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# Insurance for economic losses caused by pandemics

**Robert Hartwig**[1] · **Greg Niehaus**[1] · **Joseph Qiu**[2]

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**Abstract**
Private insurance coverage for economic losses caused by pandemics is limited. While many factors contribute to reduced demand and supply, we attribute the low amount of coverage to the high levels of capital that would be required to credibly insure pandemic economic losses with cross-sectional pooling mechanisms. Pooling over time significantly reduces the required capital and therefore the cost of insurance, but as a practical matter likely requires a government with the ability to borrow and tax. We also argue that insurance for economic losses due to pandemics likely generates positive externalities for the macroeconomy. We therefore analyze the general tradeoffs associated with different ways that a government can promote such insurance.

**Keywords** Pandemic · Insurance · Public Policy · Capital

## 1 Introduction

Pandemics are a recurring natural phenomenon that throughout human history have caused not only widespread sickness and death but also economic disruption on a massive scale. The COVID-19 pandemic is no exception, with the International Monetary Fund estimating global economic losses at $9 trillion (IMF 2020b). But unlike other economically destructive natural phenomena such as hurricanes, earthquakes and wildfires, the losses from which are substantively financed by private insurers (at least in advanced economies), very little private insurance exists to manage the financial consequences of pandemic risk. Indeed, very few products have ever been brought to market by private property–casualty insurers. This

All errors and omissions remain the authors' responsibility. Opinions stated in this paper are the authors' personal views.

✉ Greg Niehaus
gregn@moore.sc.edu

[1] Darla Moore School of Business, University of South Carolina, Columbia, USA

[2] American Risk and Insurance Association (ARIA), Malvern, USA

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paper examines the failure of private insurance markets and alternative risk-sharing mechanisms to adequately address economic losses arising from pandemics. The paper also identifies potential reasons for the lack of insurance, as well as potential solutions.

The analysis and discussion are divided into three parts. In the next section, we describe the current marketplace for pandemic insurance. While there are examples of private insurance coverage for pandemic losses, the market for private pandemic insurance is exceedingly thin in the sense that coverage options, especially those for business interruption, are extremely limited or nonexistent for most individual entities. Payments by private insurers to businesses suffering economic losses associated with the COVID-19 pandemic are expected to account for only a small fraction of total economic losses. In Sect. 3, we provide a conceptual framework that helps explain why the private market for pandemic insurance coverage is naturally thin. We conclude that a risk-sharing arrangement that operates over time could be beneficial, in part to avoid the negative macroeconomic externalities associated with a prolonged shutdown of many firms without pandemic business interruption coverage. Such an arrangement needs to involve a government with the ability to borrow and tax. Alternative ways of incorporating government involvement in a risk-sharing mechanism are presented in Sect. 4, along with an analysis of how the alternatives differ on important dimensions. The paper concludes with a short summary.

## 2 Review of pandemic risk in property/casualty insurance and reinsurance markets

Insuring against economic losses from pandemics poses a set of challenges to property/casualty insurers that collectively have severely limited the insurability of the risk in the private sector on a large scale. The result is that few products designed to specifically address the risk of pandemics have ever been brought to market by property–casualty insurers and reinsurers. Consequently, there exists a large gap between the economic consequences associated with pandemics and the ability of insurers and reinsurers to provide protection products to address those consequences.

This paper will explore many of the practical, institutional and theoretical obstacles insurers confront in the underwriting and pricing of pandemic risk. The main obstacle is the extreme aggregation/accumulation risk associated with pandemics, which severely diminishes the ability to diversify and spread risk. In addition, there is a balance sheet risk stemming from the negative correlation between the expected magnitude of insured losses and the market value of financial assets held in the insurer's investment portfolio. The collective impact of these obstacles is to require insurers to carry impractically high amounts of capital. Consider, for example, that pandemic-related business continuity (i.e., business interruption) losses alone across all businesses in the United States are estimated at $1 trillion *per month*, yet at year-end 2019 the total capital resources (policyholder surplus) of the U.S. property–casualty insurance industry stood at approximately $800 billion (Hartwig and Gordon 2020).

To illustrate the importance of each of the obstacles mentioned above, it is useful to consider how pandemic risk differs from other types of catastrophe risks, such as hurricanes, earthquakes, and wildfires, which are routinely underwritten by insurers and reinsurers. Each of these natural disasters impacts a limited number of policyholders for a limited period of time.[1] The property and business continuity (i.e., business interruption) losses associated with hurricanes, for example, are largely a coastal phenomenon with damaging winds typically dissipating over the span of hours. In contrast, business continuity losses arising from pandemics, by definition, have the potential to impact virtually all policyholders, irrespective of location and nearly simultaneously, with losses continuing over the span of months or even years. The resulting accumulation of losses of the many (rather than the few) prevents the pooling and redistribution of those losses, as essentially all policyholders are impacted, requiring the insurer to hold prohibitively large amounts of capital. Pandemic risk therefore cannot be readily spread, shared or diversified across policyholders. Further, as the COVID-19 experience during the first quarter of 2020 demonstrated, pandemic-related losses are correlated with both financial market losses and other insurance losses. During the first quarter of 2020, the policyholder surplus of the U.S. property–casualty insurance industry fell by 9.3% to $744.9 billion, due in large part to a sharp decline in asset prices as well as the establishment of COVID-19 loss reserves across numerous lines of insurance (Best 2020).

### 2.1 Supply and demand for pandemic insurance pre-COVID-19

Given the characteristics of pandemic losses and their financial impact on world economies, insurers and reinsurers have generally asserted that with some exceptions, large-scale pandemic risk is not insurable in the private sector (see Sect. 3 for more discussion on this topic). For this reason, insurers have no alternative but to exclude coverage for virtually all future pandemic exposures from insurance policies and reinsurance treaties. This does not mean that property–casualty insurers have no exposure to pandemic-related losses. Indeed, Lloyd's of London in May 2020 estimated that global insured losses arising from COVID-19 to the non-life insurance industry could total $107 billion. Lloyd's further estimated that its own losses would range from $3 billion to $4.3 billion, comparable to the losses it sustained from the September 11, 2001 terrorist attacks (Evans 2020a). Looking toward the future: research indicates that pandemic risks are intensifying as globalization and urbanization proceed apace, potentially costing as much as $23.5 trillion over the next 30 years (Hilsenrath 2020).

The apparent paradox—that the paucity of pandemic insurance available in the market does not preclude potentially large losses—results from several factors. First, much of the industry's exposure arises from contingency coverages—insurance sold to businesses to offset losses triggered by one or more of a wide range of

[1] Losses from floods and most terrorist acts are also limited to policyholders in a geographical area and for a limited amount of time. While private insurance exists for these risks, there are also government programs to insure or reinsure these losses (see Sect. 4).

covered events (i.e., risks), pandemic being only one of those events. Second, there is an expectation on the part of insurers that litigation, regulation and legislation will compel insurers, in some cases, to pay claims on policies where no coverage was intended (and thus no premium collected) by the insurer. That latter exposure represents a large and difficult-to-quantify liability for insurers, the ultimate cost for which will likely not be known for years. Willis Towers Watson, a global advisory and broking company, has estimated that insured COVID-19 business interruption and event cancellation losses in the U.S. could range anywhere from $2.0 billion to $22.7 billion, while workers' compensation losses could be as little at $0.2 billion but as high as $92 billion (Willis Towers Watson 2020). The enormous range in estimates stems largely from uncertainty related to litigation, regulation and legislation and from uncertainty about the severity of the pandemic.

In the subsections that follow, we examine the insurance market for "pure" pandemic risk. We then focus our discussion on COVID-19 and potential losses arising from specific lines of insurance with contingent exposure to pandemics or where exposure is incidental though still material in magnitude. We conclude with an examination of shifts in market dynamics precipitated by the COVID-19 pandemic in terms of changes in underwriting practices, pricing and the ability of the industry attract capital.

### 2.2 Insurance markets for pandemic risk

As discussed above, property–casualty insurers have long maintained that insuring against large-scale pandemic risk is economically infeasible. Note that this stands in direct contrast to life insurers, where pandemic risk is inherent in all mortality-based policies sold with no material adverse impact on the price or availability of coverage. Life insurers routinely model the potential impact of pandemics on their books of business and incorporate that risk into the price of their products, typically ceding the associated extreme mortality risk to reinsurers and sometimes to capital markets.[2] This observation once again begs the question as to why pandemic risk is deemed largely uninsurable in the context of property–casualty insurance.

### 2.3 Pure pandemic risk

The history of property–casualty insurance products specifically designed to manage pandemic risk is a short one. We now examine two of the most recent approaches to providing "pure" pandemic coverage in a market that historically has offered little-to-no coverage to the majority of potential buyers.[3] Both products illustrate some

[2] See National Association of Insurance Commissioners (2020). Also, Solvency II includes capital charges for life catastrophe risks, e.g., caused by pandemics. See e.g., AON (2011) and Kraut and Richter (2015).

[3] "Pure" pandemic coverage refers to insurance that covers pandemic-related losses and nothing else. Later we consider other types of insurance where pandemic risk is just one of many types of risk that could cause claims.

of the key challenges insurers and capital markets encounter in the market for pandemic insurance, driven by actual experience immediately prior to and during the COVID-19 pandemic. A more general framework for illustrating the challenges of supplying pandemic risk insurance is developed in Sect. 3 of this paper.

#### 2.3.1 Traditional insurance approach: PathogenRX

PathogenRX is arguably the best-known recent example of a property-casualty insurance product designed to address pure pandemic risk. Marketed by the global commercial insurance broker Marsh LLC, PathogenRX was jointly developed by Munich Re, one of the world's largest reinsurers, and Metabiotica, a start-up focused on helping governments and industry estimate, mitigate and manage epidemic risk. PathogenRX was introduced in 2018, approximately 18 months before the first confirmed cases of COVID-19 were reported in Wuhan, China, in late 2019. Despite the propitious timing of PathogenRX's launch and its backing by some of the largest and best-known insurance names in the world, only one policy was ever sold in the pre-COVID era (Ratliff 2020).

The failure of PathogenRX in the market occurred despite very flexible terms and conditions and a general recognition by corporations and governments that pandemics posed a material risk to their operations even before COVID-19, based in part on their experience with the 2003 Severe Acute Respiratory Syndrome (SARS) pandemic. According to Marsh's marketing materials, PathogenRX also offers buyers:

- The ability to model and estimate infectious disease risks,
- Customizable insurance coverage for losses stemming from infectious diseases, including for loss of gross profit, loss of revenue, and extra expense, and
- Parametric (i.e., pre-defined) coverage triggers, such as a mortality count or public health emergency declaration.

