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Abstract

Pandemic risks, such as Covid-19, are difficult to insure because they are characterized by multiple risks and losses that can affect a variety of enterprises and people at the same time. Insurers are unable to generate accurate pricing due to a lack of time series and granular statistical data. To address the pandemic risk posed by the spread of Covid-19, we present a model of Catastrophe Risk with Non-Damage Business Interruption Policies (NDBI). The model entails a Monte Carlo simulation of various shutdown situations, as well as the frequency and severity of losses suffered by Italian SMEs. The research emphasizes the relevance of NDBI policies for both the firms - which can cover their losses - and insurance companies - that can achieve a profit margin thanks to the reinsurance.

I rischi pandemici, come il Covid-19, sono difficilmente assicurabili, in quanto oltre ad essere caratterizzati dalla presenza di molteplici fattori di rischio, possono condurre a rilevanti perdite e coinvolgere contemporaneamente una molteplicità di imprese ed individui. La scarsa disponibilità di serie storiche e dati statistici sugli eventi in questione impedisce di fatto agli assicuratori di formulare stime attendibili e, pertanto, di procedere a una corretta tariffazione. Obiettivo del presente contributo è quello di individuare una soluzione in chiave gestionale del rischio pandemico associato alla diffusione del Covid-19 attraverso una gestione del Catastrophe Risk con polizze Non-damage Business Interruption, utilizzando il metodo Montecarlo seguendo un approccio frequency–severity per calcolarne i valori attuariali significativi (Premio, Utile, VaR, SCR, Probabilità di rovina).

Keywords: Covid-19; Polizze assicurative; Riassicurazione; Rischio catastrofale

JEL: C15; G22

1. Introduction

A catastrophe is an event that occurs very rarely and which, in its broadest sense, exceeds the capacity of the affected people to cope with, or absorb, its effects; in the context of natural hazards, it is an extreme event that causes widespread and typically sudden damage or suffering (Mitchell-Wallace et al., 2017; Niehaus, 2002; Doherty, 1997; Jaffee & Russell, 1997; Klein & Wang, 2009)

Catastrophe risks arise from extreme and unexpected events. In the insurance sector, disasters can be divided into two broad categories: catastrophes related to human activity (Man-Made or Technical catastrophes) or generated by nature itself (Natural Disasters) (Swiss Re, 2002). The term "Natural Catastrophe" refers to an event caused by natural forces that can lead to very significant losses and involve a very large number of individuals. The extent of the losses deriving from a catastrophe is not only a function of the intensity of the natural forces that are spread out, but it also concerns factors directly dependent on human actions, such as the design of buildings or the efficiency of the control of disasters in the affected region (Swiss Re, 2019)

Windstorms, floods, hail, volcanic eruptions, earthquakes, are just a few examples of natural disasters. A natural disaster can evidently cause loss of human lifes and considerable damage, the extent of which will also depend on the population density of the involved community[1] and its ability to return to a sustainable living condition relatively fast in the aftermath of the event.

Within the insurance sector, it is a shared opinion that disasters are commonly based on an event that exceeds at least one of several thresholds, expressed, for example, in terms of overall economic losses, insured losses, and loss of human lives (Swiss Re, 2015). Broadly speaking, events which appear to be so heterogeneous, such as disasters, present, on closer inspection, many similarities, so much so that at least five common characteristics can be pinpointed:

1. the occurrence of the catastrophic event must cause multiple claims in different times and places, so that the sum of the individual damages is very high;
2. all claims must be related to the same cause, which has to be of an extraordinary and exceptional nature. Therefore, neither the event that causes a single damage, even if considerable in its entity (due to the lack of the first requirement), nor the catastrophe caused by events that generate a plurality of damages which are normally covered by insurance (due to the lack of the second requirement) fall within the definition of catastrophe-risk;
3. a probability can be associated with the occurrence of the event;
4. a damage can be associated with the occurrence of the event;
5. the event is susceptible to the variability of claims over time.

[1] Damage to people, in the event of floods or volcanic eruptions, can be contained or even avoided if adequate preventive measures are taken.

A catastrophe risk, even if it has a low probability of occurrence, can seriously compromise the economic stability of an insurance company, as a result of the relevant and extensive damage it can cause. In fact, the presence of such type of risk within the insurance portfolio impacts the probability of default of the company and, consequently, the variability of the entire portfolio (Stone, 1973)

It seems therefore appropriate to pay particular attention when taking on and managing this particular type of risk, so as to avoid potential (and serious) imbalances on the overall management of the company.

From this perspective, Italy shows a high exposure to the risks of natural disasters, which, in addition to terrible loss of lives, can also cause serious damage to real estate assets. Besides, the damages associated with the occurrence of such events have always given rise to direct intervention by the State, while insurance companies have actually played only a marginal role. This situation exposes public finance to serious risks and would suggest a greater diffusion of "ad hoc" insurance policies (IVASS, 2019).

In recent months, the risks associated with natural disasters have been joined by those related to the Covid-19 pandemic, which represented - and still represent - a serious threat to public health (ECDC, 2020). However, the Covid-19 pandemic has not only had a huge impact on the health sphere, but also on an economic and financial level. In particular, in our country, both income and purchasing power have shrunk for a huge percentage of workers, with a consequent widespread failure to comply with their financial obligations (by way of example, failure to repay loans and / or payment of utilities).

