V Premio Actuarial SCOR para España y Portugal:

Social Risk Management during the First Stage of a Pandemic: Application to COVID-19

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September 2023

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Project Summary

The crisis caused by COVID-19 revealed the global unpreparedness to handle the impact of a pandemic. At the outbreak of a pandemic, time is the key variable that can save lives and prevent financial crisis. In the present paper, we propose, as a risk management tool, a reinsurance product mainly for developing countries, based on a parametric insurance design, that can supplement a state's social insurance during a pandemic. The two basic features of the proposed social reinsurance are the trigger, for (almost immediate) financial help and the cap, meant to shield from moral hazard from the cedent (here the state). We propose several trigger candidates and, following a data driven approach, we develop a method to determine a cap-curve as a benchmark. The procedure is shown using COVID-19 Italian and Chinese data as an illustration.

Keywords: COVID-19, epidemic risk, moral hazard, parametric insurance, social protection, risk strategy.

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Executive Summary

Pandemics, and in particular COVID-19, have significant impact on health systems, financial markets and vulnerable industries such as manufacturing, tourism and hospitality amongst others. For governments, planning and coordination are vital at the start of any epidemic to ensure that their health system is not overwhelmed and to further alleviate the economic impact of the pandemic.

COVID-19 - the novel coronavirus pandemic declared as such by the World Health Organization on the 11th of March 2020—has quickly reached an incomparable dimension, and every individual, every government was caught by surprise fighting against the crisis caused by COVID-19. The pandemic has triggered what is likely to be the deepest global recession since World War II.

With the aim of ensuring an efficient healthcare response during a pandemic, governments could engage in (re)insurance contracts at state level to provide financial relief to both the state and the most vulnerable population stratum. Specifically for infectious diseases, the World Bank, and other partners, developed the Pandemic Emergency Financing Facility (PEF), an insurance vehicle designed to provide rapid disbursement of emergency finance. In practice, the World Bank collects the premiums and issues bonds and swaps to private investors, which can be seen as a type of catastrophe bond. So far the PEF has been widely criticised mainly due to the generous returns to investors and difficulty in accessing funding during the early stages of the disease outbreaks.

In general, the short-term mortality spikes caused by a pandemic have a tremendous impact on the world economy. Information about the expected severity and length of a possible outbreak is a corner stone for pricing a reinsurance contract. In recent years, in particular after the outbreak of SARS in 2002, scientists have warned about the possibility of a new pandemic. The warning stated that most of the world is unprepared for such a challenge since pandemics create unmanageable risks for life, travel and business insurance and ultimately the entire (re)insurance industry.

Apart from the devastating economic and political disruption at the state level, a pandemic has an additional effect of a micro-social-economic nature, bringing many families and individuals to the edge of poverty or even beyond. Unlike any other rare event such as a tsunami or an earthquake, a pandemic can last over relatively long periods, putting severe strain on a households' income through isolation restrictions. Considering nearly 55% of the world's population do not have access to any sort of financial social protection, and many countries rely on market-based solutions to fill the gap, the recent pandemic demonstrates that the situation does not only hurt the poorest and most vulnerable, it threatens the well-being of the entire global community.

One of the roles of governments is to protect society against internal threats and to defend the country from any external threat that affects people's lives. COVID-19 represents a major threat to people's security. Allowing the state to purchase social reinsurance would limit the financial costs (i.e. income protection or any other type of unemployment benefit due to the effects of the pandemic) for the government to ensure the well-being of citizens in the case of a pandemic. This is especially important for poor countries, where the financial resources are limited, or for countries with a high degree of income inequality.

A tsunami-like amount of business interruption, travel, and medical treatment claims crashed over the insurance sector in response to the COVID-19 pandemic. Whilst some insurance companies had already added pandemic exclusion clauses to their policies following the SARS-CoV epidemic in 2003, others did not incorporate a clear defined list of possible diseases to be covered, leaving some ambiguity about individual extent of cover.

Insurance associations all over the world declared that pandemic coverage had been optional and most policyholders chose to save the money and did not purchase this type of business interruption insurance. In France, the financial regulator supervising both banking and insurance, Autorité de contrôle prudentiel et de résolution (ACPR), on the 22nd June 2020 made public that 93.3% of insurance policies did not cover the pandemic, 2.6% did and 4.1% were unclear. In Germany, many pre-COVID-19 insurance policies merely referred to the Infectious Diseases Protection Act, Infektionsschutzgesetz (2001) (IfSG), and the diseases listed therein. This ambiguity created by the fact that COVID-19 was not explicitly mentioned in IfSG led to a number of court cases. On the 1st of October 2020, the Munich Regional Court ruled that the insurance company Versicherungskammer Bayern had to pay out 1.01 million euros business interruption insurance to Augustinerkeller, a famous restaurant in Munich. However, after the ruling the Berlin-based German Insurance Association (GDV) stated that the Munich decision would have no implications for other pending cases.

The refusal of some insurance companies to pay pandemic-related claims has eroded trust in the sector in general. Numerous court proceedings followed as claimants sought retribution in numerous countries. The lawyers, representing the Interests of the insurance sector, insisted that businesses could not claim for losses resulting from nationwide lockdowns as it would be catastrophic for the industry.

Many insurance companies are not ready to undertake the risk of a pandemic. One of the traditional principles of insurance is risk pooling in the sense that the losses incurred by a few insured are spread over the entire group. Risk pooling arrangement allows the insurer to reduce their own risk. Pandemic risks have a very low probability of occurrence but with a high severity loss. However, pandemic risks cannot be considered as catastrophe risks such as earthquakes or floods. It is a macro risk that affects large populations – in this case, the entire world – and cannot be pooled and therefore cannot be covered under traditional insurance contracts. When the pandemic happens losses occur for everybody—pandemics do not respect geographical borders—therefore collective risk sharing and balancing over time are not working for this rare event.

There is a clear demand for insurance coverage for the case of a new epidemic/pandemic. Thus, insurance companies are confronted with the challenge of developing innovative policy structures and mitigation strategies for both public and private sectors.

Partnerships and collaborations between governments and (re)insurance companies are needed to enable insurance protection for pandemic risks that would be otherwise uninsurable. In this regard, we propose a pandemic insurance product/contract which aims to temper the (immediate) financial losses of the insured state and to supplement the citizenry's social protection. The contract design discussed in this project - based on parametric insurance - represents social reinsurance for governments and provides financial relief to both the state and the most vulnerable population strata by covering pandemic-related expenses like income protection, unemployment benefits, medical care, amongst others, for a short period in the very beginning of a pandemic. As many international organisations may not be able to react quickly enough, this type of insurance coverage is targeted to build a short-term bridge to the more extended aid packages. International organisations may act as buyers of such an insurance contract, which can be selected, for instance, through a tender process. Of course, (re)insurance companies are not charities. However, the loss will be bounded and this kind of contracts may be seen as an image improvement tool or even serve as a tax relaxation.

The proposed reinsurance product, designed as a supplement to the social insurance provided by the state provides fast payments, when the money is most needed, so that the government can initiate a prompt response to the pandemic. Different triggers, that activate pre-defined payments established by the contract, have different advantages and disadvantages. One of the main advantages of a parametric reinsurance is that it is immune from moral hazard. Hence, with the aim of reducing the effect from possible manipulation from the insured state, we modify the pure parametric reinsurance and add a monitoring tool that measures the effectiveness and efficacy of government's crisis management. If the government fails to implement the necessary measures to slow the spread of an infection, the payments will be frozen and no further financial help will be provided from the reinsurance side.

The next COVID pandemic is coming and we are not ready. This research prepares society for next pandemics since it describes a possible solution based on parametric insurance where a pre-agreed payout is made if pre-defined event parameters (triggers) are met. This type of insurance would provide immediate help without a time-consuming loss assessment and would alleviate the financial burden at the very first stages in a pandemic.

Social risk management during the first stage of a pandemic: Application to COVID-19

Abstract

The crisis caused by COVID-19 revealed the global unpreparedness to handle the impact of a pandemic. At the outbreak of a pandemic, time is the key variable that can save lives and prevent financial crisis. In the present paper, we propose, as a risk management tool, a reinsurance product mainly for developing countries, based on a parametric insurance design, that can supplement a state's social insurance during a pandemic. The two basic features of the proposed *social reinsurance* are the *trigger*, for (almost immediate) financial help and the *cap*, meant to shield from moral hazard from the cedent (here the state). We propose several trigger candidates and, following a data driven approach, we develop a method to determine a cap-curve as a benchmark. The procedure is shown using COVID-19 Italian and Chinese data as an illustration.

Keywords: COVID-19, epidemic risk, moral hazard, parametric insurance, social protection, risk strategy.