Marsh's target clients included companies in industries particularly vulnerable to outbreaks, epidemics and pandemics, including hospitality and travel, sports and entertainment, higher education, retail, manufacturing and mining (Marsh LLC 2020).

It should be noted that PathogenRX as of this writing (August 2020) continues to be offered by Marsh and the product's marketing materials have been revised to mention COVID-19. It is unclear whether the pandemic has led to actual sales. However, property–casualty insurers typically experience a surge in sales after major catastrophic events (e.g., sales of flood and earthquake insurance have been documented to increase *after* major events), perhaps as market participants gain a better understanding of the risk, the risk becomes more salient, or risk aversion increases.[4] At the same time, it is likely that underwriting and pricing have been adjusted to

[4] See Born and Klein (2019) for an overview of the literature on flood insurance in the U.S., including factors affecting demand.

reflect actual COVID-19 experience, resulting in more restrictive terms and conditions and higher premiums.

### 2.3.2 Capital market approach: the World Bank's Pandemic Emergency Financing Facility

Another notable but structurally very different approach to using insurance to manage pandemic risk involved the World Bank's Pandemic Emergency Financing Facility (PEF). Beginning in July 2017 with a term of three years, the PEF provided up to $425 million in insurance in the form of bonds and swaps (World Bank 2020). Interestingly, the PEF has been widely derided and deemed a failure even though the facility performed exactly as intended, paying out $195.8 million to 64 of the world's lowest income countries affected by the COVID-19 pandemic. Criticism of the PEF has focused on its perceived slowness to pay and its cost. The severity of criticism led the World Bank in July 2020 to formally abandon plans for a "PEF 2.0," despite a concurrent intensification of the pandemic throughout much of the developing world (Hodgson 2020).

The perceived failure of the PEF despite its functional success derives from the parametric triggers used to determine if and when payouts would be made. The facility was designed to provide payouts to cover "surge costs" incurred by poor countries in the event of pandemics arising from six categories of virus, coronavirus being one of them. Multiple triggers had to be met before payouts could be made. These triggers were related to the number of infections and deaths, rates of spread, degree of geographic spread and duration of the pandemic. It was not until April 16, 2020 that the last of the trigger conditions was certified as having been met. By that time, the pandemic was well underway. In the view of many, the lag deprived poor nations of the funds desperately needed to battle the spread of the virus precisely when those funds were needed most. The PEF has also been criticized as overly generous to investors who collectively received interest payments totaling nearly $100 million through February 2020, the result of annual coupons on the bonds that ranged as high as 11.5%.

It is worth noting that the "failure" of World Bank's Pandemic Emergency Financing Facility is a somewhat subjective characterization (Lane and Beckwith 2020). First, as previously noted, the facility did indeed pay nearly $200 million to 64 low income nations. Further, the assertion that the coupons on the bonds were excessive is debatable. The reality is that bonds bearing the 11.5% coupon—associated with the B tranche of the issuance—carried a material 9.44% (i.e., nearly 1-in-10) chance of sustaining at least some loss each year over the facility's three-year term. The relatively high probability of loss reflects the broad spectrum of infectious diseases covered—coronavirus (e.g., SARS, MERS, COVID-19), Ebola, Rift Valley Fever and Lassa Fever, among others. Moreover, as the bonds began to trade on the secondary market shortly after issuance, market quotes remained close to par, suggesting fair pricing relative to the opportunity cost of capital at that time (mid-2017).

One additional criticism of the PEF centers on the assertion that insurance, including ILS, are relatively expensive methods for delivering disaster relief and that funds for recovery from large-scale disasters (including pandemics) can be

more cheaply accessed via after-the-fact borrowing. In the case of the World Bank, which is rated AAA by Standard and Poor's, its cost of debt will be incrementally above that of advanced economy sovereign debt. The World Bank could therefore theoretically borrow on behalf of its less creditworthy client states, lending to them at a much lower interest rate than they could obtain on their own (assuming they can access credit at all). Lane and Beckwith (2020) point out that such an approach (i) subjects the World Bank to default risk, thereby jeopardizing its own credit rating, and (ii) presumes credit will be cheap and plentiful for the indefinite future. The issue of post-event funding alternatives to finance pandemic losses is addressed more thoroughly in Sect. 4 of this paper.

As we discuss in Sect. 3 below, the fact that very few pure pandemic risk products have ever been brought to market by insurers likely reflects the impracticality of insuring against pandemics in general, at least in the private sector, given the enormous capital requirements to underwrite the risk. The problems faced by Marsh's PathogenRX and the World Bank's PEF suggest that even very sophisticated efforts to provide pandemic risk solutions can fail in the marketplace for a multitude of reasons.

### 2.4 Contingent coverage for pandemic risk

In contrast to the market for pure pandemic risk in which coverage options are a rarity, pandemic risk is sometimes explicitly covered in the form of contingency coverages. The best known and largest market for contingency coverage is event cancellation insurance. Typically, payouts are contingent on the occurrence of a specific event. Event cancellation insurance is commonly purchased by organizers of sporting and entertainment events, conferences and associated venues. Such policies are highly customized but are typically underwritten with communicable disease exclusions which preclude coverage for epidemics and pandemics. However, communicable disease coverage can sometimes be purchased as an extension to the policy for an additional premium. While relatively few buyers purchase the extension, there are some high-profile exceptions. The organizers of the Wimbledon Tennis Tournament in London, for example, had for 17 years purchased pandemic insurance as part of its event cancellation coverage, paying $2 million per year in premium. Cancellation of the 2020 tournament due to COVID-19 resulted in a reported payout of $141 million by the event's insurers (Forbes 2020).[5] The International Olympic Committee (IOC), organizer of the 2020 Tokyo Olympics—which were postponed until 2021—likewise purchased coverage that included cancellation due to pandemics. The IOC received a negotiated sum to cover some of the losses associated with the postponement.

[5] Wimbledon's organizers announced in June 2020 that pandemic coverage for the 2021 tournament is unavailable, citing insurance market conditions. Other major sporting events have reported a similar pullback in the market by insurers amid the COVID-19 pandemic.

### 2.5 Other coverages with potentially material pandemic risk exposure

Beyond event cancellation insurance, a wide range of other coverages exist that can give rise to direct and indirect pandemic-related losses. A detailed discussion of all potentially exposed lines of insurance is beyond the scope of this paper, but a few key lines are worth mentioning both to illustrate the breadth of existing industry exposure and gauge the magnitude of the coverage gap. Among the lines with the most incidental exposure to pandemic loss are workers' compensation, commercial general liability, trade credit and directors and officer's insurance. The nature of each line's exposure to pandemic and potential COVID-19 losses is discussed below:

- Workers' compensation insurance provides wage replacement, medical and death benefits for all injuries and illnesses that occur in the course of employment, including those arising from occupational exposure to communicable diseases. Healthcare workers are the most exposed and as of mid-2020 approximately 100,000 workers in the U.S. had contracted COVID-19 and more than 500 had died (CDC 2020). As discussed previously, workers' compensation insurers are expected to incur billions in COVID-19 claims. Millions of other workers in other industries who are designated as "essential workers" (a definition that varies by state) are also potentially exposed. Their ability to claim workers' compensation benefits depends on a demonstration that COVID-19 was contracted out of the course of their employment. As mentioned previously, estimated COVID-19 losses in the workers' compensation line are highly uncertain, ranging from $0.2 billion to $92 billion (Willis Towers Watson 2020).
- Commercial general liability insurance protects businesses from a variety of claims that can arise during business operations. The insurers that write these policies are therefore concerned that U.S. businesses could be the subject of extensive litigation alleging negligence in allowing the coronavirus to spread (e.g., to customers, students, etc.). Willis Towers Watson has estimated that insured losses in the U.S. could reach $27 billion in a worst-case scenario. Losses of this magnitude would be highly disruptive to insurance markets and severely impair the ability of businesses to recover from shutdowns. To address this concern, insurers and businesses support federal efforts to implement a temporary liability shield that would protect businesses, healthcare facilities and educational institutions against most COVID-related litigation (Werner et al. 2020).
- Trade credit insurance is purchased by businesses wishing to insure their accounts receivable against the possibility of default or insolvency of the counterparty in the transaction. Trade credit insurance therefore reduces credit risk. It is instrumental in facilitating international trade where complex supply chains amplify the risk. The deep, global economic recession that ensued as countries attempted to contain the spread of the coronavirus precipitated a massive increase in credit risk. The deteriorating finances of businesses around the world exposed insurers in the U.S. and London markets (where the majority of this

coverage is written) to losses estimated to be as high as $6 billion (Willis Towers Watson 2020).[6]

- Directors and officer's insurance (D&O) protects members of an organization's board of directors and its management against personal loss if they are sued as a result of serving on the organization's board or management team. The COVID-19 pandemic is expected to lead to extensive litigation against corporations, their boards and managers arising from allegations that the company's response to the pandemic was inadequate and/or that statements the company made regarding its exposure to loss and finances were misleading and caused financial injury to stakeholders (e.g., shareholders). The sharp increase in business bankruptcies during the pandemic had by mid-2020 already contributed to an increase in D&O claims. Willis Towers Watson estimates that losses in the D&O line could reach $4 billion.

### 2.6 Pandemic coverage post-COVID

The immediate impact of COVID-19 on property–casualty insurance markets has been to intensify a pre-existing "hard market" for most major lines of commercial insurance. Hard markets are typically characterized by a tightening of underwriting criteria and a sustained upward trend in pricing—reflecting both a reassessment of risk and reduction in available capacity. Market surveys for the first quarter of 2020 revealed the largest and broadest rate increases since 2003, a period when markets were still absorbing the shock of the September 11, 2001 terrorist attacks (Council of Insurance Agents and Brokers 2020).

At the same time, insurers are planning for the future. Amid the pandemic, numerous insurers and reinsurers in the U.S., Europe and in the Bermuda market have collectively raised billions of dollars in the form of both equity and debt offerings. Issuance of insurance-linked securities has also continued apace, running ahead of 2019 volumes. These companies and investors have cited the favorable rate environment and numerous market dislocations to which capital can be opportunistically deployed at attractive rates of return. These capital raises are consistent with a pattern observed for decades within the industry whereby hard market periods, which generally occur following major market shocks (e.g., September 11 attacks, Hurricane Katrina), serve to attract additional capital even amid heightened uncertainty.