Considering the above, in this work we want to propose a model for the pricing of a "Non-physical Damage Business Interruption" (NDBI) insurance policy (which in the field of non-life insurance can be placed in the "Financial loss" or "Miscellaneous Financial Loss" business) with an associated "Catastrophe excess of loss", i.e. a form of non-proportional reinsurance that protects the insurance company against an accumulation of losses due to single events. The main purpose of such form of reinsurance is to protect the financial stability of the insurer and to "level out" the alternating financial results associated with years in which catastrophic events do or do not occur (Mata, 2006).

The above-mentioned model applied with a frequency-severity standard is based on three main phases:

1. Monte Carlo simulation of the lockdown scenario (if and how many lockdowns occur in Italy in a year);
2. in the event of lockdown, simulation of the number of SMEs that will report their business interruption to the insurance company (frequency);
3. estimate of the amount to be compensated to SMEs that have interrupted the activity (severity), obtaining the distribution of the global compensation to be used for calculating the relative actuarial values.

We will particularly focus our attention on our country, since a few theoretical studies and empirical surveys have shown that the percentage of companies protected by an appropriate insurance "umbrella" appears to be rather low in Italy. The reasons behind the lack of insurance coverage undoubtedly include the low perception of risk exposure and the high cost of insurance services. Moreover, companies mostly cover the risk of fire, theft and robbery and civil liability towards third parties and employees, while little attention is paid to the risk of business interruption, especially when it comes to signing "ad hoc" insurance policies (Santoboni et al., 2012).

After all, the impact of the Covid-19 health emergency, which forced many companies to reduce or stop their activities, has been magnified precisely by the lacking coverage of the "Business Interruption Risk": in Italy only 3% of SMEs are specifically insured; in addition, small companies in the most affected sectors, such as transport and the entire tourism industry, have experienced significant decreases in their turnover in 2020 compared to 2019 (Cerved, 2020).

This work is structured as follows. In paragraph 2, the negative effects on companies and people linked to the spread of the Covid-19 pandemic are outlined, likewise highlighting the characteristics of the Italian situation. In paragraph 3, a few of the current ways of managing disaster-related risks with insurance contracts are described. Paragraph 4 focuses on the description of the proposed model and on the discussion of the achieved results. Paragraph 5 includes the concluding remarks.

2. The Covid-19 pandemic

Not only is the current pandemic caused by Covid-19 a serious event with a high social impact, which puts public health at risk on a global level, but from a macroeconomic point of view, it also represents a catastrophic event endangering the functioning of many private and public companies (Agosto et al., 2021). 2020 represented an "annus horribilis" for world economies, which were lashed by a strong global recession, which in 2020 alone recorded a decline of 3.4% compared to the previous year (with even worse levels in the Eurozone), eventhough 2021 is showing a favorable trend reversal (Eurostat, 2020; OECD 2021).

Due to the pandemic emergency, the world's economies have had to face a considerable increase in measures aimed at containing the pandemic, with serious implications at economic and social level: although the limitations following the imposition of lockdowns have contributed to reducing the spread of the infection, with favorable effects from a health perspective, from an economic point of view there were shocks both on the demand side and on the supply side.

On the demand side, the restrictive measures on individual mobility have a direct and immediate negative impact on domestic consumption and net exports, as well as on business investments. With regard to the shock on the supply side, the direct consequences of interrupting all activities in a specific sector and in a specific geographical area can lead to indirect "contagion" effects in other sectors and other areas as well, depending on the degree of vertical integration (i.e. interdependences) of such activities and the related level of globalization. Such a shock can only be partially mitigated by replacing "physical presence" activities with remote work (smart working), since de facto, it excludes important sectors operating in the service sector (such as tourism, catering, entertainment) and the industrial sector, for which the bans determine the closure of plants and factories[2].

On the other hand, as the duration of the lockdown increases, for many companies it becomes also more likely that the interruption of their activity can turn from temporary into permanent, constituting in fact the conditions for a final closure (especially in cases of vulnerable finances or assets).

To the aspects highlighted above, we often need to add the decrease in employee productivity - due to the fear of contagion, the social distancing, the need to tend to sick family members -, the lack of labor force due to death, illness, and confinement of workers (Marsh & McLennan, 2020).

The combination of the aforementioned factors has recently prompted many insurance companies to develop insurance products that can offer coverage to employees even in the event of Covid-19 infection.

2.1 A focus on Italy

The decision to focus our analysis on the Italian context is because the Covid-19 pandemic started to spread a few weeks earlier in our country, compared to other advanced economies (i.e. Europe and US). The social distancing measures introduced in Italy were severe and initially included the closure of schools and the interruption of public events; then, starting from 9th March 2020, limitations on the free movement of people even within national borders, the closure of certain commercial activities and, lastly, from 28th March 2020, the interruption of industrial activities in several non-essential sectors. At the beginning of March 2020, therefore, the lockdown has mostly affected the service sector, in which - where possible - remote working (smart working) became largely used.

The Covid-19 pandemic has particularly affected our country both from a humanitarian point of view (Italy has been the fourth country in the world with the highest deadliness), and from an economic point of view: in the European context, Italy was among the countries that suffered the worst impact on its GDP (-17.7% in the second quarter of 2020, compared to an average EU figure of -13.9%), while the employment rate decreased by around 20% compared to 2019 (Eurostat, 2020).

Furthermore, according to Istat data referring to the first quarter of 2020, the limitation of manufacturing activities in March has involved 34% of the overall production and about 27% of the added value. In April 2020, industrial production decreased by more than 40% compared to April 2019, with an even more significant decline in certain sectors (around -85% for durable consumer goods and -53% for capital goods) and a lesser impact in other sectors (-29% for non-durable consumer goods and -14% for the energy sector). The data updated as of May 2020 indicate a partial recovery, marking an overall contraction in industrial production equal to -20% compared to the previous year (ISTAT, 2020).