1 Introduction

Pandemics have a significant impact on health systems, financial markets, manufacturing, tourism and hospitality industries, among others. Apart from the devastating economic and political disruption at the state level, a pandemic has an additional effect of a micro-social-economic nature, bringing many families and individuals to the edge of poverty. Unlike other rare events, such as, a tsunami or an earthquake, a pandemic can last over relatively long periods, putting severe strain on a households' income through isolation restrictions. During a pandemic, trust is an important factor that influences people's perception and compliance with risk management measures, see Siegrist and Zingg (2014) and Wong and Jensen (2020). However, as Siegrist et al. (2021) state, social trust has a severe impact on people's acceptance of government's implemented measures. A high level of social trust – that implies that information provided by the government is considered unbiased – has a positive effect on the participants' risk perceptions and vice versa. Thus, by deciding about the necessary measures to fight a pandemic every government has to face country's specific social trust indicators.

The economic recession caused by the coronavirus made countries in the Eurozone lose 1.8% of their GDP when comparing the GDP in the first quarter of 2021 with the prior first quarter in 2020, OECD (2021). At the same time, the public debt has reached the highest level since World War II during the COVID-19 pandemic. Due to prolonged and strict lockdowns, unemployment benefits have become crucial for millions in developed countries. In this sense, governments have included several financial programmes to target vulnerable social groups.[1]

Governance structures in African countries rely on external financial and technical assistance, see Renzaho (2020). Josephson et al. (2021) state that approximately 77% of the population in Ethiopia, Malawi, Nigeria and Uganda have lost their income due to COVID-19 as of early 2021. Whilst the evidence from the year 2020 shows that the infection and mortality rates in low-income countries are similar to or even greater than in high-income countries, see for instance Walker et al. (2020), the health care capacities are beyond any comparison. The situation is exacerbated by the food insecurity across Uganda, Nigeria, Malawi, Ethiopia following the onset of the COVID-19 pandemic. One of the World Bank Blogs reports that "over 70% of adults in Nigeria and Malawi are impacted by moderate or severe food insecurity, as well as 47% in Ethiopia, 42% in Burkina Faso, and 43% in Uganda" as of February 2021, see Gourlay et al. (2021).

In 2017, the Pandemic Emergency Financial Facility (PEF) was launched by the World Bank, and other partners, to provide rapid disbursement for infectious diseases likely to cause pandemics in developing countries. Through this 3-year insurance vehicle the World Bank issues bonds and sells them to private investors – an investment tool that can be seen as a type of a catastrophe bond. Catastrophe bonds are securities that allow insurers to move their risks to capital markets[2] and provide new investments and diversification opportunities for big market players. For the case of PEF, the World Bank offered very favourable interest rates to bondholders to compensate investors for the risk the bonds will need to make pay-outs in the event of a pandemic outbreak. The PEF was widely criticised mainly due to the difficulty in accessing funding during the early stages of the disease outbreak and the generous returns to investors. The help provided during the first wave of COVID-19 from the bonds issued in 2017 has been "too little and too late", see for instance Hodgson (2020). Therefore, in 2020, the World Bank decided to shelve the second sale of pandemic bonds.

Emergency cash transfers have been a key tool to provide a social and economic response to COVID-19, especially in low-income countries. In April 2020, the World Bank approved financial emergency support for developing countries to protect lives and support economic recovery. Half of the measures taken by the World Bank Group were through cash transfer

[1] In Spain, a monthly basic income scheme up to €1,015 was launched in June 2020 for the most vulnerable households. In the UK, social measures such as the Coronavirus Job Retention Scheme or the Self-employment Income Support Scheme were introduced.

[2] See Bauer and Kramer (2012) for mathematical modelling of catastrophe mortality bonds.

targeting – as of December 2020 – 166 developing countries but other measures involved in-kind food and/or voucher schemes. Through this COVID-19 fast-track facility, the World Bank has been making available up to 160 billion US dollars from the start of the pandemic until June 2021, Gentilini et al. (2020).

In its Social Protection Spotlight Brief, the International Labour Organisation (ILO) explores the role of social protection in addressing the COVID-19 crisis, especially in developing countries, ILO (2020a). Social security is an essential component of all four main pillars established by ILO for combating the COVID-19 pandemic.[3] In corporation with the UN agencies and the World Bank, ILO has programmed 21 million (April-December 2020) US dollars funding to respond to the COVID-19 pandemic to eliminate child labour and forced labour. The estimated total budget is 71 million US dollars for the period June 2020-June 2022 and it has been expected to increase due to an increase in funding requirements particularly in the least developed countries, ILO (2020b).

However, the World Bank and other international organisations have been harshly critisised for being bureaucratic, slow and not independent enough in their responses to COVID-19, see Debre and Dijkstra (2021) and references therein. Whilst the first wave of the pandemic had already hit many countries in early March 2020, the World Bank's financial emergency support was approved only in April 2020.

One of the traditional principles of insurance is risk pooling in the sense that the losses incurred by a few insured are spread over the entire group. Risk pooling arrangement allows the insurer to reduce their own risk. Pandemic risks have a very low probability of occurrence but with a high severity loss. However, pandemic risks cannot be considered as catastrophe risks such as earthquakes or floods. It is a macro risk that affects large populations – in this case, the entire world – and cannot be pooled and therefore cannot be covered under traditional insurance contracts, see for instance Assa and Boonen (2022). It is essential to have a social approach to pandemic preparedness and response. Then, it becomes the responsibility of the society to share the losses and of governments to minimise the damage to the economy and society safeguarding jobs and livelihoods.

It is, of course, an urgent need to find adequate measures to confront an ongoing pandemic, see, for example, Wu et al. (2021). However, acting in an optimal way at the beginning of a pandemic may be a game-changer. For instance, a quickly introduced hard lockdown may localise, slow down or even stop the spread of an infection. The question arises where to get the necessary resources that can be made available almost instantaneously. One way is to let states use insurance as a tool to protect the vulnerable in the first place and the society as a whole, see for instance Stahel (2003). Tinkering with the idea of a state mandating an insurance and risk pooling not being possible, we propose a pandemic insurance product/contract which aims to temper the (immediate) financial losses of the insured

[3] Grounded on International Labour Standards, the ILO has established a four-pillar policy structure: Pillar 1: Stimulating the economy and employment; Pillar 2: Supporting enterprises, jobs, and incomes; Pillar 3: Protecting workers in the workplace; Pillar 4: Relying on social dialogue for solutions.

state and to supplement the citizenry's social protection. The contract design discussed in this paper represents social reinsurance for governments and provides financial relief to both the state and the most vulnerable population strata by covering pandemic-related expenses like income protection, unemployment benefits, medical care, amongst others, for a short period in the very beginning of a pandemic. As many international organisations may not be able to react quickly enough, this type of insurance coverage is targeted to build a short-term bridge to the more extended aid packages.

Thus, in this framework a state is considered a policyholder. As every state itself acts in some sense as a social insurance for its citizens, we call the insurance design introduced in this paper – social reinsurance. International organisations may act as buyers of such an insurance contract, which can be selected, for instance, through a tender process. Of course, (re)insurance companies are not charities. However, the loss will be bounded and this kind of contracts may be seen as an image improvement tool or even serve as a tax relaxation. For instance, The Z Zurich Foundation (a charitable organisation founded by Zurich Insurance) has donated 1 million CHF in support of UNICEF's vaccination campaign; The Foundation of Reinsurance Group of America has announced in April 2020 a donation of $1.5 million to help support COVID-19 relief efforts. In April 2021, the Insurance Industry Charitable Foundation (IICF) has gathered the leaders from AIG, Amwins, AXA XL, EY, Lloyd's and The Hartford to discuss their COVID-19 relief initiatives. IICF explained that it would be "a way for the industry to help itself attract new talent while also helping others." Some of the IICF philanthropic projects can be found, for instance, in IICF Insurance Industry Philantropic Showcase (2002).

The paper is structured as follows. In Section 2, we discuss some principles and mechanisms of the insurance business that provide a background to understand parametric insurance as well as the main features of parametric insurance contracts. Section 3 presents the parametric reinsurance design to serve as a supplement to a state's social insurance. In Section 4, we discuss exemplary the social reinsurance product in the context of COVID-19. The example presented serves for illustration purposes only and is not aimed at a real pricing of the discussed design. We conclude in Section 5.

2 Parametric Insurance and Pandemics

Parametric insurance products have been available since late 1990s and are suited for events with low probability of happening, but very costly damages, such as natural disasters (i.e. earthquakes) or any weather-related risks. In practice, parametric insurance products are mostly used in the reinsurance sector around catastrophe risks. An epidemic or a pandemic disease spread is considered a rare event with widespread impact which might destabilise state's medical, economic, financial and political systems in a country at the same time.[4]

[4]See the National Academies of Sciences, Engineering and Medicine (2006), Madhav et al. (2017) and World Health Organization (2018).