At least some of this capital will likely be allocated to new product offerings that involve pandemic risk, often through excess and surplus lines markets which offer insurers more flexibility in terms of price and policy language. Insurers are also harnessing the creativity and ingenuity within the InsurTech sector. Lloyd's, for example, has established an innovation accelerator—Lloyd's Lab—which is working with a variety of start-up firms to expedite COVID-19 related products and innovations and to improve understanding of how to model and create products that better protect customers against future pandemics and other systemic risks (Lloyd's 2020).

[6] Estimate includes potential losses for political risk insurance and surety lines.

### 2.7 Section summary

Insurers, reinsurers and capital markets have historically struggled to bring commercially viable pandemic insurance products to market. Potential losses can easily exceed the industry's capital, surplus and premium resources. Pandemic losses are also correlated with financial market losses. Collectively, these factors pose a systemic risk to the industry and potentially the overall economy. Insurers also struggle with a legal, regulatory and legislative environment that makes contracting for pandemic risk a costly and uncertain process. These environmental obstacles compound the inherent challenges in modeling pandemic risk. Under such conditions, frequency and severity of losses cannot be precisely modeled, creating an obstacle to accurate pricing. Consequently, it is unlikely that private insurance markets will be able to offer affordable, widely available commercial insurance products that insure against some of the costliest economic consequences of pandemics, especially those arising from business continuity risks. In the next section we more formally address the supply-side challenges in the market for pandemic insurance, and in Sect. 4 we discuss the potential role of a government in overcoming those challenges.

## 3 A framework for analyzing pandemic insurance

The previous section documented that prior to COVID-19 the private insurance market for economic losses from pandemics related to a pause of economic activity was thin in the sense that relatively few entities had coverage and the amount of coverage that was purchased was low relative to the potential size of losses.[7] In this section, we examine a number of non-mutually exclusive, potential explanations for a thin pandemic insurance market.

Some potential explanations can be viewed as originating on the demand side and arise from an underestimation of either the likelihood and/or the severity of pandemic losses. The underestimation of pandemic risk could occur for many reasons, including decision makers underestimating the probability of a pandemic, or underestimating the speed and/or extent to which a virus spreads, or underestimating the probability and/or duration of a government imposed shutdown of economic activity, or being overly optimistic about the ability of scientists to develop treatments and vaccines. Regardless of why, underestimation of the risk could lead to low demand and therefore a thin market. Demand can be further reduced by people's perception that if a truly disastrous pandemic event occurs, governments likely will intervene and provide disaster assistance.

It is unlikely that widespread underestimation of pandemic risk will occur in the near future given the recent experience with COVID-19.[8] On the other hand, the

[7] Other types of economic losses were indemnified by private market insurance products during COVID, such as event cancellation, trade credit, workers' compensation.

[8] See Ratliff (2020) for an interesting story of the development of the pandemic insurance product PathogenRX, its lack of success in the marketplace, and how risk perceptions changed in January 2020.

response of governments in developed countries to COVID-19 in providing aid (see Richter and Wilson 2020 and Sect. 4) has likely increased the perception that governments will react similarly in future pandemics, which will decrease the incentive of entities to mitigate risk and to purchase insurance for losses caused by pandemics.

While we acknowledge that a lack of demand likely contributes to a thin market, we focus in this section on why it is costly to supply insurance for economic losses caused by a pandemic. We argue that pandemic risk has characteristics that would likely lead to a thin market even in the absence of distortions that reduce demand. To focus attention on the supply side of insurance, we assume that those exposed to pandemic risk have a good understanding of the risk and would be willing to pay a "reasonable" loading over and above the expected loss for insurance if it was available. Risk aversion on the part of individuals can explain their willingness to pay more than the expected loss, and financial market imperfections (see e.g., Froot and Stein 1997) can explain businesses' willingness to pay more than the expected loss. Of course, as the loading (price) on the insurance increases, the quantity of insurance demanded is expected to decline, i.e., the market is expected to become thinner.

We discuss both a private market supplying the insurance and a government supplying the insurance for the purpose of identifying situations in which one would have advantages/disadvantages relative to the other. While certainly motivated by the COVID-19 pandemic, this section does not consider the current situation; instead, it identifies and discusses general issues that must be addressed to provide a successful pandemic risk-transfer scheme for the future. It is therefore conceptual, not descriptive nor empirical.

### 3.1 Conceptual framework/setting

We consider the risk associated with insuring $N$ entities for the economic losses associated with business closures due to an infectious disease. We think of these $N$ entities as being in a given country, but a broader perspective is also possible. The entities could be individual businesses or represent a group of businesses, say in a given geographical region. Without specifying the size or economic conditions of an entity, assume that entity $i$ has a probability of $p_i$ of economic losses $L_i$ from a breakout of an infectious disease in a given year. Presumably $L_i$ is related to the amount of economic activity in $i$. For now, we will not specify a probability distribution for $p$ or $L$, as below we consider various hypothetical examples.

We consider the possibility that the probability of a loss and/or the severity of a loss could be correlated across entities, with the idea that epidemics (disease is contained to a few entities) would be characterized by a low correlation, and that pandemics (disease spreads across many entities) would be characterized by a relatively high correlation. We specify the correlation structure in examples 3 and 4.

Note that the underlying risk structure (the probability distributions for the probability of a loss, $p$, the severity of losses, $L$, and the correlation structure is assumed to be constant over time periods. This type of stationarity is almost certainly violated in practice as, all else equal, the likelihood that multiple entities would experience losses (the correlations) increases with economic integration (globalization)

and decreases with advances in medicine. Similarly, the probability that an entity $i$ experiences a loss can change over time and the magnitude of economic losses can change over time, e.g., with economic activity and medical breakthroughs. These aspects of the problem are ignored.

### 3.2 The capital required for pooling risk cross-sectionally

Initially, we focus on the amount of capital needed to provide a credible mechanism to pay claims that occur in a given time period. In the subsequent section, we analyze pooling risk over time. We refer to the time period as a year. We ignore all administrative costs (e.g., costs incurred to enroll entities and pay claims) associated with implementing a pooling mechanism. We define a *credible mechanism* as one that would provide a very high probability of being able to pay all losses that occur within a year. To achieve this high probability, the pooling mechanism must have access to sufficient financial resources to pay most losses that could occur, which we somewhat arbitrarily set as the 99th percentile value of total potential losses.[9]

We consider the pooling mechanism as occurring at the aggregate level that includes all $N$ entities. This could be through a private insurance market or possibly a government program. Regardless of whether a private market or a government solution is used, we assume that the pandemic risk is managed as a standalone pool of risk, independent from the rest of the risks that exist. In other words, we ignore potential risk-sharing benefits across types of risk.[10]

We further assume that a private insurance market works well in the sense that insurers/reinsurers can transfer risk among themselves costlessly, so that each insurer holds a proportional share of the aggregate pandemic risk portfolio. In other words, the risk is shared efficiently among insurers via a frictionless reinsurance market (see Borch 1962). Under these assumptions, each insurer/reinsurer, would pay a proportion of all pandemic losses, although the proportion could vary across insurers/reinsurers based on their risk tolerance, which we do not specify. Also, with this assumption, the total amount of financial resources needed to provide a credible (99% probability) pooling mechanism of all pandemic losses would be the same for a private market as for a standalone government program.

Below we calculate the amount of financial resources needed in several hypothetical examples to illustrate some of the factors that determine the cost of providing a credible insurance mechanism. In each of the examples, we define 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*. Figure 1 illustrates these definitions for an arbitrary probability density function for pandemic losses. For simplicity, we initially assume that the assets are invested in risk-free, zero-return securities.

[9] As a benchmark, Solvency II seeks a probability of insolvency equal to 99.5%.

[10] See Ibragimov et al. (2009) and Mildenhall (2020) for explanations of why pooling some types of risk exposures with others may not be desirable.

We assume that a private market has a cost of holding capital. To identify these costs, consider an equity investor in an insurer. Conceptually, the investor could have alternatively invested in a portfolio of mutual funds that has the same asset portfolio as the insurer. The difference is that there is likely to be more information frictions (agency costs and information asymmetry costs) with an investment in the insurer because the insurer's managers are not only managing the asset portfolio but also the liability side of the balance sheet (Kielholz 2000). In addition, there are potential tax costs associated with the insurer investment (see e.g., Niehaus 2020). The purpose of this paper is to focus on the amount of capital needed, not the capital costs per dollar of capital.

The nature of the costs associated with a government holding the necessary level of capital is likely to differ from a private market. For example, there would not be tax costs associated with the government holding the capital. However, there would likely be other costs. For example, politicians might be tempted to use the funds for other purposes or invest the funds to achieve other political goals besides providing a pooling mechanism for infectious disease costs. We can think of these political costs as a form of agency costs associated with a government structure as opposed to a private corporate structure. There may also be efficiency losses in having a government entity manage the pooling arrangement as opposed to private insurers. We defer additional discussion of these costs to Sect. 4.

We now present a series of hypothetical examples. The purpose of these relatively elementary examples is to illustrate how the required amount of capital varies with important characteristics of pandemic risk, specifically, with uncertain loss severity, cross-sectional correlation in the frequency of losses, and cross-sectional correlation in the severity of losses. The focus is not on the absolute amount of capital needed in a given example, but on the relative amount of capital across the examples. Researchers, practitioners, and instructors in the risk and insurance field can skip the examples and go right to the subsection titled "Summary of Examples", which is before Sect. 3.3. The examples might be useful for students and those new to the underlying principles of insurance.

#### 3.2.1 Example 1: ideal conditions

Assume that there are 1000 entities, the probability of an event ($p$) is 0.02 for each entity, and the severity of an event ($L$) is the same for each entity and equals \$100. Importantly, assume that the outcome for one entity is independent of another entity. In this simple case, the distribution for *total losses* for all 1000 entities has a binomial distribution with an expected value \$2000 and a 99th percentile value equal to \$3100. Thus, prior to the realization of losses, the total liability is \$2000 and the assets needed to have a credible pooling arrangement is \$3100, which implies that the amount of capital required to provide credible insurance is \$1100, or a little more than one-half the expected total loss. On a per entity basis, the expected cost is \$2, and the amount of capital required is \$1.1. Stated differently, the required capital per entity is 55% of the expected loss.