3. Covid-19 pandemic risk management with a (NDBI) policy

The Covid-19 pandemic has had a major impact within trade-related workplaces, resulting in increased health risks for frontline workers supporting commercial operations, supply chain transactions and logistics. In the context of risk management techniques that can be used to tackle the Covid-19 pandemic, which tend to minimize long lasting negative impacts, the use of Business Interruption (BI) insurance policies could certainly play a fundamental role. These are policies that generally represent the extension of a property policy, effectively protecting the insured company in the event of business interruption by dealing with the relative loss of profit or with the higher costs to be incurred (Rose & Lim, 2002).

In the insurance practice, the use of NDBI insurance policies is proliferating, allowing companies that use them to benefit from the same protection and coverage as the "non-life" BI, however with one substantial difference: the interruption of the company's business - or of one of its departments or plants - originates from events that do not necessarily cause material damage, but rather from the so-called "trigger events", which are events that cause the interruption of the activity of a particular business without producing material damage.

In the past decade, due to the spread of several epidemics such as SARS, MERS, ZIKA, numerous insurance companies have started to offer NDBI insurance solutions to businesses. Since such policies produce their effects even in the absence of material damage, they are well suited for protection from business interruptions and / or profit losses deriving from risks associated with epidemic events; these policies also allow to obtain coverage for damages resulting from measures issued by the Authorities (such as electricity blackouts, strikes and cyber-attacks, etc.). It is therefore clear that (NDBI) policies can represent a valid solution for the protection of companies in the current Covid-19 pandemic.

In the analysis of catastrophe risks, such as the one related to the Covid-19 pandemic, stochastic models play a leading role and are essentially developed for risk management in insurance and reinsurance contexts. These models provide good support to management to identify all the strategies that allow for the diversification and mitigation of the risk impending on the entire portfolio (especially as regards reinsurance policies) and to determine an appropriate insurance premium (Lakdawalla & Zanjani, 2012; Finken & Laux, 2009).

2 According to Cerved data (2020), the sectors with the greatest losses in their 2020 turnover were the following: Travel agencies and tour operators -51.3%; Air transport -50.8%; Hotels -47.1%; Transport management -46.7%; Restaurants/Catering -33.8%.

4. The model

Based on what we have asserted so far, the NDBI policy appears particularly suitable for guaranteeing the business continuity of micro, small and medium-sized manufacturing, commercial and service businesses; it is therefore not only a prerogative for large companies.

Besides, the observation of the Italian production context testifies to the fact that SMEs are the most vulnerable companies to the Covid-19 NDBI risk: in fact, since they do not have the same financial strength as large companies, the prolonged interruption of their business for a certain period of time could represent, to all intents and purposes, the prelude to default.

Despite the impact of the health emergency, which forced many of these companies to reduce or stop their business, in the second half of 2020 only 3% of SMEs had specific BI coverage in Italy. Considering that the Covid-19 pandemic has not stopped and that it has continued - and still continues - to display its negative effects not only from a health perspective, but above all from an economic perspective, it is clear that for SMEs the drafting of a NDBI policy has now almost become necessary to secure business continuity.

The model considers a catastrophic condition including a "lockdown" occurrence, and the study is specifically applicable to Covid-19. Because the data and historical series available were evaluated at the start of the Covid-19 pandemic, they are "limited," confirming how difficult it is to foresee and hence estimate a similar disaster risk. Indeed, many situations and variables have altered since then. The purpose of this paper is to show how the methodology used to create the model could be a good starting point for facing up to economic damage caused by the emergence of any catastrophic risks, such as Covid-19, but also pandemics, wars, and other events that, in the future, could cause the "lockdown" event and all the previously mentioned disastrous economic situations. Indeed, it is well known that if this model would had been implemented for preventing the Covid-19 pandemic, it may have resulted in less economic hardship, particularly for the public, by stipulating an NDBI policy with insurance; in fact, the state's public expenses in support of SMEs forced to close would have been lower. Although it is difficult to estimate the likelihood of an event leading to a lockdown, such as in the case of a pandemic, we are aware that there are thousands of viruses in the world that can potentially cause situations similar to Covid-19, so much so that all European Union countries are required to prepare pandemic plans that must be monitored and updated on a regular basis based on the presence of viruses. The model calculates the likelihood of a pandemic-related lockdown after it has occurred. This assessment, specifically of Covid-19, is based on scientific evidence, namely that when a virus spreads, it follows cyclical patterns, specifically in waves, as was the case with the Spanish pandemic, which lasted two years with waves of expansion and relegation. In fact, despite the vaccine, Covid-19 has recorded four waves to date, and many scholars and virologists fear a fifth. When the chance of the virus reappearance is practically definite, the lockdown variable is analyzed, and with it, the actuarial values useful for evaluating the policy are attained.

From the insurer's point of view, it is clearly undeniable that the management of a portfolio of NDBI policies requires great attention, and the adoption of a very rigorous and complex risk management process. Suffice it to think, in fact, that - unlike other catastrophic events (such as hurricanes, earthquakes, floods), usually limited to well defined areas - pandemics and particularly Covid-19, can cause a dangerous “accumulation factor” of risk for any insurance company, given its enormous and sudden capacity for spreading and the equally huge potential economic losses associated to it.