The sudden nature and the uncontrollable aggregation of losses makes pandemics uninsurable as the huge economic losses would go beyond the capacities of any insurance company. Schanz et al. (2020) states that

> "Pandemics are, by definition, not diversifiable as they occur on a very wide or even global scale."

That is why, in the event of a pandemic, parametric insurance may be more beneficial than classical indemnity insurance, see for instance Hillier (2022).
The principle of parametric insurance is simple. Instead of indemnifying for the actual loss incurred – as in traditional insurance contracts – parametric insurance covers the probability of a predefined event happening and pays out according to a predefined scheme. In this way, the so-called parametric insurance provides fast payments for claims when predetermined parameters are met. This type of insurance helps governments to initiate a prompt recovery after a disaster as payments are made within a few days of a catastrophic event.

Contracts based on parametric insurance consist of two main elements: triggering events and the pay-out scheme. These two elements define the scope of the policy and are vital for pricing insurance parametric contracts.

The insurance pays if an event hits the defined trigger level, i.e. if pre-defined event parameters are met or exceeded. The defined trigger level is measured by an *objective* and *reliable* parameter or index – given by an independent, third party data source - that is related to an insured's exposure to risk. For example, in natural disasters, a triggering event might be a hurricane where the parameter is a pre-defined level of wind speed. All triggering events must be *fortuitous* and *quantifiable* to be able to model them. The pay-out scheme outlines the amount paid out to the insured in the case that the event reaches the trigger level.

The PEF also shares some features of the parametric insurance. In particular, the payments are predefined at the beginning of the contract and the trigger depends on factors such as infection and death rates, growth of infection rate and countries affected by the epidemic, amongst others.

Characteristics of the parametric insurance

Indemnity amount: Traditional insurance reimburses the insured for the actual losses incurred. In contrast, payments of parametric insurance are triggered by a fortuitous and quantifiable event exceeding a parametric threshold and pays out according to a predefined scheme.

Claims handling: While the assessment of actual losses with traditional insurance might be both complex and time-consuming, the pay-out of parametric insurance is instead a matter of days. Hence, the insurers' administrative burden is reduced.

Basis risk: The differences between the actual losses and the trigger creates basis risk. For example, a low-intensity earthquake might not trigger a parametric payout but still can provoke some damages and therefore some losses. Thoughtful design for triggers can limit the basis risk but cannot eliminate it.

Structure of the contract: While traditional insurance contracts typically have standardised wording, parametric insurance is a customised product with uniquely tailored index and pay-out provisions. However, the wording of the parametric insurance contracts tends to be much shorter than standard traditional policies.

Moral hazard: When a variable exceeds an agreed threshold, the agreed payment needs to be made. Consequently, parametric insurance contracts are immune from moral hazard because they are triggered based on objective and reliable measurements beyond the control of the insurer and the insured. In contrast, in non-parametric products, once covered, the insured will behave more riskily.[5]

Advantages of parametric insurance for pandemics

- A parametric insurance would provide fast payments, when the money is most needed, and help government to initiate a prompt response;
- it bridges the gap to the aid provided by international organisations;
- it provides a simple way around the uncertainty as the insurance payments are contractually agreed and do not need to be assessed first.

Challenges of parametric insurance for pandemics

Due to the very nature of pandemics:

- All triggers (for example, death rates and/or infection rates above a certain level for a pre-defined period) will depend on the governments' actions like lockdown, obligatory masks and social distancing, provided financial support etc. Therefore, a well designed trigger is difficult to obtain. The joint trigger of the PEF, for example, was criticised as the activation criteria were almost impossible to reach simultaneously – creating a considerable obstacle for accessing the funding when it was really needed.
- The introduction of a cap to mitigate moral hazard, will require a surveillance tool as the publicly available data on dead and infected reported by countries can be contaminated (on purpose or due to reporting errors), see for instance Karlinsky and Kobak (2021). By comparing the infected/dead data from different hospitals and testing stations inside one country, using compositional functional data analysis, one can detect the outliers, see Rieser and Filzmoser (2022). What happens if there are

[5]In practice, in traditional insurance, the insurer combats moral hazard by using deductibles and/or different level of premia.

too many or too severe outliers can be specified in the contract. Adopting a machine learning approach for outlier detection, like in Benatti (2019), can keep the costs of such a surveillance tool very low.

- Moral hazard becomes an issue as countries can manipulate the triggers in order to get the insurance. Therefore, the amount of help expected from the reinsurance product we suggest, should be smaller than the expected damage from the declaration of the state of emergency if this is not really necessary. Concerning the other triggers like the number of dead or infected – this can be monitored by outlier detection tools as suggested above.

In addition, as it is stated, for instance, in Carter (Carter, 2013, p. 4) "[...] it is well accepted law that insurances covering human life (i.e. life, personal accident and sickness policies) are excluded from the principle [...]"
As the dangers of a pandemic are life threatening indeed, a possible overcompensation by a parametric insurance can be neglected.
Note that, from now on, we will call the presented product a reinsurance contract since the parametric insurance described on this section is intended to serve as a supplement to a state's social insurance.

3 Social Reinsurance Product Description

The proposed reinsurance design based on parametric insurance principles, targets primarily to provide a quick financial payout to a country affected by an epidemic event. The state is considered a policyholder. This product is not aimed at overtaking governmental duties or enforcing specific lines of action. In particular, the latter requirement is in line with the UN's principle of non-intervention in the inner affairs of other states (UN General Assembly, 1970).

Reinsurance premia could be funded through international organisations such as the United Nations or any World Reinsurance Fund and/or donations. Another alternative for developed countries can be the charge of an insurance tax on certain types of insurance.

An important aspect of a classical parametric reinsurance, as we mentioned in Section 2, is that it is immune to moral hazard, in the sense that neither the insurer nor the insured are able to influence the event. Unfortunately, in the case of epidemic reinsurance, it is impossible to separate the occurrence and development of an epidemic (for instance, death rates or infection speed rates) from the government's management of the situation. For this reason, we modify the classical parametric reinsurance and add a cap reflecting the success of government's actions like a lockdown and/or masks wearing. The main components of our reinsurance product namely the trigger and cap-curve are explained below.

We would like to emphasise that the surveillance tool kit can be substantially extended.

For instance, a machine learning programme can be implemented and used by the reinsurance company in order to detect possible data laundering, similar to Jullum et al. (2020) or to Kobak et al. (2016). Additionally, a certain number of tests per day can be contractually stipulated. As the individual tests might be too expensive, group tests procedures as described in Aldridge et al. (2019) can be used instead. However, an extensive discussion of these topics will certainly go beyond the scope and target of the present paper.

The Trigger

By definition, a parametric reinsurance product requires a *trigger*, which induces an immediate payment of a predefined amount of money. In our design, we propose several triggers that might be activated in a way similar to a domino effect. In Table 1 several possible triggers and their disadvantages are listed. As a first trigger, the contract may stipulate the date when the ceding government declares the state of emergency. The first payment can be defined, for instance, as the value of a market basket per household, for the next several weeks and is then, in this way, unconditional. It is expected that this action will encourage the government in introducing lockdown measures and motivating its citizens to stay home.

A second, third, etc. trigger and thus payments might be due after certain predefined (deterministic) time intervals if the state of epidemic is not abolished, or at least controlled. A second payment may be linked to the universal income, proposed in Pavolini (2020) (for Italy), for the following months.

Deterministic (given the starting date) triggers have the advantage that the states introducing severe lockdown measures and therefore having low death and infection speed numbers will not be punished for tackling the situation better than expected. Using as a trigger a certain level of the death rates or the infection speed would prevent reinsurance payments in those countries. However, in order to alleviate moral hazard, we modify the pure parametric reinsurance and introduce a monitoring tool (i.e. the cap-curve) that measures the effectiveness and efficacy of government's crisis management. If the government fails to implement the necessary measures to slow the spread of an infection, the payments will be frozen and no further financial help will be provided from the reinsurance side.

Candidate trigger	Feasibility summary
Declaration of the state of emergency + a certain number of dead and/or infected.	Would need to be specifically called for an epidemic.
Declaration of the state of emergency in one or several neighbouring countries.	Would need to be specifically called for an epidemic/pandemic.
A certain boundary for the official number of deaths, death rates, infection speed or fatality ratio has been exceeded.	■ Not reliable triggers. Would need control by an independent organisation, e.g. UN. ■ The minimal number of tests should be contractually stipulated. ■ States calling an early lockdown and preventing high death and infection speed numbers will be disadvantaged.
Official lockdown called + a certain number of dead and/or infected.	■ Definition of a lockdown required. ■ Manipulation possibilities for the reinsurance company and the state. ■ Political influence on the part of reinsurance company.
Outbreak size (the number of cases of infections and fatalities) + outbreak growth (increase in the number of dead and/or infected over a defined time period) + outbreak spread (the number of countries affected by the outbreak)	■ Waiting for all three parameters to be met may allow the virus to spread. ■ Not suitable for epidemics. ■ Manipulation possibilities for the reinsurance company and the state.