This example illustrates the great benefits of pooling risk. If each entity had to hold enough assets to ensure that it would be able to pay all its own losses, then

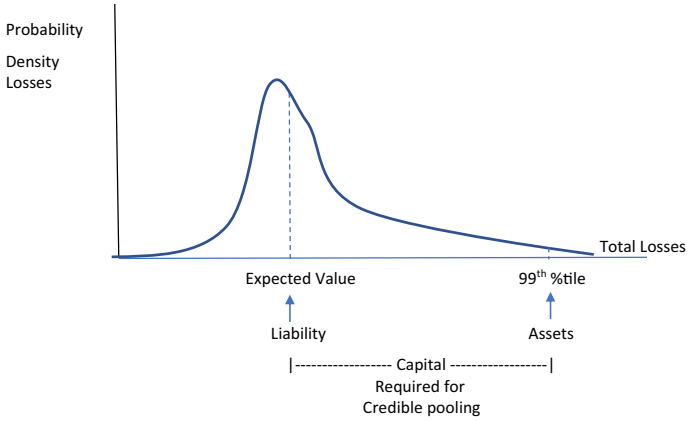


**Fig. 1** Illustration of assets and capital needed for a credible pooling mechanism for a given probability density function for total losses

each entity would need to set aside $100. If this risk is pooled using a mutual agreement among the 1000 entities, each entity would need to contribute $3.1 and there would be sufficient funds to pay every entity's loss with probability 0.99. The contribution is just 55% more than each entity's expected loss. Alternatively, an insurer could offer each entity credible insurance by raising equity capital equal to about $1100 and charging a premium to each entity that covers the expected claim costs per entity, $2, plus the cost of compensating the capital providers.[11]

This example assumes ideal conditions for pooling risk and therefore provides a benchmark for the subsequent examples. The probability of a loss and the size of the loss if it occurs are known and are the same for all entities, the outcomes across entities are independent of each other, the outcomes do not depend on the decisions of any of the participants, and there are a relatively large number of entities. The remaining examples relax some of these assumptions by incorporating characteristics of pandemic risk. As we will see, the pandemic characteristics generally make pooling risk more costly.[12]

### 3.2.2 Example 2: uncertainty in severity of losses

The magnitude of the losses that an entity incurs from a pandemic is highly uncertain, because economic shutdowns can vary in terms of scope (how many businesses stop operating), degree (is there a complete shutdown or reduced activity),

[11] Finding the exact amount of capital to raise is more complicated than this paragraph suggests as the premium depends on the amount of capital and the amount of capital depends on the premium. See Harrington and Niehaus (2003) for a simple model incorporating the simultaneity. Of course, finding the optimal amount of capital in practice is much more complicated.

[12] If entities differ in their underlying probability distributions, specifically with respect to the "fatness" of the tail of the distribution, then pooling exposures may not be beneficial. See Ibragimov et al. (2009) and Mildenhall (2020).

and duration (weeks, months, or years). We therefore introduce uncertainty in the magnitude of the loss if a loss occurs (hereafter referred to as severity), but we continue to keep the probability of a loss equal to 0.02. We assume that each entity has the same probability distribution for severity. The severity experienced by each individual entity is an independent draw from a lognormal distribution with an actual mean of \$100 and an actual standard deviation equal \$200.[13] With this assumption, the expected severity is the same as in the previous example, \$100, but there is considerable uncertainty in the magnitude of the losses that each entity with a loss experiences. Figure 2 illustrates the density function of the assumed lognormal distribution.

With these assumptions, the expected loss per entity is still \$2, but the 99th percentile value is \$5.4 per entity, implying that in a mutual arrangement, each entity would need to contribute 170% [(\$5.4 − \$2)/\$2] more than their expected loss, or a little over three times the amount that was needed in Example 1 when losses were fixed at \$100. The more uncertainty there is in losses, all else equal, the greater the cost of providing a credible pooling arrangement.

### 3.2.3 Example 2b: incorporating limits

Insurers can reduce the uncertainty in their loss payments by incorporating limits on their coverage. Suppose, for example, that the pooling mechanism provides coverage only for losses up to \$500 per entity in the pooling arrangement described in Example 2. Given the assumed lognormal distribution for losses, only about 3% of the participants would have losses exceeding this amount. Incorporating this limit lowers both the expected value of the payment that a participant will receive (from \$2 to \$1.75), as well as the 99th percentile value of payments per entity (from \$5.4 to about \$3.5). Consequently, the required contribution per entity would drop from 170% to about 100% of the expected claim payment.

The lower the coverage limit, the less capital required to provide a credible insurance mechanism for the coverage provided, all else equal. For example, if the coverage limit in our example was further reduced to say \$200 per entity, then the required contribution per entity would be about 80% of the expected claim payment. However, the lower the limit, the less coverage that is being provided, i.e., less risk sharing is taking place. Nevertheless, coverage limits can be an effective tool to promote a private market for relatively low pandemic losses. The desirability of coupling a private market with relatively low limits with a government offering (or possibly requiring) excess coverage above the private market limits, either directly

[13] We are assuming that severity has a lognormal distribution with a mean of \$100 and a standard deviation of \$200, not that the log of severity is normally distributed with a mean of \$100 and a standard deviation of \$200. To elaborate, sometimes (but not here) the lognormal distribution is characterized by parameters, say $m$ and $s$, which are the mean and standard deviation of the log of the random variable. In that case, the actual mean and standard deviation of the lognormally distributed random variable are $\exp(m+s^2/2)$ and $\exp(m+s^2/2))(\exp(s^2-1)^{1/2}$.

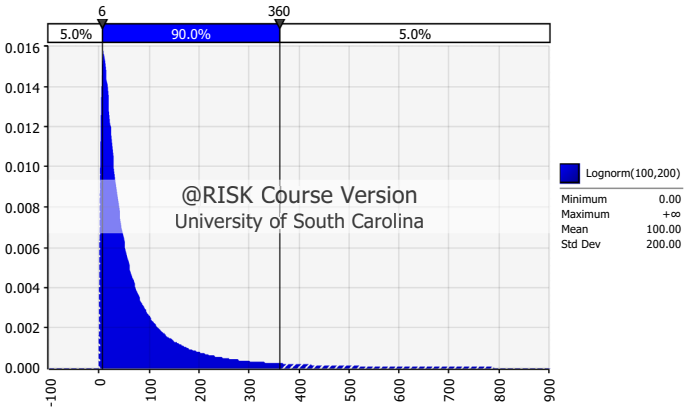


**Fig. 2** Lognormal distribution with mean of $100 and standard deviation = $200 used to model uncertainty in the severity of losses

to consumers or through a reinsurance arrangement with private insurers will be discussed in Sect. 4.[14]

### 3.2.4 Example 3: correlation in loss severity

In the previous examples, all the entities were assumed to have the same probability distribution for the frequency and severity of losses and the outcomes for one entity were independent of the other entities. We now introduce correlation by modeling the average severity experienced by all of the entities. Specifically, we assume the average severity has a lognormal distribution with an expected value of $100 and a standard deviation of $200. In this setting, if the average severity is larger (or lower) than expected, then that higher (lower) than expected severity applies to all of the entities that have a loss, which intuitively induces a positive correlation in the individual entities' losses conditional on a loss occurring. We continue to assume that the probability of a loss for all entities is 0.02 and independent of each other.

The result is that the amount of capital required to have a credible pooling arrangement increases dramatically. For a mutual pooling arrangement, each entity would have to contribute capital equal to $15 in addition to the expected loss of $2. Stated differently, the capital required is 750% of the expected loss. Thus, correlation in losses increases the required capital dramatically.

[14] We also investigate allowing the probability that an entity has a loss, $p$, to be uncertain such that the expected probability for each entity still equals 0.02. Specifically, for each individual entity, we assume that the probability of a loss is independently drawn from a Beta distribution with parameters equal to 1 and 49. We keep the severity of the loss if it occurs as a lognormal distribution with a mean of $100 and standard deviation of $200 (as in Example 2). Even though we have added uncertainty in the probability that an entity has a loss, the amount of capital needed is very similar to Example 2.

### 3.2.5 Example 4: additional correlation through the frequency of a loss

In the next example, we assume that the loss frequency that applies to all entities is uncertain. That is, a probability of a loss is selected randomly and that probability applies to all the entities. This is a way of incorporating correlation in the occurrence of a loss across entities (see Hisakado et al. 2006). Intuitively, when one entity has a higher (lower) than expected probability of a loss, then all the entities have a higher (lower) than expected probability of a loss.

Specifically, we assume that the probability of a loss that applies to all entities is drawn from a Beta distribution with parameters 1 and 49, which is illustrated in Fig. 3. This distribution implies that, on average, the probability of an entity having a loss is 0.02, as has been the case in all of the examples. We continue to assume that the average severity of losses has a lognormal distribution as was the case in Example 3. With these assumptions, the 99th percentile value of losses is about $21 per entity, implying that capital equal to about $19 per entity is needed to provide credible insurance. In a mutual arrangement, each entity would need to contribute 950% more than their expected loss to have a credible pooling arrangement. Thus, correlation in the occurrence of losses also has a significant effect on the amount of required capital.

### 3.2.6 Example 5: pandemic versus natural catastrophe risk

We now provide an example to compare insurance for pandemic risk to insurance for a natural catastrophe risk. The idea underlying the example is that natural catastrophe risk is usually limited in that it impacts only entities within a given geographical region. Therefore, catastrophe risk is likely to have correlation in losses for entities in a given geographical area, but not for all entities. In comparison to the setting described above for pandemic risk, natural catastrophe risk would likely cause correlation within groups of entities, not across all entities. We therefore estimate the capital that would be needed to provide a credible pooling arrangement if instead of applying the probabilistic assumptions of Example 4 to all 1000 entities, they were applied to separate groups of 20 entities each. This imposes correlation in frequency and severity for the 20 entities within each group, but keeps the frequency and severity across groups uncorrelated. With 20 entities per group, there are 50 groups. The amount of capital required per entity in this case is about $4.4, or 220% of the expected loss. This is high, but not close to the 950% that we found for the pandemic risk in Example 4.

