otherwise balanced portfolio of these securities. Nevertheless, this lack-of-diversification may also exist for investors in high-yield bonds who are not explicitly catastrophe sensitive and appear happy to accept much lower spreads on equivalently rated bonds, even though unfavorable shifts in the regional or global economy represent implicit catastrophes that are difficult to diversify against.

4.3.2 Regulatory & Legal Challenges

Risk securitization raises a host of regulatory and legal challenges. Some of these challenges parallel those of traditional securitization transactions but, because of the inventive nature of risk securitization, are more complex. Other challenges are novel. The discussion below focuses on the novel challenges.[105]

[105] One of us separately has analyzed all of these regulatory and legal challenges in depth. [Schwarcz, 2022] The above discussion is based in part on that analysis.

One such challenge is whether—and if so, how—to regulate SPVs as reinsurers. By effectively providing reinsurance, SPVs used in risk-securitization transactions should, in principle, be regulated as reinsurers. Because their purpose would be to reimburse payments made by the primary pandemic-risk insurers, those SPVs must stay solvent in order to provide that reimbursement.[106] In a related but narrower context, the body that accredits state insurance departments as having met baseline standards of solvency regulation has recommended—consistent with the idea of regulating SPVs used in risk-securitization transactions—that regulators assess and monitor the risks of using SPVs in transactions involving insurers.[107]

If SPVs used in risk-securitization transactions were regulated as reinsurers, they would be required to be licensed or accredited in their state of domicile.[108] They also might be subject to minimum capital and surplus reserve requirements, and might need to comply with regulatory examinations, officer-and-director qualification requirements, and various other restrictions.[109] The cautionary tale of the collapse of the monoline insurance industry suggests, however, that regulation cannot always guarantee SPV solvency. Monoline insurers acted as sureties for mortgage-backed securities. Notwithstanding the monoline industry's high degree of regulation, the 2008 global financial crisis caused all but two monoline insurers to fail.[110]

Another novel legal challenge is whether governments could require businesses to purchase pandemic insurance. In the United States, this challenge has certain parallels to the individual mandate of the Affordable Care Act ("ACA"), which requires individuals either to purchase health insurance or to opt out by paying a penalty in the form of a tax.[111] In addressing the enforceability of that mandate, the Supreme Court held that the Commerce Clause of the Constitution does not allow Congress to require

[106] Compare U.S. Gov't Accountability Off., GAO-90-82, *Insurance Regulation – State Reinsurance Oversight but Problems Remain* 4 (1990) (observing that whereas the purpose of regulating primary insurers is to protect policyholders, the purpose of regulating reinsurers is to assure their solvency—and thus their ability to reimburse payments made by the primary insurer).
[107] National Association of Insurance Commissioners, *Captives and Special Purpose Vehicles,* NAIC Working Paper (July 2013), at 3 (discussing insurers using captive offshore SPVs as reinsurers for the purpose of avoiding regulation imposing domestic reserve requirements).
[108] Marion Leydier et al., *Q&A: Insurance & Reinsurance Regulation in USA*, LEXOLOGY (June 29, 2020), https://www.lexology.com/library/detail.aspx?g=9c4f572f-36af-4fc8-b3c8-a5a4dffa9deb.
[109] *Id*.
[110] Tima Moldgaziev, *The Collapse of the Municipal Bond Insurance Market: How Did We Get Here and is There Life for the Monoline Industry Beyond the Great Recession,* 25 J. OF PUB. BUDGETING, ACCT. & FIN. MGMT. 1 199, 200 (2013).
[111] See Nat'l Fed'n of Indep. Bus. v. Sebelius, 567 U.S. 519, 539 (2012) (summarizing the individual mandate of the Affordable Care Act).

individuals to purchase health insurance.[112] Nevertheless, the Court ruled that the mandate was enforceable as a tax designed to promote the purchase of health insurance, not unlike a tax on cigarettes designed to reduce the use of nicotine.[113]

A U.S. government mandate requiring businesses to purchase pandemic insurance or to opt out by paying a penalty in the form of a tax should similarly survive a constitutional challenge. Any opt-out payments could even be used by the government to create a pandemic catastrophe fund or to purchase PCAT bonds that could not be sold to capital market investors. One of us also has argued that, in contrast to the ACA's individual mandate, a federal mandate requiring businesses to purchase pandemic insurance may well be within Congress's power to regulate commerce.[114]

Yet another novel challenge—defining the insurance-payment trigger for parametric PCAT-bond issues—mixes legal and business considerations. That definition will determine when the SPV becomes legally obligated to indemnify the insurer. Also, because the priority of PCAT bonds is subordinated to the indemnification, that definition will control the SPV's obligations to pay principal and interest to investors in those bonds. Ultimately, however, defining the insurance-payment trigger will be a business decision. Chubb's Pandemic Business Interruption Program suggests several possible triggers, including a Declaration of Emergency by the U.S. Department of Health and Human Services or the President, the occurrence of a government-enforced lockdown, or reliance on triggering events specified by the U.S. Centers for Disease Control and Prevention based on medical criteria.[115]

4.3.3 Achieving adequate participation

Participation in a risk-transfer system for pandemics is a multi-pronged challenge. Insurance pricing that is adequate yet affordable, and that can fairly discriminate among insureds on the basis of risk differentials, is critical to attracting the voluntary purchase of insurance products. A government