Table 1: Summary of candidate trigger feasibility assessment.

The Cap-Curve

We propose to use as a basis for the *cap* the *infection speed* and will explain our concept in more details in an example (Section 4.2). The main advantage of working with the infection speed, is that it quickly reflects the effectiveness of the measures taken to fight the spread of the epidemic. In contrast, the death-related variables react with a certain delay, due to the course of disease until death, and are dependent on the treatment opportunities. Also, the infection speed is more robust than death-related variables. However, the infection speed can be more easily manipulated than, for instance, death rates, because it highly depends on the number of tests conducted. Given these pros and cons, the reinsurance company might want to choose a different basis, which better comprising its interests and those of the ceding state.

The reinsurance agreement described above can be compared with a lookback option on a forward contract. Some crucial quantities like the number, the time and the amount of payments will be contractually fixed as it is usually done in forward contracts. But all payments except the first one are linked to a lookback option having a predefined cap-curve as a strike. Here, we would like to emphasise that the cap-curve can be turned into a piecewise constant function or be even randomised.

4 Application to COVID-19

First reports of an outbreak of a novel coronavirus-infected pneumonia (COVID-19) were identified in December 2019 in the city of Wuhan, Hubei Province, China. Declared a pandemic by the World Health Organization on 11 March 2020, the highly contagious virus has rapidly become a global concern. Every individual, every government has been caught by surprise fighting against the crisis caused by COVID-19. Some governments imposed lockdowns and announced economic measures to safeguard jobs and guarantee wages during the COVID-19 pandemic, but for the countries' economies this has a cost. The organisation Oxfam (confederation of 20 independent charitable organisations focusing on the alleviation of global poverty) has reported already in July 2020 Oxfam Media Briefing (2020) that by the end of 2020 more people could die of starvation, as a result of COVID-19, than of the virus itself. The financial support is not coming timely and to the desirable extent.

The insurance companies have been criticised because most policies, especially business income insurance,[6] do not provide cover for infectious diseases and those that do, usually exclude viruses like COVID-19. The reinsurance we are proposing would act quickly, and being a business contract, and not a "charity", provides targeted help and excludes bargaining from the side of the ceding state and/or changing the rules "on the fly" on the part of the reinsurance company. It is too late for this pandemic, but everybody wants to be insured against the next one, therefore in the following we exemplify how one could analyse data and price such a social reinsurance product.

In the following subsections we will describe the data together with the methodology to calculate the cap-curve and present an illustration of product design for COVID-19 pandemic.

[6] This kind of insurance covers the loss of income that a business suffers after a disaster.

Note that we only use the data available up to the end of March 2020. The reason is that the reinsurance product we suggest is meant to alleviate the burden of a state in the very beginning of a pandemic. The world is trapped in the "panic and neglect"-cycle, meaning that the measures taken to prevent or more easily fight the next pandemic will be most probably deficient. Long before COVID-19, scientists have been warning against insufficient investments into pandemic preparedness measures, see, for instance, Center for Strategic and International Studies (2022).
Therefore, we assume that in the case of the next pandemic, the governments and citizens will behave in a way similar to spring 2020.

4.1 COVID-19 Data analysis and methods employed

To illustrate the proposed reinsurance design, we consider data covering the first wave of the pandemic from two countries, China and Italy. As for China, we particularly focus on the historical data in Hubei province, the first epicentre of the outbreak. The R package, nCov2019, developed by Yu (2020), provides direct access to real-time epidemiological data of the outbreak in China. The historical data provided by the package, which forms the basis of our analysis is a public GitHub repository and has been updated daily during the pandemic.[7] Although not all data sources are official statistics, this kind of detailed data offers a unique opportunity to study the spread of the novel pathogen. The data shows that the epidemic was controlled by the end of February with almost no new cases in Hubei and by early March, a rapid increase in the number of recoveries is seen, particularly in Wuhan. As for Italy, we explore the historical data from the Italian Civil Protection Department COVID-19-Italy-Data (2020) including 21 regions. The raw data contains the number of cumulative confirmed cases, total active cases, daily new positive cases, new recovered cases and new deaths.

The chosen countries are not crucial for our analysis. Instead, one could have simulated the data. However, we would like to stress that the presence of a surveillance tool guaranteeing clean data reporting is crucial. Some studies show that the data reported by Italy, a country that has been severely hit during the first wave of COVID-19, has an undercount index (the index showing the ratio of the estimated true numbers of dead and infected to the reported numbers) of 1.3, see Karlinsky and Kobak (2021), being a very good result. As for China, the officially reported results serve just as a cap-curve – an ideal scenario of how a country could fight a pandemic. Thus, the two countries should only be considered to be chosen for illustrative purposes.

Based on the available data, to be precise, on the infection speed, we define and determine a cap-curve for the proposed reinsurance product. The starting point of the curve can be chosen, for instance, to be the first date when the increase in number of deaths (given

[7]GitHub repository Wuhan-2019-nCoV (2020) derives data from the literature Huang et al. (2020) for December 1, 2019, to January 10, 2020, after which it relies on the Chinese news aggregator Toutiao API.

a pandemic) compared to the last 5 years' average exceeds 0.1%.[8] This date has been calculated to be the 24th of January 2020 for Hubei and the 3rd of March 2020 for Italy.

We use the number of cumulative confirmed cases at time t, CC_t, to define the infection speed for a city at time t, v_t. Specifically, the infection speed v_t is the ratio of the *newly* confirmed cases at time t ($\mathrm{CC}_t - \mathrm{CC}_{t-1}$) and the currently *uninfected* cases at time $t-1$. Denoting the total population by (TP),

$$v_t = \frac{\mathrm{CC}_t - \mathrm{CC}_{t-1}}{\mathrm{TP} - \mathrm{CC}_{t-1}}.$$

Here we have two important assumptions. First, it is impossible to obtain daily updated population data, hence we use the official population data from the Hubei Statistical Yearbook 2019 published by the Hubei Provincial Bureau of Statistics (Hubei Provincial Bureau of Statistics, 2019) and from I.Stat (I.Stat, 2020). Second, we assume recovered patients will be immune to the virus, and so, do not include recovered cases in the calculation of the infection speed.

Following the definition of the infection speed, daily rates for Hubei (41 days ranging from 24 January to 4 March 2020) and Italy (41 days ranging from 3 March to 12 April 2020) were calculated.

Next, we present scatter plots to compare the trends of the infection speed for the two areas, Hubei and Italy, see Figure 1.

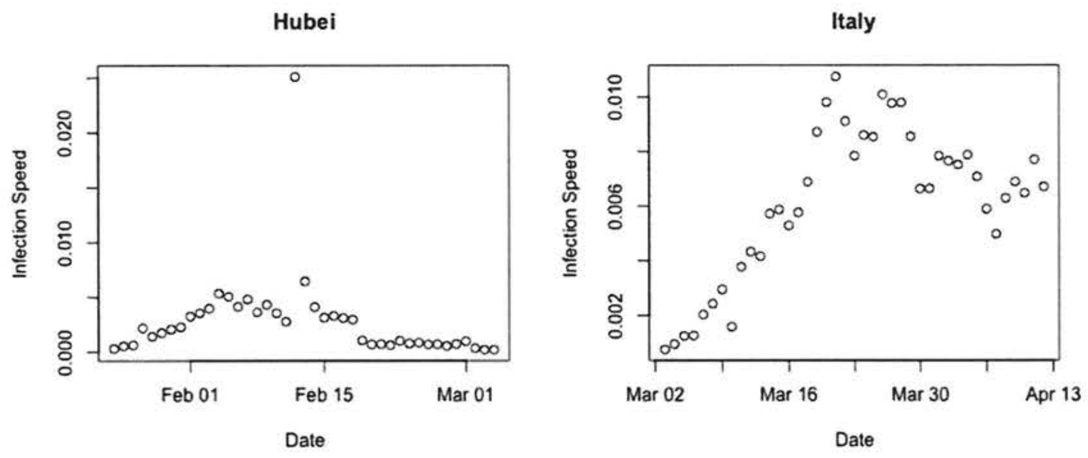

Figure 1: Infection speed

[8]This 0.1% is chosen arbitrarily, as an example.