### 3.2.7 Summary of the examples

These hypothetical examples, which are summarized in Table 1, illustrate that the amount of capital required to provide a credible cross-sectional pooling arrangement increases substantially if there is correlation in the frequency and severity of losses, both of which characterize pandemic losses. Example 1 provides a baseline case of when pooling works well—i.e., a large number of exposure units, loss distributions are known, losses are not correlated across exposures, and the interested parties

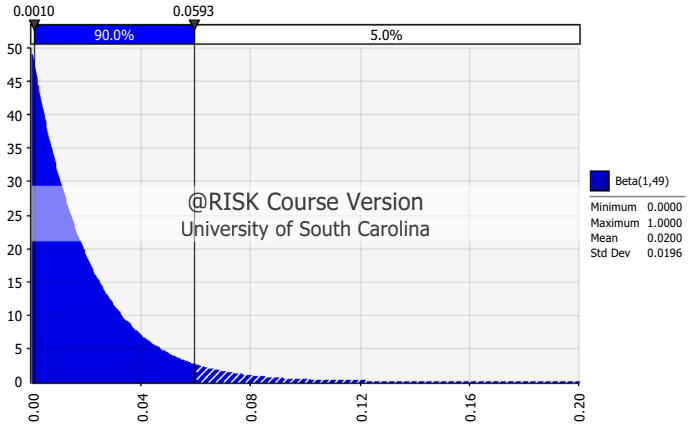


**Fig. 3** Beta distribution with parameters 1 and 49 used to model uncertainty in the frequency of losses

cannot influence the loss distribution. In this case, the capital required is 55% of the expected loss costs. The introduction of uncertainty in losses in Example 2 increases the capital required by a factor of three (from 55 to 170%). Correlation in the average severity of losses across entities (Example 3) increases the required capital substantially to about 750% of the expected loss costs. If there is also correlation in the probability of the probability of a loss (Example 4), then the required capital is about 950% of the expected loss costs. Of course, these numbers are contingent on the specific assumptions made about the probability distributions, but they illustrate the important general point that even when pooling arrangements can be organized and managed at zero costs (which is what we assumed), the capital required to provide a credible pooling arrangement for pandemic risk would be substantial.[15]

### 3.3 Pooling over time

The previous section indicates that a credible cross-sectional pooling arrangement for the economic losses associated with pandemics can require a large amount of capital. We now analyze the possibility of pooling the risk over time, under the assumption that the losses in one year are independent of those in another year. To illustrate conceptually how this might work, we consider a 50-year time period and treat all the entities in a given year as a separate cohort. We think of pooling over time as each of the 50 annual cohorts agreeing to share losses equally with the other 49 annual cohorts. For simplicity, we ignore the time value of money.

To illustrate the potential benefits of pooling over time, we compare the capital required for all the entities under the cross-sectional pooling arrangement

[15] It is also worth noting that the correlation in the probability of a loss in Example 5 is relatively modest, as there is less than a 2.5% probability of having more than 75 entities experience a loss at the same time.

**Table 1** Summary of the hypothetical examples

| | Example # | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Assumptions | | | | |
| Frequency | Brnlli-prob fixed (0.02) independent | Brnlli-prob Fixed (0.02) independent | Brnlli-prob fixed (0.02) independent | Binom-prob uncrtn (Beta) correlated |
| Severity | Fixed ($100) | Uncertain (LogN) independent | Uncertain (LogN) correlated | Uncertain (LogN) correlated |
| Number of entities experiencing a loss | | | | |
| Mean | 20 | 29 | 20 | 20 |
| 10th percentile | 14 | 14 | 14 | 2 |
| 25th percentile | 17 | 17 | 17 | 6 |
| 75th percentile | 23 | 23 | 23 | 28 |
| 90th percentile | 26 | 26 | 26 | 47 |
| Required capital per entity to have credible insurance | | | | |
| Amount of capital per entity ($) | 1.1 | 3.4 | 15 | 19 |
| Capital/(ExpLoss) (%) | 55% | 170% | 750% | 950% |

in Example 4, which was 950% of the expected loss, to the capital that would be needed for a credible pooling arrangement over 50 years. To do this, we estimate the probability distribution of aggregate losses from Example 4 and assume that a separate independent draw from this estimated distribution determines the aggregate loss in each of the 50 years. We then simulate the mean and 99th percentile value of the average loss over the 50 years, which are used to find the amount of capital needed as the difference between the 99th percentile value and the mean value. The details are in the "Appendix".

Note that the sequential nature of time is ignored in this analysis. Instead, one can think of pooling over time as requiring each annual cohort to contribute the annual expected loss plus the required annual capital for each of the 50 years and then the total losses over all 50 years are paid. Alternatively, one can think of the pooling arrangement as receiving funds each year and paying out losses each year as they occur, where any excess funds are carried over to the following year and any deficit is borrowed from the participants at a zero interest rate.

The exact results depend on the distributional assumptions for aggregate losses each year, but the message is clear: the amount of overall capital required would be substantially lower than in Example 4. Under one distributional assumption (Inverse Gauss distribution), the capital required per entity per year is 125% of the expected loss, which is substantially lower than what would be required in a cross-sectional pooling arrangement, which was 950% of the expected loss. Under an alternative

distribution assumption (Lognormal distribution), each entity would need to contribute capital equal to 325% of the expected loss each year with pooling over time.

A problem with pooling risk over time is finding a way to actually implement the arrangement so that sufficient funds are available each year that a large loss could occur. To illustrate, using the example above, each year the arrangement would receive 125% more than the expected loss, which equals \$4500 ($\$2000 \times (1 + 1.25)$) in contributions. This amount exceeds the expected annual payout of \$2000, but a large loss could occur in one of the early years before a sufficient buffer has been accumulated. Indeed, in the example, there is over a 10% probability that a loss larger than \$4500 could occur in any given year, including the first year.

A potential response is that the pool can borrow funds to make up any shortfall that might occur. However, the feasibility of obtaining credible commitments from all the relevant entities is questionable, and if it were possible, the transaction costs would be high. In a dynamic economy with exit and entry, the arrangement would need to identify the terms under which entities could leave and newly created entities could join the arrangement over time.

There are additional reasons that a viable pooling arrangement over time would be difficult, if not impossible, to arrange and implement in a private market setting. For example, if there are changes over time in the underlying probability distributions describing the frequency and/or the severity of losses that are different across entities, then those entities that experience lower frequency and/or severity might defect from the large pool, and possibly form smaller pools with other entities that have similar changes.[16] Therefore, differential changes across entities in economic growth or in the quality of public health services might make a pooling arrangement unstable over time. In addition, given that frequency and severity of losses can change because of an entity's actions and policies regarding public health and economic growth, there is also a moral hazard problem associated with pooling over time.

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 fiat 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. In Sect. 4, we further discuss the potential advantages and disadvantages with implementing a government solution to pooling risk over time.

[16] There is a formal literature on the stability of sharing arrangements. See e.g., Ligon et al. (2002) and Genicot and Ray (2003).

### 3.4 Other considerations affecting the cost and benefits of a pooling arrangement

The previous sections focused on the amount of capital associated with providing a credible pooling mechanism for the economic losses from pandemics. There are other characteristics of pandemics that could make a private market "thin" in the sense that coverage is available for only a relatively small proportion of potential or expected losses. We now discuss some of these factors.

#### 3.4.1 Correlation of asset values to losses

As discussed above, pooling arrangements need to hold assets in excess of their expected loss payments. These assets typically are invested in financial securities, which ideally generate positive returns from interest, dividends, and capital gains. In general, the returns on the financial securities held by insurers are uncertain, which when combined with the uncertainty associated with loss payments (discussed above) can affect the credibility of the pooling arrangement to pay all losses. The overall effect of uncertain asset returns depends on three factors.

First, higher expected returns on the assets, all else equal, increases the credibility of the pooling arrangement. Intuitively, the investment returns on the assets provide additional financial resources to pay losses. Second, greater the uncertainty associated with investment returns (sometimes measured by standard deviation of returns), all else equal, reduces credibility. Intuitively, more uncertainty in asset returns increases the likelihood of obtaining very low asset values and therefore increases the likelihood of not having sufficient resources to pay all losses. Third, the problem with the pandemic losses is that they arise from an economic slowdown or shutdown, which also tends to lower asset returns. Thus, when pandemic losses are high, asset returns tend to be low. The greater is the negative correlation between asset returns and loss payments, all else equal, the lower is the credibility of a pooling mechanism. To maintain the same credibility, the pooling mechanism will need to hold additional capital, which makes the pooling arrangement even more costly to operate.

#### 3.4.2 Expected frequency and severity differs across entities

In the examples above, we assumed that prior to the revelation of any random variables, all of the entities, as well as the insurer, were homogeneous in their expectation of the probability of an entity having a loss (0.02) and in their expectation of the magnitude of the loss if a loss occurred ($100). In practice, both the severity of losses and the probability of a loss are likely to vary across entities in observable ways. Loss severity will be higher, for example, for entities with greater economic activity (revenue), those engaged in activities that are not viewed as being essential, those with a more cautious clientele, those located in more densely populated areas, etc. Similarly, the probability of a loss will be

higher for entities located in areas with a more mobile population and that are more densely populated.

In theory, this heterogeneity, provided it is symmetrically known, does not present insurmountable problems for a pooling arrangement. To avoid an adverse selection problem (the high expected loss entities participate but the low expected loss entities do not), the contributions to a mutual pooling arrangement or the premiums paid to a private insurer would need to vary based on the expected losses of each entity.[17] A potential alternative is to not vary the contributions/premiums, and instead make participation mandatory. This approach, however, would likely give rise to political costs as those entities with low expected losses would want to reduce their subsidization of those entities with high expected costs.

A more difficult problem arises if those who are operating the pooling arrangement cannot distinguish entities with high expected losses from those with low expected losses, but that the entities know their own expected losses. In this case, the adverse selection problems cannot be solved by varying contributions/premiums because the information needed to determine the appropriate premiums is private. For example, a retail business's susceptibility could depend on its clientele, about which the owner is likely to have better information. On the other hand, understanding the scope, degree, and duration of a pandemic often requires specialized scientific knowledge, and thus the "experts" (scientists) are the ones who will likely have superior information, not the exposed entities.

Variation across entities in their expected losses also raises the issue of whether a pooling arrangement should provide equal compensation to all participants even though they may differ in their actual losses. All else equal, compensating entities for their actual loss (indemnity contracts) provides better risk sharing. The downside with providing compensation based on the size of the loss is that it requires measuring the loss, which is costly. In addition to reducing administrative costs, a flat benefit can also reduce moral hazard, a topic to which we now turn.