Observing the available data, during the worst months of the pandemic, it has been confirmed that the business interruption mainly concerned micro-enterprises, representing as much as 48.7%, compared to 32.7% of small enterprises, 19.2% of medium-sized enterprises and 14.5% of large enterprises, with a share equal to 69.4% of the overall entrepreneurial fabric (which also includes smaller companies, which activity was initially "suspended", then reopened (ISTAT, 2020).

We used two fundamental variables $(\mu;\sigma)$ to test the model because we didn't have a comprehensive data set of all the data in the financial statements of the SMEs in Italy. Where μ is a general value of the predicted monthly income of SMEs and σ is the root of their variance.

The first variable considered is the average monthly income expected net of fixed costs of SMEs (not considering variable costs as a forced closure due to the lockdown implies variable costs equal to 0 in the closing period), which according to Cerved data accessed in September 2020 is equal to € 21,239.754, which will be the average of the variable Y (compensation relating to the single damage) in the model.

The second variable considered is the average monthly income expected net of fixed costs of SMEs (not considering variable costs). The latter was calculated first by taking the square root of the variance and reporting its monthly amount, yielding a value of € 16,401,730,000; the mean square deviation was then calculated by taking the square root of the variance and reporting its monthly amount, yielding a final value of € 36,970.4, which in the model turns out to be the stain (compensation relative to the single damage).

The calculation of the variables $(\mu;\sigma)$ would be more accurate if the model has been validated on an actual data set, such as assuming that the data in the financial statements of all SMEs, or those who want to insure, are available.

In the study case we are going to propose, the pricing process of an NDBI insurance product is examined, for which it is appropriate to resort to a non-proportional reinsurance treaty of the "Catastrophe Excess Of Loss" type.

In this regard, the above-mentioned Loss of Profits model is applied following not a typically "tailor made" approach, which consists of shaping the insurance policy on the basis of separate accounting data for each individual company, but rather a "standard" approach, taking the average data on the balance sheets of all SMEs that are currently covered by a BI policy in our country (3%).

A detailed description of all the variables implemented in the model is provided in Table 1.

Table 1. Variable description

Nrisc	N. of risks
Nsim	N. of simulations
Lambda	Poisson parameter for the lockdown probability
S	Total refund
PE	Fair Premium
PP	Pure Premium
C	Gross Premium
ε	Probability of failure
SCR_mi	Solvency Capital Requirement with internal model
SCR_fs	Solvency Capital Requirement with standard formula
Q	Quantile S>0 with 95%
Sr	Compensation payable by the reinsurer
PEr	Fair Premium of the reinsurance
PPr	Pure Premium of the reinsurance
Cr	Gross Premium of the reinsurance
Spr	Refund post reinsurance
PPpr	Pure Premium post reinsurance
Cpr	Gross Premium post reinsurance
U	Expected compensation (PP-PE)
Upr	Expected compensation post reinsurance

Specifically, the analysis that we are going to propose below has been carried out through the following steps:

- consideration of the empirical distribution of the aggregate damage, after having described and analyzed the statistical bases for defining the technical bases, through the application of a Monte Carlo standard frequency-severity simulation;
- calculation of the gross premium, once the average of the empirical distribution of the aggregate damage (fair premium) has been identified and an adequate safety loading has been added;
- calculation of the Solvency Capital Requirement (SCR) relating to the Premium sub-module of the Non-Life Underwriting Risk, adopting an Internal Model and using a Value at Risk of 99.5%;
- calculation of the reinsurance premium, using a reinsurance model for "catastrophe excess of loss", once the full catastrophe, the extent and the global compensation retained by the insurer and transferred to the reinsurer have been established.

In order to be completed, the analysis has required the use of further hypotheses, namely that:

- the NDBI policy for "lockdown" is mandatory, given the current emergency in Italy. This is to provide universal validity to the model. In fact, the most common type of NDBI coverage is a "tailored" policy, which means that each company insures its own financial loss due to business interruption. The hypothesis of mandatory nature recalls the benefit generated both on the part of the insured and on the part of the insurer by the fact that all SMEs present in Italy are insured with an NDBI policy, regardless of their desire to insure for monetary losses due to business interruption;
- the duration of such policy is annual and its coverage produces effects only in the case of the first "lockdown" event. This second hypothesis is assumed because non-life policies typically have a contractual duration of one year, and because the model algorithm estimates the probability of occurrence of one lockdown, a different calculation should be made to estimate the probability of occurrence of multiple lockdowns;
- the policy guarantees a maximum coverage of one month during the same year. This is to give generality to the model, because on average, when there was a lockdown, a company closed for about a month, and the assessments were made using the average net monthly loss of turnover; however, this does not imply that the company can close for more or less than a month, and that once the lockdown has occurred, it can renew the insurance contract;
- 3% of Italian SMEs sign the NDBI policy contract with the examined company. Indeed, at the time of this assessment only 3% of the Italian SMEs had already stipulated a type of NDBI policy; again, for generality, it was assumed that only one insurance company provided that type of policy, and that all those SMEs insured themselves into it;
- no other company, apart from those already insured, signs any NDBI insurance contract for "lockdown" with the examined insurance company during the said year. This is because when the insurance is new, and no customer enters or leaves the contract during the year in order to make the Premium and Reserve calculations simpler and more general.

We explicitly stress that the methodological approach proposed in this paper relies on the strong hypothesis that the distribution of the global compensation S is not inferred by empirical evidence, we simulated it as described in Section 4.1. So our model will be definitely validated if enough real data would be available.

4.1 Hypothesis and Monte Carlo simulation

In order to model the distribution of the global compensation S[3] that the insurance will have to pay to the policyholders in one year, 100,000 Monte Carlo simulations were performed using a frequency-severity model.