For both areas, we observe that there is a similar trend, first the trend increases and then it decreases. Furthermore, we see that for Italy there are no outliers. On the other hand, for Hubei it is obvious that a data point has value which is significantly larger than the values of all other points. The large increment is caused by the change of diagnostic method of COVID-19 by the government. It is said that around 20% $\sim$ 30% of them can be confirmed by RNA tests. Additionally, we see that there are excess zeros in the data for Hubei and Italy. Both outliers and excess zeros should be removed because they are not in line with the general pattern of the data.

4.1.1 ARIMA models for the infection speed

Autoregressive Integrated Moving Average (ARIMA) models are a general class of models mainly used for forecasting time series data. Generally, ARIMA models are denoted as ARIMA(p,d,q) where p is the order of the autoregressive model (AR), d is the degree of differencing and q is the order of moving-average (MA) model. ARIMA models use differencing in order to convert a non-stationary time series into a stationary one, and then predict future values from historical data.

First, we will define an autoregressive moving average (ARMA) model of order p,q which is denoted as ARMA(p,q) with no covariates:

$$y_t = \phi_1 y_1 + \cdots + \phi_p y_{t-p} - \theta_1 z_{t-1} - \cdots - \theta_q z_{t-q} + z_t,$$

where y_t represents time series data and z_t is a white noise process (i.e., zero mean and iid).

The ARMA model is combined from the AR and MA models. In this model, the impact of previous lags along with the residuals is considered for forecasting the future values of the time series.

If we write the model using backshift operators B, where $By_t = y_{t-1}$, the ARMA model is given by

$$\phi(B)y_t = \theta(B)z_t \text{ or } y_t = \frac{\theta(B)}{\phi(B)}z_t,$$

where $\phi(B) = 1 - \phi_1 B - \cdots - \phi_p B^p$ and $\theta(B) = 1 - \theta_1 B - \cdots - \theta_p B^q$.

For ARIMA errors, we simply replace $\phi(B)$ with $\nabla^d \phi(B)$ where $\nabla = (1 - B)$ denotes the differencing operator. Notice that this is equivalent to differencing both y_t and x_t before fitting the model with ARMA errors. The ARIMA model is the combination of AR and MA models and differencing. Specifically the ARIMA(p,d,q) model is denoted as

$$y'_t = \phi_1 y'_{t-1} + \cdots + \phi_p y'_{t-p} + \theta_1 z_{t-1} + \cdots + \theta_q z_{t-q} + z_t,$$

where p is the order of the autoregressive part, d the degree of first differencing involved and q the order of the moving average part.

We follow the steps below to build the ARIMA(p,d,q) model.

Step 1: Testing and Ensuring Stationarity

To model a time series with the Box-Jenkins approach, the series has to be stationary. According to this approach when the process is non-stationary we take the difference of the series, which is known as *differencing*, one or more times in order to achieve stationarity. As a result, this approach produces an ARIMA model. A stationary time series means a time series without trend, having a constant mean and variance over time.

We apply the appropriate differencing order (d) to make a time series stationary before we can proceed to the next step.

Step 2: Identification of p and q.

In this step, we identify the appropriate order of AR and MA processes by using the Autocorrelation function (ACF) and Partial Autocorrelation function (PACF). The ACF defines how data points in a time series are related, on average, to the preceding data points. Also, the PACF is a summary of the relationship between an observation in a time series with observations at prior time periods with the relationships of intervening observations removed. ACF and PACF can be used to check for stationarity and also to identify the order of an ARIMA model.

Step 3: Estimation

Once we have determined the parameters (p,d,q) we check whether our fitted values are in line with the real data.

Regarding the data we used in this study, firstly, we need to check whether the first difference of the infection speed for Hubei and Italy would act like a sequence of random noise.
Figure 2 indicates that both time series graphs are stationary. Secondly, we examine the ACF and PACF plots of the differenced data for Hubei and Italy in order to identify the possible orders we should use for the models.

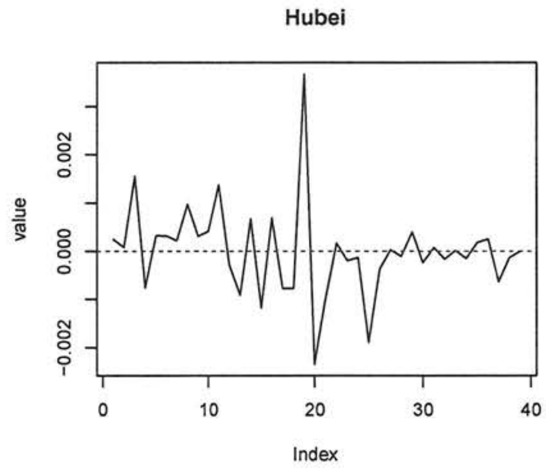

Figure 2: First difference of the infection speed for Hubei and Italy.

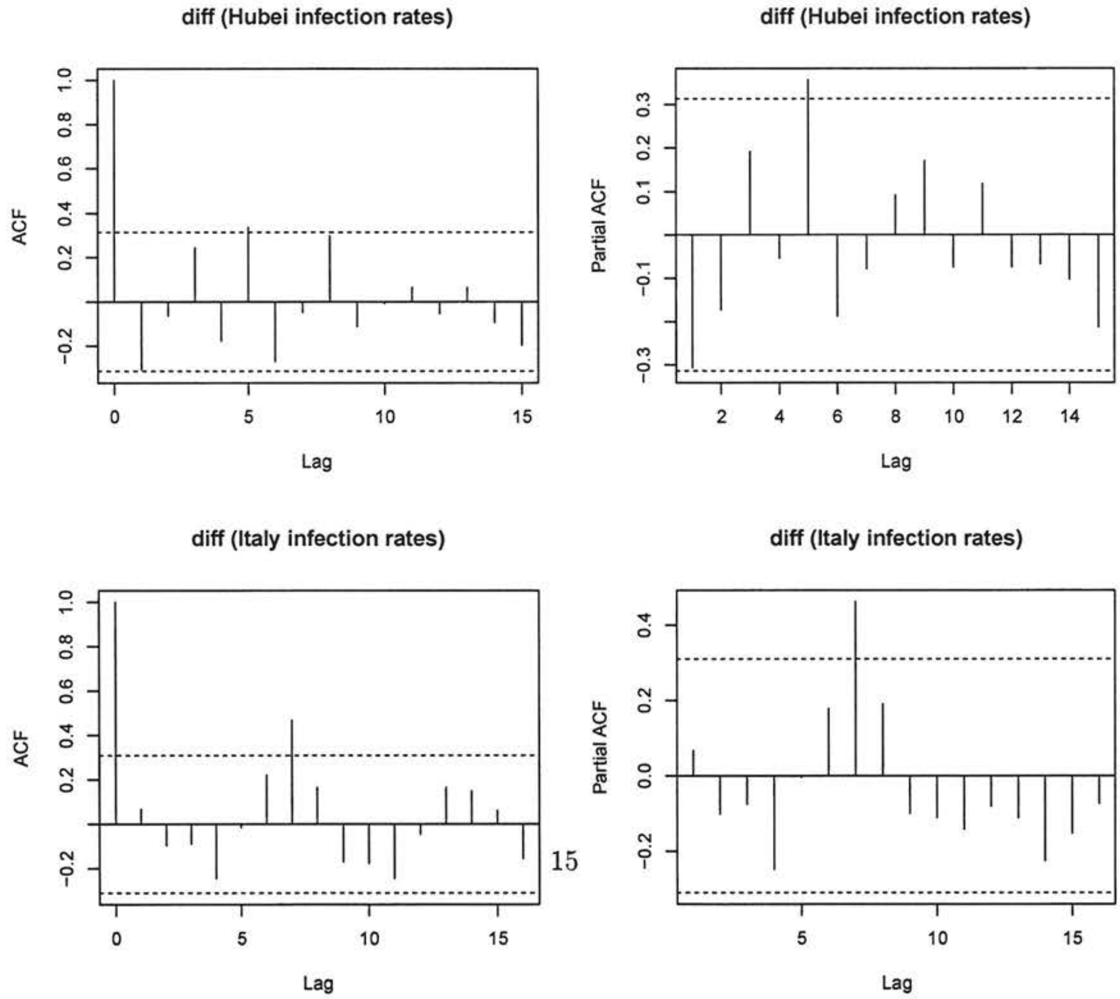

Figure 3: ACF and PACF plots.