### 3.4.3 Moral hazard

Potential moral hazard problems arise whenever the actions of participants in a pooling arrangement can influence either the probability of a loss or the severity of a loss. One way to mitigate moral hazard is to monitor participant's behavior and write contracts that are contingent on this behavior (although this may be costly). Another way to mitigate moral hazard is to limit the extent to which risk is shared by including deductibles, coinsurance, limits, exclusions, etc. Regarding the latter approach, making participants pay part of the losses that occur (i.e., placing some of the risk on participants) forces the participants to internalize the impact of their behavior on the expected losses. A third method of mitigating moral hazard is to have non-indemnity insurance contracts in which the payment by the insurer is determined by either a set of event parameters (e.g., the number of countries affected or number of

[17] The contribution needed to cover the cost of capital would also depend on each entity's marginal contribution to the uncertainty in total losses. See e.g., Bauer and Zanjani (2016).

deaths) and/or a loss index (e.g., the losses suffered in a geographical region), which are correlated with an individual entity's losses but not directly influenced by the entity. These parametric and index triggers are sometimes used in insurance-linked securities, such as catastrophe bonds.[18] Indeed, the pandemic bond issued by the World Bank in 2017 and discussed in Sect. 2 used a parametric trigger.

Moral hazard is likely to be an issue with pandemic risk for several reasons. The economic costs associated with an interruption of normal business activity depend on managers' actions to control costs and generate revenue during the interruption period. If a business receives compensation for all or most of its additional costs and its lost revenue, then it will have little incentive to find and implement innovative ways to prepare for and respond to an interruption to lower the costs incurred. Also, decisions regarding the timing, extent, and duration of business interruptions are often made by a regional or national governing body, and political officials will naturally tend to initiate, broaden, and extend a forced interruption if the cost is born mostly by future generations or taxpayers who are not the politician's constituents.

#### 3.4.4 Samaritan's dilemma

If participation in either a private or public pooling mechanism is voluntary, then some entities may not participate, because they have the expectation that if a major loss occurs, public assistance will provide ex post coverage at no cost. This is sometimes called the "Samaritan's dilemma" (Buchanan 1977). A solution is mandatory participation.

#### 3.4.5 Positive externalities associated with a pooling mechanism

Most of the discussion to this point has focused on the private costs and benefits associated with pooling risk, i.e., the benefits and costs to the entities in the pooling arrangement. However, an important consideration is the potential benefits that others in society receive as a result of having a pooling arrangement that compensates entities for their loss. One potential external benefit is that it reduces the likelihood that business relationships among contracting parties or between the business and its employees will be damaged or disrupted. Also, by helping to maintain economic activity, even at a lower than normal level, compensation to entities that experience a loss can reduce the magnitude and duration of a recessionary economic period. A disadvantage of purely private insurance mechanism is that these positive externalities would not be taken into consideration in the pricing and distribution of the insurance. Potential solutions include government subsidies for private insurance or even government provision of the insurance at reduced rates.

[18] The use of non-indemnity triggers to reduce moral hazard is discussed in Niehaus and Mann (1992), Doherty and Richter (2002), Doherty and Smetters (2005), Froot and O'Connell (2008), and Finken and Laux (2009). The tradeoff is greater basis risk. Teh and Woolnough (2019) provide an overview of the literature and an analysis of basis risk associated with index-based contracts.

Also, the lack of insurance for the economic losses associated with a business interruption implies that additional risk is placed on lending institutions. Given the connectedness of the financial industry, the failure of some financial institutions could jeopardize the solvency of other institutions. Contagion can also occur if information about the solvency problems of one or a few institutions spread to other institutions. In short, there is potential failure of, or significant damage to, the entire financial system (systemic risk) due to uninsured pandemic losses. To the extent that a functional risk-transfer mechanism for the economic losses from a pandemic can reduce the likelihood of a bad recession, there is a positive externality associated with having such a risk-transfer mechanism.

### 3.5 Section summary

The most important problem facing the private supply of pandemic insurance is the large amount of capital required to make the insurance credible. Other problems (correlation between pandemic losses and insurer assets, moral hazard, adverse selection, low take-up rates due to underestimation of risk) are also important considerations. While a private market could provide some coverage by limiting the amount of coverage and the number of entities covered, widespread, high-limit coverage is not likely to be forthcoming from the private market. There are, however, positive externalities associated with avoiding long periods of depressed economic activity, which broad coverage could help prevent. Comprehensive government programs designed to directly address large-scale business continuity losses from pandemics are necessary to address this risk prospectively and could, over time, potentially encourage the innovation of limited specialized pandemic coverages by private insurers and reinsurers. It is useful to think about broad coverage provided by a government as a pooling arrangement over time, which utilizes the government's ability to transfer resources over long time periods by borrowing and taxing. The tradeoffs associated with different ways of organizing a government mechanism are analyzed in the next section.

## 4 Government's role

Since society has a vested interest in mitigating and compensating pandemic losses and a private market alone cannot provide sufficient insurance coverage, we consider how a government can promote greater sharing of future pandemic risks. During COVID-19, governments around the world not only imposed social-distancing measures to control the spread of the virus, but also actively provided significant financial resources to businesses and individuals, with the intention to protect employment and avoid bankruptcies. Current government actions, however, are not necessarily the optimal mechanism for the future. In this section, we outline four general approaches available to governments which aim to facilitate and support the sharing of pandemic risk. We evaluate these four approaches based on the degree to which they are likely to achieve specific public policy goals.

## 4.1 Four approaches to government involvement

### 4.1.1 Approach 1: provide post-event aid

One approach is for the government to let the private market deal with pandemic risk without government involvement. As explained above, the private market will fail to provide substantial coverage and many entities will suffer large uncompensated losses if a pandemic occurs. The government, on an ad hoc basis, can then "come to the rescue" and provide aid to those impacted. This approach, which is depicted in Fig. 4, involves no pre-event financing nor pre-event commitment for how the aid will be allocated if an event occurs. The government reacts to a pandemic event as it is occurring and allocates resources to the entities affected by the pandemic. The necessary funds are borrowed, placing the cost burden on current and future taxpayers.

The COVID-19 pandemic was handled by most governments using the post-event aid approach. Alpert (2020) provides a description of the aid provided by 14 different countries, including the dates the aid was announced, the amount of aid, and references to news articles about the aid. The Coronavirus Aid, Relief, and Economic Security (CARES) Act in the U.S. is an example of post-event aid; it deployed over $2 trillion in economic relief to workers, families and small businesses. The UK's government subsidized up to 80% of the salaries of eligible workers when the COVID-19 outbreak occurred in the country. It also provided $379 billion to support business loans. Germany initiated an Economic Stabilization Fund with $650 billion to support loan payments and take equity stakes in struggling companies. It subsequently provided $54 billion to small businesses and the self-employed to cover operating costs. It is worth noting that in addition to explicit government relief funds, post-event aid can also be provided in implicit forms, such as legislation that limits a company' liability from pandemic-related lawsuits or reduces a firm's payroll taxes.

### 4.1.2 Approach 2: provide reinsurance

Prior to a pandemic event, a government could provide reinsurance to insurers that sell primary pandemic coverage to businesses. The reinsurance coverage would be for losses above a designated threshold and would have a designated limit and might contain a co-share provision. The government reinsurer would reimburse insurers based on the terms of the reinsurance contract. Although the government reinsurer could have accumulated some resources during periods without an event, a major pandemic would likely require government borrowing with tax payments to support the debt. This approach is depicted in Fig. 5.

Several countries use government reinsurance schemes to cover terrorism risk. See Michel-Kerjan and Pedell (2005) for an overview and comparison of the French, German, and U.S. systems that were set up in the wake of the 9/11 attacks.[19]

[19] As an alternative to government reinsurance, a government could provide contingent financing to insurers. Pool Re in the UK provides an example. Pool Re was created as a mutual reinsurer for property insurers and reinsurers in the UK after the IRA bombing of the Baltic Exchange in 1992. Pool Re col-

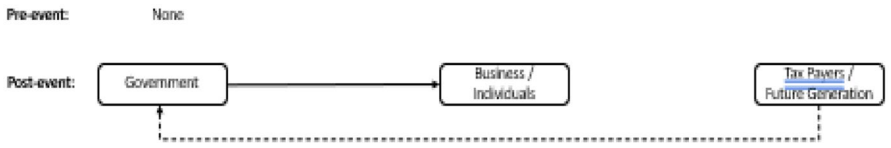


**Fig. 4** Provide post-event aid

### 4.1.3 Approach 3: provide insurance

The government could provide voluntary insurance coverage directly to entities that are exposed to pandemic risk. With this scheme, the government insurer collects premiums and is authorized to borrow funds in case a pandemic occurs prior to accumulation of sufficient premiums. This approach, which is depicted in Fig. 6, would require the government to either create the organizational structure to market the insurance directly to insureds or pay commissions to existing marketing entities in the private insurance industry. Since pandemics are relatively rare events, it would likely not be efficient for the government to develop a new organizational structure to pay claims; instead, it could pay claims through existing government entities, such as the Federal Emergency Management Agency (FEMA) in the U.S., or third parties such as banks, insurers, or claims processing companies in the private market.

The National Flood Insurance Program (NFIP) in the U.S.is an example of a government program that directly indemnifies against future losses. The NFIP markets its policies through participating insurance agents and insurers, who also participate in the claims process.[20] Outside the U.S., governments of many countries also face insurance coverage issues related to catastrophe risk and often provide insurance directly to the policyholders. These schemes are sometimes referred as "residual markets".[21] For example, Taiwan has material earthquake risk and therefore established Taiwan Residential Earthquake Insurance Fund (TREIF) to provide residential earthquake insurance. In New Zealand, the Earthquake Commission (EQC) also supplies residential earthquake insurance directly to homeowners.

### 4.1.4 Approach 4: provide social insurance

Under a social insurance scheme, many or all entities are required to participate, and all participating entities are entitled to receive event-contingent benefits. Typically,

Footnote 19 (continued)
lects funding from its member insurance companies and pays a "premium" to the UK Government for its commitment to lend funds to cover terrorism losses in case Pool Re does not have sufficient financial resources. In addition, Pool Re also purchases reinsurance from the private market. By the end of 2019, Pool Re accumulated a fund of £6.7B to pay potential claims (Ralph 2020) and it purchased £2.4B of private reinsurance coverage to enhance its claim-paying capacity in 2020 (Evans 2020b).

[20] The Pension Benefit Guaranty Corporation (PBGC), which insures private defined benefit obligations is the U.S., is another example of a government insurer.