To this end, the following hypotheses have been formulated:

- the variable N, number of "lockdowns" in a year, follows a Poisson distribution with the λ parameter equal to 0.6 (therefore the probability that a lockdown will occur in a year will be equal to $P = 1 - e^{-\lambda} = 0{,}4511884$);
- for j ranging from 1 to 4,456 (i.e. the number of insured risks), let I_j be the probability that the j-th SME closes during the year due to the "lockdown". It has been assumed that the I_j conditioned to $N > 0$ are i.i.d. (independent and identically distributed) and follow a Bernoulli distribution with parameter 0.7[4];
- the sum of I_j is the total number of SMEs to be compensated. For the insurer it will therefore be necessary to simulate a number of variables equal to the above-mentioned sum in order to obtain the value to be compensated in euros;
- let Y_j be the variable representing the compensation relating to the $j - th$ SME, which is supposed to be equal to 0 if N is equal to 0. In fact, if the "lockdown" does not occur, the damage to be compensated is 0 and is distributed according to a Lognormal distribution when $N > 0$[5];
- to further highlight the independence between the value of the global compensation and the total number of claims reported, it was decided to multiply the expected value of Y_j by a factor ranging from 1 to 1,3 depending on the value of the sum of the I_j, which we call M, which is distributed according to a binomial (sum of independent Bernoulli).

In the execution of the model algorithm, a number of simulations equal to 100,000 are initially performed. In each simulation:

a. the number of lockdowns occurred in that situation is simulated. If $N = 0$, than $S_i = 0$;
b. if, on the other hand, $N > 0$ - therefore with the above-mentioned hypotheses, the premium only covers the first lockdown – we should proceed as follows:
    1. 4,456 bernoulli I_j are simulated and added together to obtain the number M_j of the complaints relating to the $i - th$ simulation;
    2. the factor ranging from 1 to 1.3 is calculated, and it is to be multiplied by the mean of Y_j, then a M_j number of lognormal values are simulated[6];
    3. the value of Si will be equal to the sum of the Mi lognormal values, which correspond to the compensation relating to the single SME that has decided to close.

The distribution generated by the simulation is shown in Figure 1, where a mass of probability concentrated in zero can be observed, when the insured event does not occur.

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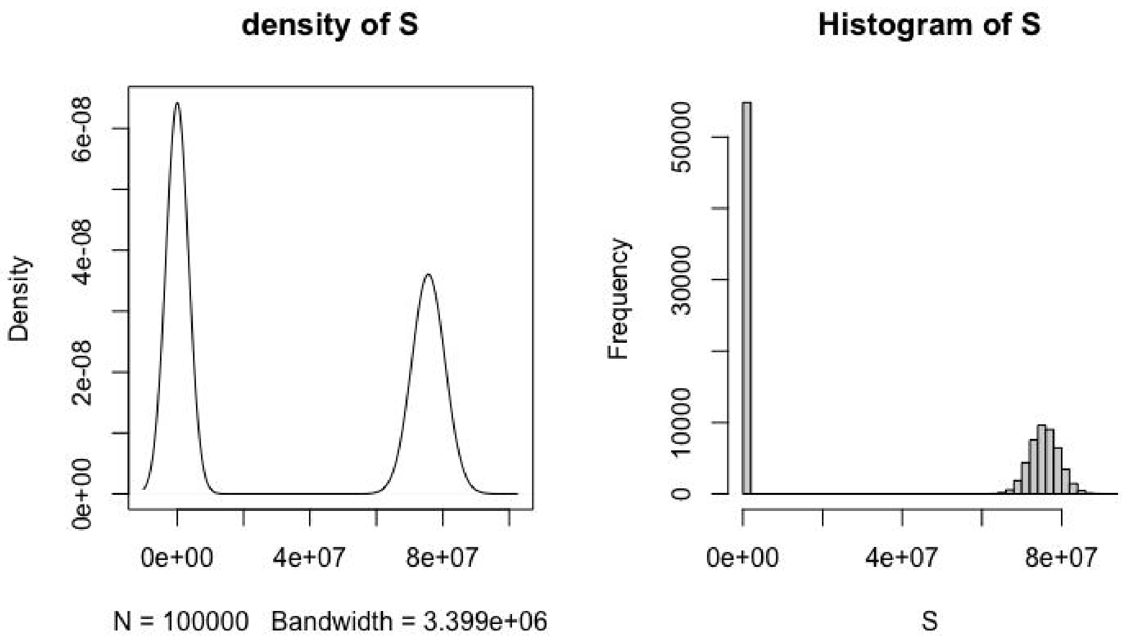
[3] From this distribution, significant values such as the expected value, variance and quantiles are calculated and useful actuarial values (VaR, SCR, fair premium) are found.

[4] Therefore, where the "lockdown" event has occurred, each of the SMEs can independently choose whether to close or not with a sufficiently high probability.

[5] In this case, the parameters of the lognormal are such that they replicate the mean (21,239.754) and the variance (13,668,108,333) of the average monthly profit of an SME.