Figure 3 shows that, although the ACF and PACF values are small, there are a few significant values due to being above the confidence limits. Since autocorrelation coefficients are used to determine MA orders and partial autocorrelation coefficients are used to determine AR orders, we observe that the maximum ARMA order would be $(5, 5)$ for the Hubei data. On the other hand, it seems that there is seasonal effect for Italy as its ACF and PACF plots are only significant at lag $= 7$. Furthermore, by using the Akaike Information criterion (AIC) we find that the best model for Hubei is ARIMA(2,1,1). For Italy, the ARIMA order is (0,1,0) and seasonal order is (1,0,0) at lag $= 7$. Finally, we conduct residual diagnostic tests to determine the goodness of fit of the models.

- The residual plot should be random;
- There should be no pattern when plotting the residuals against fitted values;
- There should be no significant autocorrelation and partial autocorrelation.

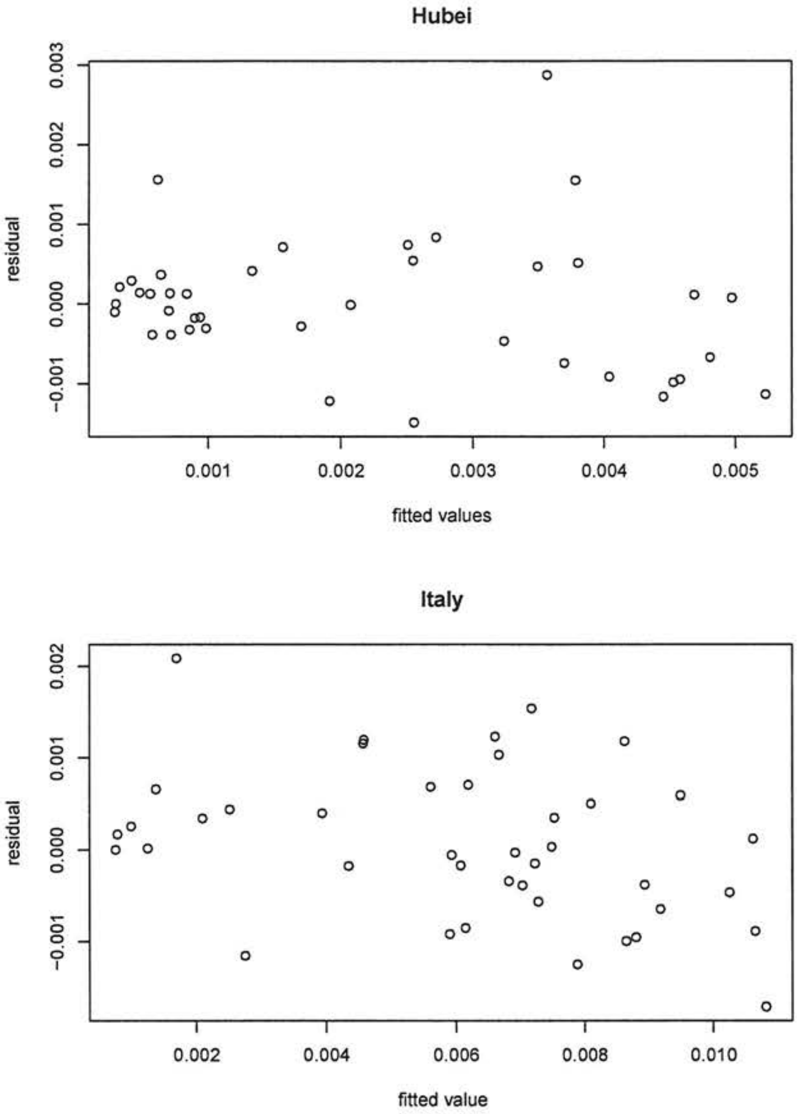

Figure 4: The fitted values of the infection speed in Hubei and Italy.

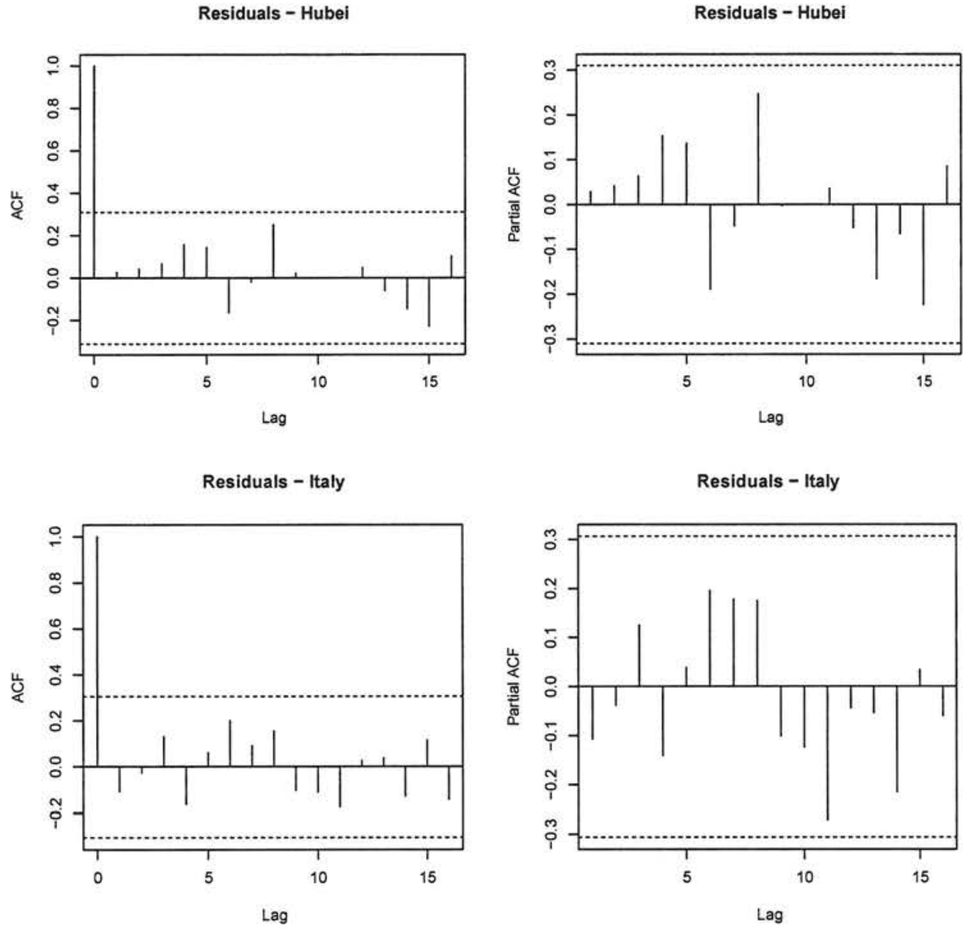

Figure 5: Residual diagnostic plots for the infection speed in Hubei and Italy.

Figure 4 presents the residuals versus predicted values obtained from the fitted ARIMA models. These graphs are important to test the null hypothesis that the residuals are independent and identically distributed (*iid*) which is one of the most important assumptions of the ARIMA modelling. We performed a *turning point test* which is available in R programming language to test *iid* null hypothesis. For the Hubei data, the p-value is 0.3061 which means that we fail to reject the *iid* hypothesis. Moreover, Figure 5 shows that all ACF and PACF values are within the confidence intervals. Therefore, the ARIMA(2,1,1) model provides a good fit. For the Italy data, the p-value is 0.7048 and thus we cannot reject the *iid* hypothesis. All other plots support the fact that ARIMA (0,1,0) with seasonal ARIMA order (1,0,0) provides an appropriate fit for Italy data as well.

4.1.2 The curves for Hubei and Italy

Finally, we plot the infection speed curves for Hubei and Italy using the fitted values of the ARIMA models we described in the previous section. Figure 6 displays the observed and fitted values for both regions on the same graphs which indicate that the models fit the data well.

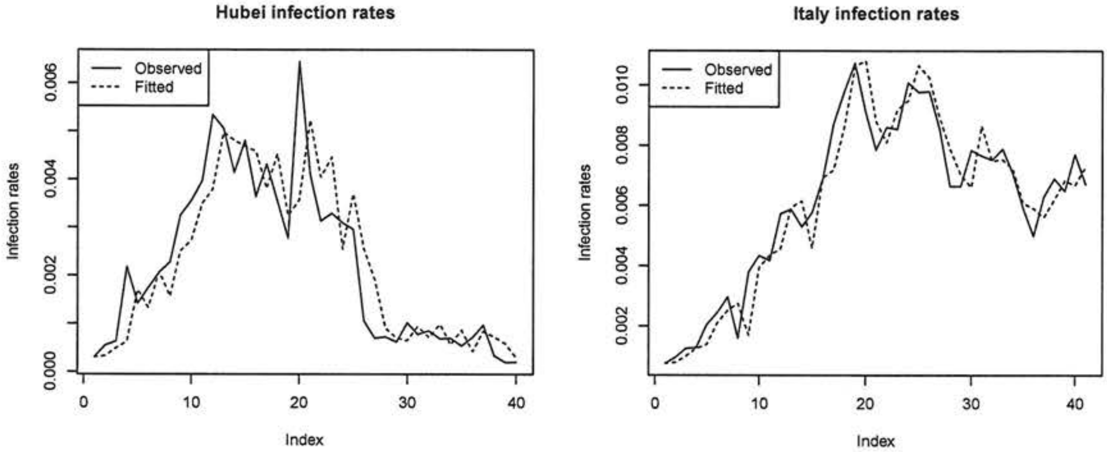

Figure 6: Fitted values of the ARIMA model.