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[112] *Id*. at 520–21 (reasoning that the Commerce Clause allows Congress to regulate actions of those participating in a market, not the inactions of those choosing not to participate in the market).
[113] *Id*. at 575 (holding that the federal government has the power to impose a tax on the uninsured).
[114] [Schwarcz, 2022] The Commerce Clause gives Congress general authority to regulate business. Unlike individuals, most businesses are involved in interstate commerce, and a pandemic can close down businesses and seriously harm the national economy. *Cf*. Nat'l Fed'n of Indep. Bus. v. Sebelius, 567 U.S. at 572 (the Court's primary concern with upholding the ACA's individual mandate under the Commerce Clause was that individuals generally do not participate in interstate commerce). The Court has been more willing to use the Commerce Clause to uphold Congressional regulation of activities that have a substantial impact on interstate commerce. *See, e.g.,* Gonzalez v. Raich, 545 U.S. 1 (2005) (holding that Congress may regulate a local activity that is not itself economic if it is a part of a "class of activities" that has a substantial impact on interstate commerce).
[115] *See* [Chubb, 2020], at 6.

purchase mandate can help ensure adequate participation by business entities. (Re)insurers are generally willing underwriters of fairly priced risk-transfer mechanisms, so long as the risk does threaten ruin to the (re)insurer. For this reason, it is central to any pandemic risk-transfer system that robust and reliable mechanisms for (re)insurer capital and surplus relief and/ or retrocession be part of the system.

For multiple reasons, pandemics notwithstanding, we can expect to observe continued growth and expansion of the CAT-bond market (thereby paving the way for a future robust PCAT-bond market). First, there is continued focus on helping bring risk-transfer solutions to underserved populations. Investor interest in Environmental, Societal and Governance (ESG) goals has increased and promises a broader range of perils and exposures being priced and brought to market. Second, a larger variety of firms and public sector entities increasingly use CAT bonds in their risk-management strategies. Finally, as countries and organizations work to achieve the United Nations Sustainable Development goals, there will be greater investments in critical infrastructure, such as water plants, energy systems, schools, and transportation networks—all of which could benefit from financial protection against increasing disaster risk (Braun and Kousky, 2021).

5 Conclusions & Implications for Risk More Broadly

The global financial markets have a virtually unlimited capacity to absorb and manage risk, including catastrophe risk. Even the costliest catastrophe losses can look almost insignificant in relation to the daily market movements in the global financial markets. The catastrophe reinsurance market, on the other hand, has to deal with the aggregation of these risks as well as the maintenance of sufficient risk capital to enable it to trade in this business. This private (re)insurance business model, working alone, is inefficient, and the natural place for catastrophe-retrocession protection lies in risk securitization. PCAT bonds are the most obvious, viable means to achieving this protection, at least in the near-to-mid-term.

However, the current spreads in the existing ILS market are quite high in relation to those normally enjoyed by bond investors for securities of similar loss characteristics. Indeed, historically, insurers (as bond issuers) were reluctant to enter this market because the required spreads and associated bond-issuance expenses were considered prohibitively high. The situation has improved, although there remains much room and need for growth in this market.

In the SPVs set up to issue PCAT bonds, we see entities with a simple structure and a simple plan. The only critical or variable elements are the loss parameters. The frictional costs of bond issuance and investing include both direct and indirect costs, including the indirect cost associated with uncertainty. The only real uncertainty (short of outright fraud) is with regard to the occurrence (or not) of a covered catastrophic event, its cost, and possibly the timing of such an event. This leads to the conclusion that in the case of an SPV set up specifically to issue CAT bonds (in our case, PCAT bonds), the differential frictional costs of investing in CAT bonds are almost totally accounted for by the uncertainties in the catastrophe loss modeling because other costs are not unlike those encountered in other (non-CAT-bond) transactions.

It is well known that different catastrophe models produce estimates of exposure, at any given probability or return period, that can vary by large percentages, particularly at the extreme return periods where risk securitizations are likely to be involved (Karl, Medders and Maroney, 2016). Uncertainty in the quality of these estimates is also one of the main reasons given for investors demanding such high spreads (Patel, 2015). These uncertainties are statistical in nature and they arise, primarily, from the relatively small number of actual (extreme) events where good loss data are available to test and to calibrate the underlying catastrophe models. The accuracy of these models will improve over time, but such improvements are almost certainly going to be slow and limited. In order to make any progress with the pricing of these securities, we need to accept the uncertain nature of these estimates and concentrate efforts on identifying the levels of this uncertainty so that investors and issuers can feel comfortable that what is being transacted is being priced 'fairly.' So, in order to identify the corresponding risk, ρ, for PCAT pricing purposes, the error distributions of the catastrophe models' loss estimates are important. This information, estimated as part of the modeling and model validation process, must become an integral part of the modeled-loss reporting that is made available to investors.

Current CAT-bond spreads are grossly conservatively large. Even if a reduction in ρ reduced spreads by 50%, these spreads will still be over three times expected losses and should remain attractive to investors. A 70% reduction in current spreads would still result in spreads 85% above expected losses. In practice, it is unlikely that such reasonable but dramatic changes to pricing levels will happen overnight. In time, it is reasonable to expect, however, that a better understanding of CAT (including PCAT) bonds and their associated risks should help to reduce these spreads to more rational levels, perhaps down to around 50% of current values. Reductions in the current spreads of such proportions would provide property insurers, via SPVs, with a significant incentive to issue PCAT bonds as a cost-effective alternative to traditional catastrophe protections, at least for the top layer(s) of their reinsurance and retrocession programs.

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