[21] Individual states in the U.S. also provide residual market mechanisms for catastrophe risk. For example, states on the gulf coast and in the southeast have residual markets for coastal property.

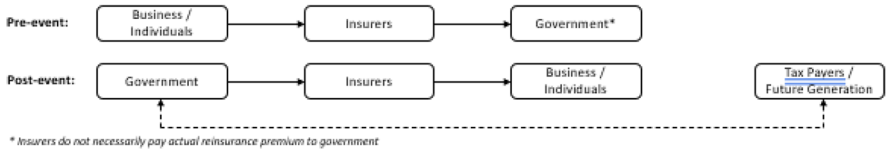


**Fig. 5** Provide reinsurance

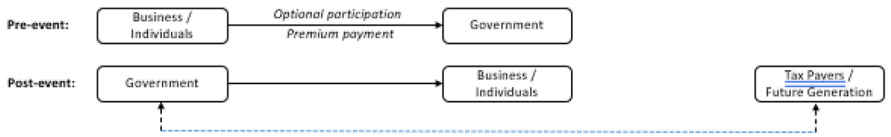


**Fig. 6** Provide insurance

participants are required to make pre-event payments, often in the form of a tax. An administrative system is needed to process and pay the contingent benefits. For most schemes, both the pre-event payments and the benefits paid from a social insurance system increase with potential losses, and are capped at a relatively modest level of potential losses. The idea is to provide modest coverage for a broad spectrum of population. Figure 7 provides a visual description of a social insurance mechanism.

Unemployment insurance in the U.S. is an example of a social insurance mechanism. Employers and employees are required to pay taxes so that individuals can receive monetary payments if they become unemployed. Unemployment benefits are determined by the states and paid for through a combination of federal and state taxes. The social security system is another U.S. example. Payroll taxes are used to pay the retirement and disability benefits of workers.

Germany has a social insurance program called *Kurzarbeit*, which pays workers who have been furloughed a percentage of their lost wages. For example, if an employee without children is moved from full-time employment to half-time employment, then the program will pay 60% of one-half of the employee's salary (IMF 2020a; Chazan and Milne 2020). Italy's *Cassa Integrazione Ordinaria*, which is a program similar to Germany's *Kurzarbeit*, has been expanded as result of the COVID-19 pandemic. Under this system, employers who have suspended or reduced work activity due to the pandemic can apply for emergency support that would entitle most employees to 80% of their salary. Employees in industries particularly hard hit by the pandemic (such as tourism and entertainment) are eligible for benefits of longer duration than other workers (KPMG 2020).

More broadly, the COVID-19 pandemic has led the European Union (EU) to deepen its commitment to collective action for the benefit of displaced workers within its member states. Specifically, the European Commission has proposed a new policy instrument known as temporary Support to mitigate Unemployment Risks in an Emergency, or SURE (European Commission 2020). Under the SURE Initiative, members are eligible for up to 100 billion Euros in loans granted on favorable terms. The purpose of the loans is to help EU Member States defray the

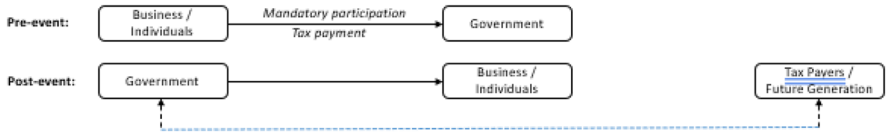


**Fig. 7** Provide social insurance

increased costs of their national short-term unemployment programs. In this sense, the SURE Program is akin to a social reinsurance scheme in that it is the social insurance mechanism in the member state that is the recipient of assistance.

### 4.2 Evaluation of the four approaches

Sections 2 and 3 identified the need for government intervention, and Sect. 4.1 identified four general ways that government could (and does in some cases) intervene in insurance markets. We now consider the relative strengths and weaknesses of these schemes in achieving various public policy goals. Specifically, we consider the following four goals: (1) operational efficiency, (2) matching compensation with losses, (3) incentives for risk mitigation, and (4) macroeconomic impacts.

#### 4.2.1 Goal 1: operational efficiency

Operational efficiency can be defined as how much money is used to cover operating expenses as opposed to indemnify losses. In the insurance market, this is an important consideration. For example, the U.S. P&C insurance industry has an expense ratio of 27%, according to National Association of Insurance Commissioners (2019), meaning 27% of the P&C industry premium collected is spent on agency fees, broker commissions, employee salaries, and other operational costs. In 2018, these costs were $168 billion. Operational efficiency is influenced by both system design and business execution. All else equal, a system will be more efficient if (a) it has fewer profit-seeking "middlemen" and (b) less bureaucracy/better day-to-day business execution. A common view is that private business is more effective than government regarding (b) but that well-designed government involvement can reduce middlemen.

Among the four government schemes, an advantage of a social insurance scheme is that it cuts out the "middlemen" because it can use existing government entities, such as the tax authority, to collect payments from participants. On the other hand, a social insurance system is unlikely to have an efficient method of verifying that losses occurred (and their magnitudes). For example, the tax authority would likely need to employ additional auditors who can verify losses while the pandemic is ongoing so that timely payments can be made to keep entities viable. Alternatively, benefits could follow a schedule based on payroll or revenue, which would improve operating efficiency, but worsen the matching of compensation to losses (see below). Yet another option would involve a parametric trigger (e.g., official pandemic declaration) with benefits being paid to all eligible entities without any regard to actual

loss. While this approach avoids entirely the need for auditors to determine loss, thereby accelerating the payment of losses and materially lowering administration costs, it is the worst option in terms of matching compensation to losses.

Post-event aid may appear to be relatively efficient as well, especially considering that the administrative costs are only incurred when a pandemic occurs, which (hopefully) is relatively rare. On the other hand, the ad hoc nature and the lack of planning associated with post-event aid is likely to lead to inefficiencies in the distribution of relief funds and poor matching of compensation with losses. To reach as many entities as possible, as quickly as possible, and without prior planning, the government will likely incur high costs; also, the potential for graft is high.

If the government serves as the reinsurer or insurer, costs will be incurred in developing the administrative structure for distribution, financial management, claim services, etc., as well as the ongoing operating costs of providing these administrative functions, once they are established. These costs are likely to be greater if the government directly provides insurance rather than reinsurance (since the latter involves interaction just with private insurers, while the former requires dealing with the primary insured entities and potentially their intermediaries (i.e., agents and brokers). Moreover, the lack of competitive forces could reasonably be expected to make a government insurer less efficient than a private insurer.

In Table 2, we summarize this discussion by ranking the operational efficiency of providing post-event aid as medium, reinsurance as medium, insurance as low, and social insurance as high.

#### 4.2.2 Goal 2: matching compensation with losses

An effective insurance mechanism would accurately measure losses and provide compensation based on those losses. This is important from the perspective of the welfare of the individual insureds and from the societal perspective of using an insurance mechanism to reduce the impact of a pandemic on the macroeconomy. We discuss the macroeconomic issues below; here we focus on the individual insureds.

Ideally, a pandemic insurance mechanism would replace a substantial share of an entity's losses, but to mitigate moral hazard (see below), it would not fully compensate for all losses. Finding the optimal amount of coverage depends on many factors, but all else equal it is better to have a higher correlation between compensation and losses.[22] Also, a system that provides compensation in excess of losses is wasteful of resources (inefficient—see above), creates incentives to increase the risk, and likely generates negative opinions about the insurance mechanism, which reduces political support.

A problem with a post-event aid system is that it will likely be hastily designed and pushed through the legislative process so that compensation can be provided quickly. As a consequence, it is likely to sacrifice the goal of matching compensation with losses in order to get aid distributed quickly. In response to COVID-19,

[22] Note that this policy goal could be also be classified as part of the efficiency goal, given that a scheme that provides resources to those without losses is using resources inefficiently.

**Table 2** Comparison of different ways that government can be involved in pandemic risk sharing with respect to four public policy goals

| Goal | Government provides | | | |
|---|---|---|---|---|
| | Post-event aid | Reinsurance | Primary insurance | Social insurance |
| Operational efficiency | Medium | Medium | Low | High |
| Risk mitigation incentives | Low | High | Medium | Low |
| Match funds with needs | Low | High | Medium | Low |
| Impact on overall economy | Medium | Medium | Medium | High |

the U.S. government's Economic Impact Payments were sent to individuals through the tax system.[23] Often payments did not correlate with losses and some entities did not receive compensation because the entity did not file taxes.[24] Likewise, the Federal Pandemic Compensation Program, which provided unemployed workers with an additional $600 above their state unemployment insurance benefit, resulted in a median wage replacement rate of 134%, with 68% of workers receiving more in unemployment benefits than they earned from their jobs (Ganong et al. 2020). Also, the U.S. Paycheck Protection Program (PPP) for COVID-19 business relief was distributed through the banking system, so business owners needed to apply for PPP at the banks. Different banks have different policies, systems and practices, which created discrepancies in fund distributions.

A social insurance mechanism that provides a relatively uniform amount of compensation compared to the losses suffered by entities is likely to have a relatively low correlation between compensation and losses. In other words, simple social insurance systems will do poorly relative to this goal. Moreover, attempts to improve a social insurance scheme along this margin are likely to undermine some or all of the operational efficiency advantages of social insurance discussed above.

Provided entities understand the risk, a private insurance market with voluntary primary coverage (and government provided reinsurance) is likely to be significantly better at achieving this second goal, since it allows entities with greater coverage needs to voluntarily choose to purchase more insurance coverage from private insurers.[25]

[23] There are multiple channels through which the government can distribute compensation payments, including the tax authority (IRS), the disaster management system (FEMA), and entities with lending authorities (SBA and Federal Reserve). The tax authority likely has the broadest reach, and therefore would likely be an appropriate entity to disburse funds in a pandemic.

[24] Some businesses did not file taxes because taxes "pass through" to the individual owners.

[25] This advantage of utilizing a private insurance market (with government provided reinsurance) can be undermined if entities systematically underestimate the risk. In this case, entities would purchase less insurance than if they were fully informed. Evidence of low take-up rates exists in several existing insurance programs. For example, the current terrorism take-up rate for the coverage provided by the Terrorism Risk and Insurance Act (TRIA) embedded in property policies is about 60% (Marsh 2019). The take-up rate of residential earthquake insurance in California is only about 10% (Marshall 2018).