Predictive models can provide valuable insights into the future spread of a pandemic. However, relying on historical data only reflects past trends and patterns. Predictive models can also help forecast the potential trajectory of the pandemic at least for a short period when the data is relatively stationary, i.e. during a specific wave of the pandemic. These models can be used to identify potential areas with high infection rates where stricter lockdown measures may be necessary, can help identify the most effective testing and contact tracing strategies, and predict the potential effectiveness of different vaccination campaigns.

One can use similar ARIMA models to model infection speeds data for different countries in order to determine the duration of the reinsurance payments. If the measures taken by the governments are not sufficient, the fitted models and estimated parameters will produce higher simulated infection speeds which would exceed the given benchmark curve (in this case Hubei) stopping the reinsurance payments. In this way, without a particular management strategy having been contractually established, the government will be rather willing to take severe measures (for instance, Greece, during COVID-19 outbreak), in order to get the full reinsurance payment.

4.2 COVID-19 example of product design

We present a numerical illustration assuming that the Italian government is in possession of a *10-year social reinsurance contract,* as described in Section 3. Hence, we consider the Italian data from COVID-19 as if it were a new pandemic. First, the contract specifications together with the main assumptions to calculate the premium are described. Next, we analyse the (financial) implications of the acquisition of the reinsurance product given the evolution of the Italian speed infection.

Three contract specifications: triggers, payments and the cap-curve

1. Triggers: The first triggering event that activates the first payment is the *call for a state of emergency due to the pandemic* as discussed in Section 3.

2. Payments: Two set of payments are included in this product.

- The first one, activated immediately after the first trigger, is defined as half the *food expenditure per household* during an 8-week period. For the Italian case, the stipulated amount, that the government would receive, is 460€ per each of the $25.517 \cdot 10^6$ households.[9]
- The second payment is due 8 weeks after the first payment, only if the parameters estimated from the fitted ARIMA models produce infection speed rates that will not exceed the cap-curve during the 8-week period. Note that based on the data obtained during the COVID-19 from China, we obtained fitted values for the infection speeds using ARIMA models and their parameters. If the model fitted for Italy (the policyholder) produce higher speed rates which exceed the infection speeds for benchmark country providing the cap-curve (Hubei in this example), then the reinsurance payments will stop. This second payment is defined as a monthly payment of a similar amount of the *universal basic income*, i.e. 500€ for the Italian case,[10] for the next 2 months to low-skilled workers.[11]

3. Cap-Curve:

Considering the data from the previous pandemics, and classifying the affected countries in clusters depending on their degree of success, one can fit ARIMA models to the infection speeds data and build an average curve, as it is illustrated in Section 4.1, for the early days of COVID -19. The proposed contract also introduces a duration limit of 8-week to check

[9] Information of the number of households can be found at `https://w3.unece.org/PXWeb2015/pxweb/en/STAT/`. The amount paid per household corresponds to the Italian household average monthly expenditure in 2018. For more details see `https://www.statista.com/statistics/881144/household-average-monthly-expenditure-italy/`

[10] This monthly payment, Pavolini (2020), is in line with the Italian *Citizenship Income*, that is a means-tested cash benefit targeted at poor and socially excluded households. In particular, the benefit for a single-member household tops up annual income to 6,000€.

[11] In Italy, over 13 million adults have low basic skills. This group of people faces higher risk of poverty.

if the measures taken by the government are effective to fight against the pandemic which is evaluated by examining the cap-curve, that takes Hubei data in China as a reference. Therefore, the cap-curve we introduce as a monitoring device enables us to avoid defining other triggering events which might be subject to moral hazard in the pandemic risk.

It is important to contractually agree when the comparison of the cap-curve with the newly gained infection speed data should begin. Our proposal is to link the starting point to the increase in the number of deaths. As mentioned in Section 4.1, the comparison might start when the reported accumulated number of deaths due to the epidemic exceeds the average cumulative number of deaths over the last 5 years by a certain percentage, for instance by 0.1%. The accumulation of the average number of deaths will start at the 1st of the month when the first deaths due to an epidemic have been reported. This will prevent that the month of an epidemic outbreak will influence the starting point of both the infection speed curve which comprises the cap-curve.

Along with the triggers and the payments, the cap-curve is crucial for pricing of the product. The reinsurance company/companies will have to model the daily probabilities for cutting the cap-curve by the ceding state. Depending on the timing of the triggering events, these probabilities might diminish the price of the contract considerably. In order to construct a realistic model for "cutting probabilities" a behavioural study (as in abiding to government measures as e.g. wearing masks) and a broad socio-economic survey (as in economic development of the country) in the ceding state are necessary. Such an analysis would go far over the scope of the present paper. Therefore, in our example below we use simplistic assumptions for solely illustrative purposes.

Main data and assumptions

- The probability for an epidemic outbreak in Italy is set to equal the probability of a global pandemic causing nearly 6 million pneumonia and influenza deaths (i.e. 8 deaths per 10,000 people). This probability is estimated in Madhav et al. (2017) to be 1% for 1 year time. Thus, assuming the independence between the years, the probability of a pandemic during the next 10 years would be approximately 9.6%.

- We acknowledge that one of the cornerstones to price our product is the question about the probability that given a pandemic the infection speed in Italy will hit the cap-curve. As this example serves solely as an illustration and does not represent a contract ready to sign, we assume the aforementioned probability to be 50% – a Bernoulli trial. Here, the reinsurance company could introduce various models to capture the causal dependence in the contagion mortality for better estimates of this probability like it was mentioned in Section "Cap-Curve" above.

- We assume a zero interest rate to calculate the premium, for ease of calculations, although a common global trend in Europe these days, see Del Negro et al. (2019).

- In the example, we are also analysing the implications of a shift in the cap-curve by 0.2% taking into account the criticism on the reliability of the Chinese data. On the other hand, we believe that building the benchmark cap as an average over European countries would produce a curve that lies much above the curve obtained from the Chinese data. However, the average can be built only when the pandemic will be completely over and the entire data will have been evaluated.

Note that the choice of the probability of a global pandemic is crucial in pricing our product. Based on the global mortality of past pandemics, Madhav et al. (2017) have three different proposals: $3\%, 1\%$ and 0.02%. Although some companies are recently using the 0.02% for COVID related insurance pricing, in our example we use the risk of 1%.

Reinsurance pricing for Italy

The present value of the first set of payments based on the food expenditure per household amounts to

$$460 \cdot 25.517 \cdot 10^6 = 11.73782 \cdot 10^9 €$$

The present value of the second payment based on the idea of a universal basic income amounts to

$$1000 \cdot 13 \cdot 10^6 = 13 \cdot 10^9 € \, .$$

Hence, the net premium for a 10-year contract is given by

$$0.096 \cdot \left(11.73782 \cdot 10^9 + 0.5 \cdot 13 \cdot 10^9\right) = 1.75083 \cdot 10^9 € \, .$$

Reinsurance payments for the COVID-19 crisis in Italy

On the 31st January, the Italian government suspended all flights to and from China and declared a state of emergency with the duration of six months. By the contract design, on the 31st of January the first reinsurance payment is triggered. For more analysis of the COVID-19 development in Italy see for instance Şahin et al. (2020).

The second payment is subject to the satisfactory evolution of the infection speed rates. In Figure 7 we present the curves associated to Chinese (the cap-curve) and to Italian data on the same scale to see when/if the infection speed in Italy hits the cap-curve which will stop the reinsurance payments. However, the Hubei infection speed has always been lower than Italy infection speed during the first wave of the pandemic.
Shifting the Chinese curve a certain amount, for example 0.1%, in order to account for the average data in Europe – this is more suitable for the application in Italy, the Italian curve would lie above the modified cap-curve for a short period which might make a second reinsurance payment possible. Constructing the cap-curve using the right data is crucial for the reinsurance payments to be made. In this paper, our aim is just to illustrate a

possible approach to construct a cap-curve. However, COVID-19 experience might provide an insight for an upcoming pandemic and how to design similar products for the future.