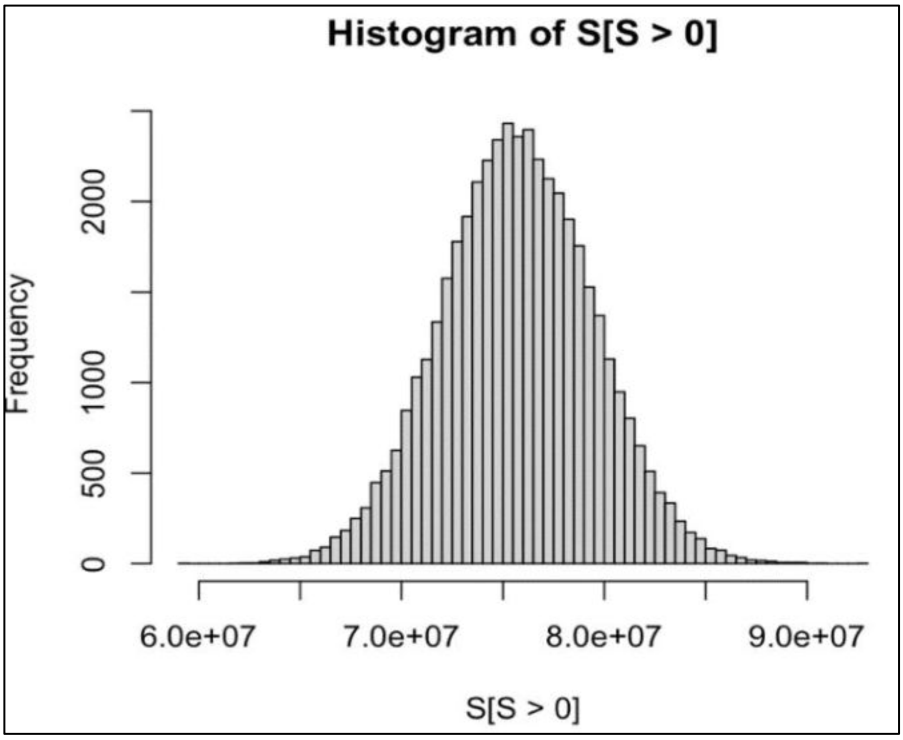
[6] The total number of claims for each simulation was chosen to emphasize the relationship between the expected number of claims (reports) and the random variable Y (random amount of compensation to be connected with each claim). As a result, a multiplicative factor Mis computed, ranging from 1 to 1.3, and it is multiplied by the theoretical average. It is calculated from the total number of complaints, that ranges from 0 to 3,257. We normalize the latter amonue between 0 and 1, and then recalibrate it, leading to a range from 1 to 1.3, where 1.3 corresponds to the value at the point where the most claims were filed, and 1 corresponds to the smallest number of claims. As a result, M will vary between 1 and 1.3 depending on the total number of complaints to be multiplied by the average of Y.

Figure 1. Empirical distribution of the aggregate damage S.



Conversely, a probability distribution shifted to the right (Figure 2) represents the value of the global compensation in the case that the lockdown event occurs, and it is the sum of the *lognormal*. The model has been calibrated to use the most appropriate probability distributions for defining the technical bases that are used as a reference for calculating the model's contract rate. The random variables for determining the technical grounds in a non-life actuarial valuation are not straightforward. While the technical bases to be considered in a technical assessment of a life insurance product are undoubtedly a financial technical basis (structure by maturity of interest rates or technical rate I recognized to the policyholder) and a demographic, in the case of a technical assessment of a CAT non-life insurance product, the random variables to be considered are a financial technical basis (structure by maturity of interest rates or technical rate I (damage). To reduce the model's complexity, it was decided to calibrate the random variable Y (random amount of compensation to be associated with each claim; damage function) in this way: after generating the individual compensation values, as many as the total number of complaints depending on the number of total complaints, we find the parameters of a lognormal which replicate the average and variance of the average monthly net incomes of SMEs from ensure, therefore, Y is generated with a lognormal.

Figure 2. Empirical distribution of the aggregate damage S> 0



Since the insurance is actuarially fair, the “fair” premium (P) is the expected value of the damage distribution. Therefore, the estimate made for the premium will be the sample mean of the simulated S values. The Fair Premium can be expressed as:

Fair Premium or Premium (P) = $\sum_{i=1}^{Nsim} Si/Nsim = E(S)$

It is therefore appropriate to use a "functional" that associates a real number (pure premium) to the probability distribution of S.

Given the specific form of the S distribution, caused by the high variability of the insured event, the principle used for calculating the pure premium deemed appropriate in this case was that of the "standard deviation", according to which the safety loading is proportional to the standard deviation of S. The Pure Premium can be written as follows:

Pure Premium ($\prod$) = P + $\gamma\sigma(S)$; con $\gamma > 0$.

Finally, after having found the pure premium $\prod$, an additional safety loading is performed, using the principle of "constant loading", for the calculation of the gross premium (C). The Gross Premium can be expressed as:

Gross Premium (C) = $\prod$ + b; with b > 0.

Specifically, we assume that the above constant loading is independent from the riskiness of the contract and that it takes into account:

1. the contract acquisition costs (such as, for example, the purchase commission which constitutes the agent's remuneration);
2. the premium collection costs (such as the collection commission paid to the agent as compensation for managing the collection of premiums);
3. the general management expenses, which include several items of general expenses incurred by the insurance company for the administration of the contract.