As summarized in Table 2, our ranking of how the various schemes match compensation with losses is as follows: when the government provides post-event aid—low, reinsurance—high, insurance—medium, and social insurance—low.

#### 4.2.3 Goal 3: incentives for risk mitigation

Reducing risk by compensating entities for their pandemic losses (which is a good thing) can also adversely affect their incentives to reduce the probability of a loss occurring and/or reduce the magnitude of the loss once it occurs (which is a bad thing). Therefore, the impact of a risk-sharing scheme on incentives for risk mitigation is an important consideration when evaluating alternative ways that a government can be involved in providing pandemic risk insurance. (Note that mitigation incentives should include incentives for innovation to help businesses continue to operate, while keeping employees and customers safe.)

Private insurance typically provides incentives for risk mitigation through the underwriting process and by having insureds bear some risk through various policy provisions, such as deductibles, coinsurance, limits, and exclusions. Insurers' underwriting processes differentiate the risk profiles of potential insureds and charge premiums accordingly. Insurers usually are effective at identifying those entities that have mitigated the risk or are committed to do so. Insurers offer a lower premium to such insureds because they expect lower future claims. For example, when residents living in Florida make their houses more resistant to hurricane damage, they usually can receive a reduced premium.[26]

Given private insurers' experience and expertise in managing moral hazard, there are advantages of a government program utilizing private insurers to market and price pandemic insurance and to settle pandemic claims. Thus, an important argument for including the private insurance sector in the pandemic risk solution is to incentivize risk mitigation. Research has shown that risk mitigation, even not implemented at full scale, can significantly lower potential losses (McMorrow et al. 2013).

Theoretically, a government insurance program could operate like a private insurer and mimic the underwriting processes and contract design features used by private insurers. However, a monopoly government insurer would not face competitive pressures to develop and use innovative approaches to provide incentives for insured entities to mitigate risk. Furthermore, a government insurance program would likely be subject to political pressure to suppress rates for insureds with the greatest pandemic risk,[27] thus blunting the effectiveness of underwriting as method of providing incentives for risk mitigation.

[26] Despite insurers' incentive and capability to mitigate moral hazard, not all moral hazard will be eliminated for at least two reasons. First, mitigation efforts are costly and therefore it is not optimal to eliminate moral hazard. Second, some types of moral hazard will not be impacted by commercial insurance contracts. For example, a population's vulnerability to a pandemic depends on a number of co-morbidities of the individuals in the population, which depend largely on individual behavior, not business practices.

[27] For examples of rate suppression in the National Flood Insurance Program, see Kousky and Shabman (2014).

Social insurance programs tend to treat participants similarly in terms of pricing and benefits. This occurs in part because social insurance programs typically place greater emphasis on covering as many people as possible and on maintaining relatively equal treatment of the insureds. Consequently, underwriting is likely to be limited compared to the private insurance sector, and the tax or premium formula used by a social insurance program is not likely to reflect risk mitigation measures or have as much differentiation of across observable risk classes. Thus, the risk mitigation incentives from a social insurance scheme are not as strong as the schemes that utilize the private insurance sector.[28]

The mitigation incentives provided by a post-event aid scheme depends on the public's perception of the likelihood that aid will be provided and the comprehensiveness of that aid. If entities view that the government will compensate most losses, then the entities will have little incentive to mitigate pandemic risk. This is the Samaritan's dilemma problem (Raschky and Schwindt 2016). On the other hand, if entities do not perceive that aid will be forthcoming but they understand the magnitude of the risk that they face, then they will have strong incentives to mitigate.

To summarize, among the four government schemes discussed, private insurance companies underwriting pandemic risk upfront and the government serving as the insurance industry's backstop reinsurer is likely the most effective approach from the risk mitigation perspective; it therefore receives a ranking of high in our Summary Table 2. The government serving as an insurer receives a grade of medium, and both the post-event aid and social insurance programs receive a low grade.

#### 4.2.4 Impact on the overall economy

A pandemic insurance mechanism is important for the overall health of the economy. This point is illustrated by the impact of terrorism insurance coverage post 9/11. The lack of terrorism insurance, primarily driven by insurers not willing to cover the risk, created broader economic issues. Examples include business loans not being approved and construction projects halted because there was no proof of insurance coverage.[29] The same situation could emerge for pandemic insurance post COVID-19. Insurance, whether provided directly by the government or through the private sector (and then reinsured), helps to avoid this type of market failure. More generally, a pandemic insurance mechanism can keep businesses operating, reduce unemployment, and help maintain consumer spending, all of which help prevent an extended recessionary period.

Do the four mechanisms differ in their impact on the overall economy? Post-event aid differs from the others in that it is not in place when a pandemic occurs. It must first work its way through the political process, which creates at least temporary

[28] See Feldstein (1974) for classic evidence that social security reduces private savings. For a general analysis of social insurance programs, see Feldstein's presidential address to the American Economic Association (Feldstein 2005).

[29] These issues led to the Terrorism Risk and Insurance Act (TRIA) and its multiple renewals since its initial passage.

macroeconomic damage as well as uncertainty about the extent to which business will be able to recover from a shutdown. On the other hand, it is a more flexible tool than the other programs in that it can be tailored to the needs at the time. It can be scaled based on the damage observed and adjusted over time. The latter advantages suggest that post-event aid can also be used along-side any of the other three schemes to augment benefits if needed. As we have mentioned several times already, the possibility of augmenting benefits, however, makes the Samaritan's dilemma worse.

Mandatory social insurance is likely to provide greater macroeconomic benefits to society because of its broad reach and because a large proportion of benefits paid will go to those with a high marginal propensity to consume (e.g., low-to-middle income families, small businesses). Mandatory social insurance programs, therefore, essentially provide a safety net for the economy. The government provision of insurance or reinsurance, assuming that they are voluntary, would help bolster the macroeconomy during a pandemic, but the degree to which they help depends on the extent to which the pandemic insurance is purchased.[30] Therefore, as summarized in Table 2, we give post-event aid, reinsurance, and insurance a grade of medium, and social insurance a grade of high.

### 4.3 Section summary

Our evaluation of the four pandemic risk-financing schemes is summarized in Table 2 using the four goals discussed above. There is not a clear conclusion that can be drawn based on these analyses, as each approach has its own advantages and disadvantages. However, our sense is that the worst option is to wait until another pandemic occurs, and then provide post-event aid. This option performs poorly on three of the four goals outlined above. The one goal on which it ranks relatively high is operational efficiency, in large part because it does not incur costs until another pandemic event occurs. The other three approaches have advantages and disadvantages and therefore the choice among them will depend on one's relative weighting of the various policy goals. In addition, we have simply provided a foundation for organizing one's thoughts about the issues. There are many details that would need to be fleshed out and these details could impact the relative rankings of the various approaches.

[30] Another consideration is adverse selection, which is likely to be important in the context of pandemic risk because of the high level of heterogeneity and information asymmetry. For example, if an insurer collects a fixed percentage of a company's income as a "pandemic insurance premium", the industries with a low-risk profile (e.g., office workers who can mostly work from home) will likely opt out because these low-risk industries know they are subsidizing the high-risk industries with their participation. Eventually, the risk pool will consist of mostly high-risk insureds, effectively leading to underfunding and insufficient coverage. A solution for adverse selection is to make the insurance mandatory. Of the four government insurance schemes discussed in this paper, only social insurance is mandatory.

## 5 Conclusion

Pandemics represent a recurrent scourge on humanity that throughout recorded history are responsible for not only incalculable human suffering but also extreme and lasting economic damage. The COVID-19 pandemic, which swept through the world in 2020 and is still developing in many countries, was no exception. Unquestionably, economic interdependencies in our modern, globalized society accelerated the spread of the virus and intensified its economic consequences, throwing the global economy into its sharpest contraction since the Great Depression.

Certainly, many executives, risk managers, and insurance professionals knew that the occurrence of a pandemic and its associated economic losses was a possibility, if not a certainty at some point in the future. However, as we document in Sect. 2 of this paper, the private insurance market provided limited insurance coverage for economic losses caused by a pandemic. Indeed, very few insurance products protecting against "pure" pandemic risk have ever been brought to market. While insurers are exposed to pandemic loss through some products with contingent or incidental exposures, our analysis suggests that the overwhelming majority of pandemic risk is uninsured.

What explains the limited coverage provided by the private market? While acknowledging there might be reasons on the demand side, such as underestimation of the frequency and severity of pandemics, we argue in Sect. 3 that a pandemic insurance market fails largely because the amount of capital needed to supply credible insurance coverage is prohibitively high. More specifically, we use hypothetical examples to explain how correlation in the frequency and severity of losses, both key characteristics of pandemics, leads to an extraordinarily high capital requirement. The examples also illustrate that the required capital drops considerably if the risk is pooled over time, as opposed to across entities in a given time period.

We conclude that government involvement is needed to solve the private insurance market failure, due to government's unique ability to tax, borrow and pool risk across time. Moreover, we argue that an effective pandemic risk-sharing mechanism would generate positive externalities for the macroeconomy by reducing the disruption in economic activity and preventing a prolonged economic recession.

The paper then suggests that a government can support the sharing of pandemic risk by providing either (1) post-event aid, (2) reinsurance, (3) primary insurance, or (4) social insurance. We evaluate the strengths and weaknesses of these schemes based on four policy goals: operational efficiency, matching compensation with losses, incentives for risk mitigation, and macroeconomic impacts. We conclude that post-event aid meets the fewest policy goals, while the other three approaches have advantages and disadvantages on different dimensions. Despite there not being a clear conclusion for what is the optimal design for the future, we identify important tradeoffs associated with different forms of government involvement.

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## Appendix

Additional Explanation of the Assumptions Used to Analyze Pooling over Time in Sect. 2.2.

In Example 4, we assume that the frequency of claims that applies to all entities has a binomial distribution with an uncertain probability of a loss. The uncertainty about the probability is described by a Beta 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, we simulate 5000 outcomes for the aggregate loss for all 1000 entities. We then find the probability distribution that fits these aggregate loss outcomes, using the AIC statistic to rank the fitted distributions. The distribution with the lowest AIC statistic is a lognormal distribution with a mean of $2650 and a standard deviation of $14,342. The distribution with the second lowest AIC statistic is the Inverse Gauss distribution with a mean of $1946 and standard deviation of $5050.

Using each of these distributions, we simulate the mean and 99th percentile value of the average loss over the 50 years, which are then used to find the amount of capital needed as the difference between the 99th percentile value and the mean value.

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