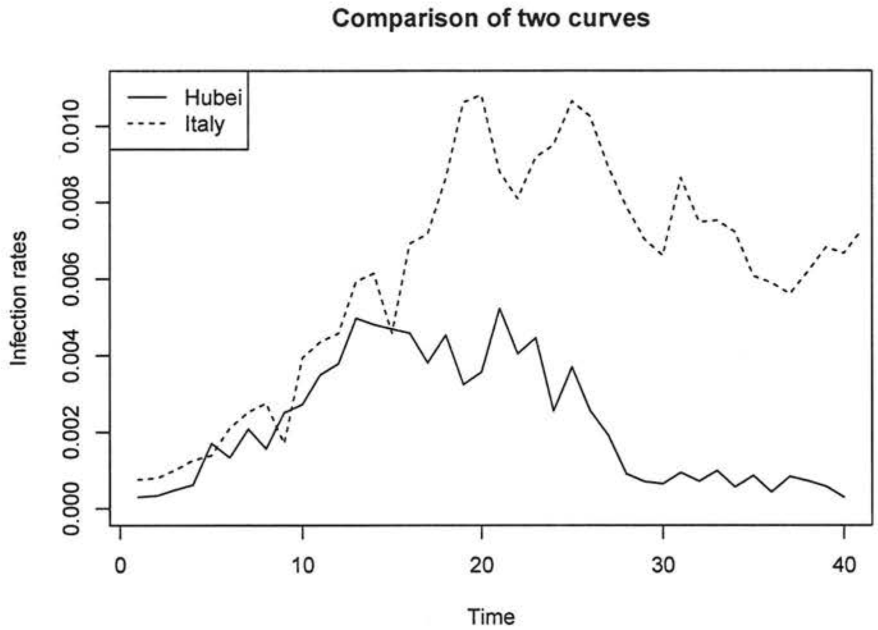

Figure 7: Cap Curve

As a starting point for the comparison of both curves (Italian versus benchmark data) we chose the *first day* when the accumulated number of deaths associated with the pandemic exceeded the 0.1% boundary compared with the average cumulative number of deaths of the last 5 years. In Italy, this was the case on the 3rd of March 2020. We refer to it as the first day of excess mortality. Comparing the infection speed rates beginning on the 3rd of March shows that Italy would not get the second tranche given the data of COVID-19 as during the 8-week period which started on 31st January with the declaration of the state of emergency ends, the Italy curve is always higher than the benchmark cap-curve [12].

In this specific example, the first day of excess mortality (3rd March 2020) is inside the interval between the first and the second payment (31st January 2020 and 27th March 2020). The decision regarding the second payment is therefore straightforward. However,

[12] Aforementioned 8-week period is still within the fitted data period which would not require any forecasting.

the first day of excess mortality may take place after the 8-week interval or before the call of state of emergency. If the excess accumulated number of deaths compared with the last 5-years' average cumulative deaths stays under the chosen boundary of 0.1% during the whole 8-week interval (i.e. if the Italian curve does not even start between the 31st of January and the 27th of March), then clearly the second help package should be paid on the 27th of March. If the excess accumulated number of deaths surpasses 0.1% already before the call of state of emergency (31st January 2020), the curve for Italy will start with that specific day. Hence, the payment of the second package will be made if the curve stays under the cap-curve during the whole period starting at the date of the aforementioned ratio exceeding 0.1%. Here, we would like to emphasise that a different procedure compromising the reinsurance company and the ceding state can be introduced.

This paper uses ARIMA models to obtain a smooth infection rate curve that can be used as a cap-curve for the designed product. We chose to use fitted values from ARIMA models and intentionally avoid forecasting using these models. This is because ARIMA models are typically used for forecasting under the assumption of stationarity, which may not be appropriate for pandemic data due to the significant interventions that can occur, such as vaccination and lockdowns, which might dramatically change the course of the pandemic. The fitted ARIMA models have two advantages. First, the model and the estimated parameters provide useful information about the evolution of the pandemic in countries/regions that experienced it after other countries. This is why we chose to use data from Hubei, the epicenter of the COVID-19 pandemic, to produce the cap-curve as the knowledge obtained can be used for other countries that are expected to be on the same/similar stage with a time lag. Second, when there is another COVID-like pandemic, these models and the parameters will provide prior information that can be used to produce a cap-curve for the "new" pandemic.

5 Conclusion

In recent years, in particular after the outbreak of SARS in 2002, scientists have warned about the possibility of a new pandemic. The warning stated that most of the world is unprepared for such a challenge, see for instance World Bank (2017), since pandemics create unmanageable risks for life, travel and business insurance and ultimately the entire (re)insurance industry. As predicted, on 11 March 2020, when the World Health Organization declared COVID-19 a global pandemic, the governments have been caught unprepared to fight against the crisis caused by the spread of the coronavirus. Unfortunately, business income insurance policies do not provide cover for infectious diseases and those that do usually exclude viruses like COVID-19.

In terms of financial impact, the shock to the global economy from COVID-19 has been faster and more severe than the 2008 global financial crisis and even the Great Depression. The World Bank's forecasts envision the deepest global recession since World War

II, with millions of people falling into unemployment and poverty. In response to the COVID-19, some governments have launched unprecedented public health and economic responses. Numerous poor and middle-income countries have sought financial help from the International Monetary Fund as they struggle to cope with the economic fallout from the COVID-19 epidemic. United action is needed to create a resilient international pandemic response in the future. Governments, international organisations and (re)insurance companies should work together to prevent another disaster like COVID-19.

The proposed reinsurance product, designed as a supplement to the social insurance provided by the state, is based on a parametric (insurance) mechanism. It provides fast payments, when the money is most needed, so that the government can initiate a prompt response to the pandemic. Different triggers, that activate pre-defined payments established by the contract, have different advantages and disadvantages. One of the main advantages of a *parametric* reinsurance is that it is immune from moral hazard. Hence, with the aim of reducing the effect from possible manipulation from the insured state, we modify the pure parametric reinsurance and add a cap-curve, as a tool to assess the success of government's response to the COVID crisis, i.e. lockdown or mandatory face masks, amongst others. It is worth mentioning that the proposed reinsurance design can be transformed into an individual insurance contract. In this case, the surveillance of the state's actions (and consequently the cap) is not necessary, the problem of moral hazard disappears. An individual might purchase such a product for a monetary support during a lockdown.

Unlike other existing proposals in actuarial literature, that focus on the financial losses of an *individual*, our proposed product aims at alleviating the costs of the insured *state*. For our state parametric insurance, we adopt a data driven approach that constructs the cap-curve based on daily infection speed data. We choose the best ARIMA model which fits the available daily data and use estimated parameters of the model to obtain fitted values for infection speed. By displaying the fitted daily infection speeds, we construct a smooth curve for the cap.

One could have got the impression that the countries which are ineffective in slowing down the spread of an infection for reasons beyond their control would be penalised by the presence of a cap-curve. However, as it was described in Section 4, the first tranche can be ready to be paid out very early so that a lockdown can prevent the infection spread. The social reinsurance payments would happen just in the very beginning of a pandemic/epidemic bridging the gap to other aid schemes. Thus, a developing country agreeing to introduce a lockdown, social distancing, masks etc. would not be penalised.
An example, provides the case of Greece, where an early and very strict lockdown has kept the number of infected and dead during the first COVID-19 wave at the lowest level in Europe, see Bloomberg (2020).

By talking about developed countries, we have to adjust many elements of the product, possibly taking into account some cultural characteristics, as the developed countries would rely just on themselves.

Some important directions of future research can be identified. Firstly, it would be essential to model some variables, such as, the probability of an epidemic and the probability that the infection speed will hit the cap-curve, amongst others, to price the proposed reinsurance product. None of these are easy to estimate. Administrative costs are crucial and must be evaluated in a more realistic pricing framework. However, it is a secondary problem considering the importance of the estimation of the probabilities for a pandemic occurs and how much it affects the value calculated. A different structure for the cap-curve can be adopted to include the actuarial state-space models which are designed to estimate the infection speed. The model proposed by Wilkie (2022) might be one of the candidates. Still, we might need to optimise the chosen parameters used in the model as it produces projections rather than forecasts in its current version.

On the other hand, it would be opportune to analyse how effective were the measures taken by different governments during COVID-19, in terms of infection speed, mortality rates and fatality ratios. The expected shortfall of their total losses should also be analysed, as a measure of each government effectiveness. Pandemics do not respect the geographical borders of countries, thus pandemic insurance might need to be considered not only at a national level, but also for groups of neighbouring countries.

Designing a product for developed countries containing utility optimisation features would be an interesting task. Here, one has the freedom of modelling the utility of the obtained insurance payment and comparing it to the premium payments to be done every year. For developing countries, where the insurance product presented in this paper is thought to provide "money for bread", the utility of an insurance payment would be almost infinite.

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