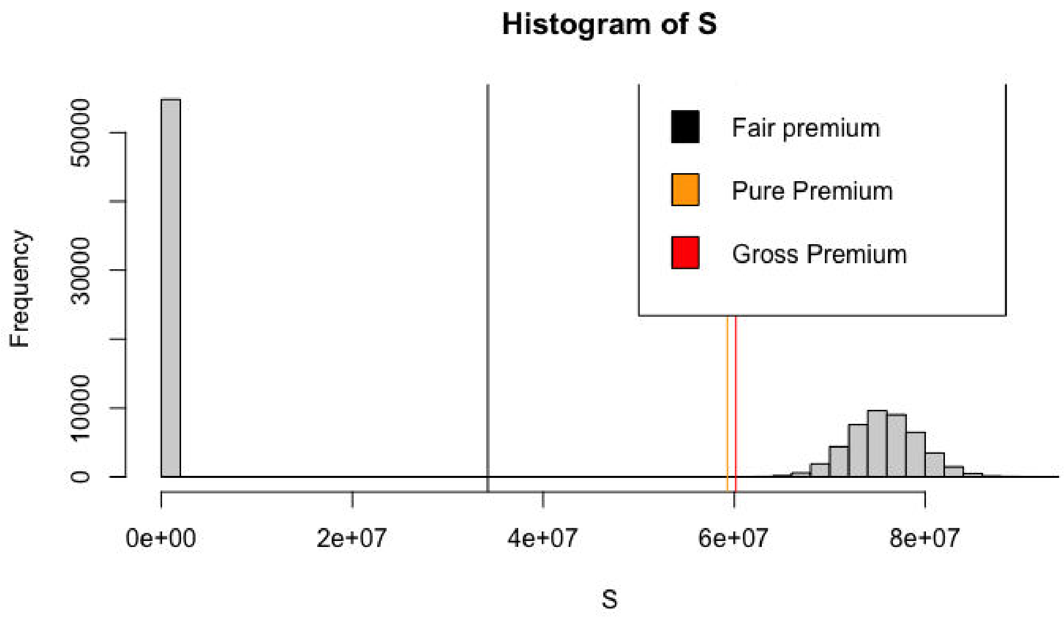
The expected value of the E(S) distribution, as shown in Figure 3, is equal to € 34,203,481; since E(S)=P, given the high variability, we choose $\gamma = 0.664$, the Pure Premium Π will be equal to € 59,277,367.

The gross premium, using the constant loading principle, equal to € 200 per contract, will therefore be equal to:

C = Π + 200*Nrisc = € 60,168,567.33 €

As observable, such value is much higher than the expected value of the distribution of the aggregate damage E(S) due to the high variability present in this portfolio of policies (suffice it to think of the distribution range - minimum value and maximum value - observable in the previous figures).

Figure 3. Premium, Pure Premium and Gross Premium



The insurance company will therefore be obliged to indemnify each company that wishes to subscribe to an "NDBI" policy against the payment of a fairly reasonable annual premium equal to € 13,502.82.

As concern the hypotheses, some clarifications are needed. In detail, the λ value 0.6 of the lockdown probability is the result of a series of data retrieved from Cerved at the end of September 2020. The applied technique projected that the lockdown would occur due to an increase in the percentage of intensive care unit admissions (due to the saturation of the health department). As a result, the underlying hypothesis considers an indicator α) that measures the percentage of ICU beds filled by Covid-19 patients and assumes a nationwide threshold of 30%. By ministerial decree, the first lockdown happens when the α indicator (% of hospital admissions in intensive care) exceeds the limit threshold. It's worth noting that during the model review period, Covid Zones (white, yellow, or red) at the regional level had not yet been established, and the vaccine was still in the testing stage. With the given data, it has been hypothesized that the curve of hospital admissions in critical care surpasses this threshold at least once a year with a probability of roughly 45%, hence a Poisson distribution has been assigned to this $\lambda = 0.6$ that is thus associated to a probability P=0.4511885$. Everything else is dependent on this value, and while this initial hypothesis is thought to be quite strong, it has no bearing on the model, which can now be readily adjusted with more realistic data and variables. Actually, 100,000 simulations are run in the model using the Monte Carlo method, and then the number of lockdowns in a year is simulated using a Poisson distribution of λ parameter. Modifying this parameter, for example, setting it to 0.3 or equal to 0.2591818, the number of scenarios in which the lockdown does not occur will increase; in fact, the chance of the lockdown occurring has dropped. In particular, the predicted worldwide compensation $E(S)$ as a whole will fall, from € 34,203,481 to € 19,673,659, lowering all major actuarial values that rely on the global compensation for mathematical construction, such as a fair premium, pure, and fare. We further explore the above issue to test the reliability of our hypotheses, and report in Table 2 a sensitivity analysis looking at the results obtained when comparing different λ values as input:

Table 2. Sensitivity analysis

Parameter	Alternative HP1	**Our HP**	Alternative HP2
λ	0.5	**0.6**	0.7
$P = 1 - e^{-\lambda}$	0.39346934	**0.45118836**	€0.5034147
Fair Premium or Premium (P) = E(S)	€29,841,919	**€34,203,481**	€38,097,018
Pure Premium ($\prod$)	€54,458,505	**€59,277,367**	€63,292,426
Gross Premium (C)	€55,349,705	**€60,168,567**	€64,183,626
Annual Premium per company	€12,421	**€13,503**	€14,404

4.2 Risk of subscribing the SCR Non-Life premium

At this point, let us focus on calculating the SCR. As known, Solvency II provides that maintaining an appropriate level of solvency represents one of the fundamental objectives for the sound management of an insurance company, all the more so where the total amount of costs that will affect the contract portfolio is - precisely - uncertain and unknown at the moment of the stipulation phase. The concept of solvency must therefore be understood in a probabilistic sense and in the context of realistic hypotheses on possible scenarios, particularly on the random elements that constitute them. Therefore, it is possible to consider the concept of solvency as the ability to meet, with an established probability, the random commitments that are realistically described by a probabilistic structure (Pitacco, 2008).

The Solvency Capital Requirement is calibrated in order to ensure that all quantifiable risks to which an insurance or reinsurance undertaking is exposed are taken into account: in this sense, the term covers both existing and "new" risks that should be acquired in the following 12 months and it is calculated as an aggregate value for all business lines, according to a modular logic.

To the best of our knowledge, this is the first attempt in the literature to model the Covid pandemic as a catastrophe risk. As a result, we hypothesized the use of the standard formula due to the following reasoning.

The Solvency 2 framework specifies a number of techniques for computing the SCR, each of which increases in complexity:

- Standard formula;
- Standard formula with company-specific parameters;
- Internal model (partial) and Standard formula (only some risk modules are evaluated with an alternative approach to the Standard Formula);
- "Full" internal model (all risks are assessed by the company with its own methodology)

In the proposed scenario, the Standard formula for calculating the SCR is a series of "factor-based" formulas that companies must apply to their liabilities for various risks; in reality, a correlation matrix is used to combine the numerous risks represented in the sub-modules, which we remember to be in the SCR basic (Market, Health, Default, Life, Non-Life and Intang). The SCR for the Premium & Reserve sub-module of the Non-Life Underwriting Risk is computed in the unique situation of the examined policy; thus, independent of the distribution of the catastrophic risk, the SF is calculated as 3 * σ * V. The non-life branch's XVI policy includes the NDBI policy (pecuniary losses of various kinds, in particular loss of profits). In the XVI non-life class (pecuniary losses), the value of is equal to 0.17 NpLob (100%), where V is the portfolio's premium volume.

Regarding the existing business, the capital requirement only covers unexpected losses and corresponds to the VaR of the basic capital funds of an insurance or reinsurance undertaking subject to a confidence level of 99.5% over a period of one year.

Let FST (x) = P (ST <= x) be the distribution function of the surplus in T> 0, which for simplicity we assume continuous and strictly increasing. Having set a probability ε (which should be considered as "small", that is, less than 0,5), the ε-quantile S, changed in its sign, is defined as the Value At Risk (VaR) of the position; we have:

VaRε(ST) = -xε = -FST-1(ε). ST.

In our case, having found the VaR at 99.5% of the distribution (equal to € 85,179,047), in order to calculate the SCR using the internal model, it will be necessary to subtract the volume of premiums in the portfolio from the annual 99.5% Value at Risk.

As shown in Figure 4, the value of the SCR_IM (SCR Internal Model) that the insurance company must guarantee for the solvency of the risk in the portfolio will be equal to € 25,010,479.67.

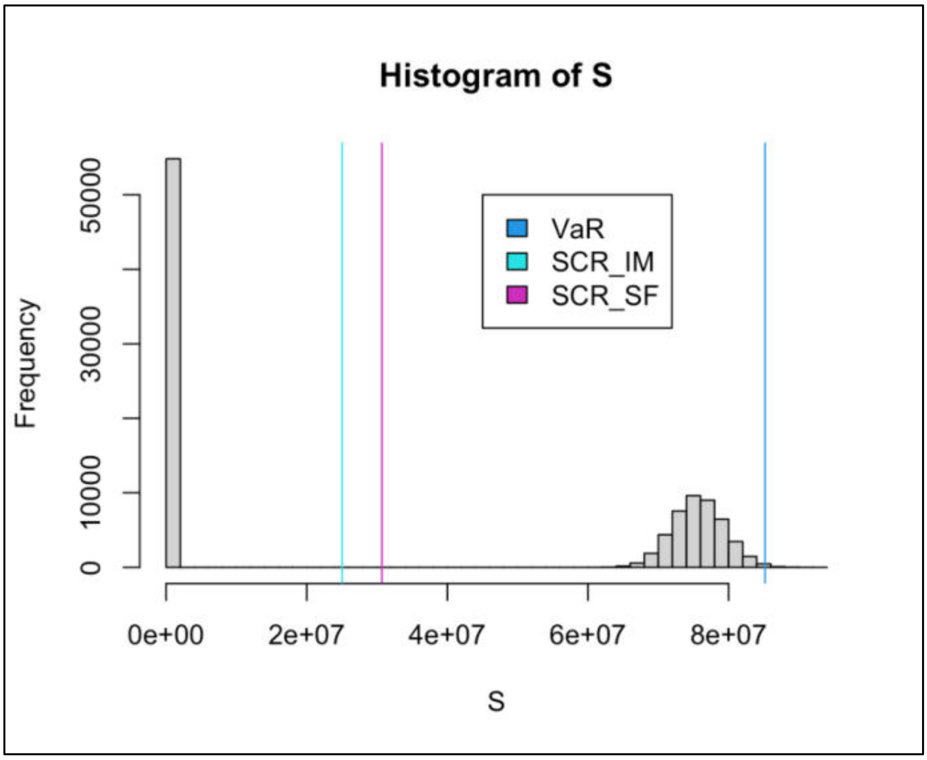
On the contrary, in the case of calculation of the premium SCR using a standard formula, the Solvency II directive provides that the SCR be equal to 3 * σ * V, where:

- for the XVI non-life class (monetary losses), "σ" is equal to 0.17 * NpLob (100%);
- V (in our case "C") is the volume of premiums in the portfolio

The SCR_SF according to the standard formula is therefore equal to 3 * 0.17 * 60,168,567.33 € = € 30,685,969.34.

Since the SCR required by applying the standard formula is greater than that obtained by adopting an internal model, the insurance company in question would clearly find it more convenient to apply this latter method for calculating the SCR.

Figure 4. Solvency capital requirement and VaR



Furthermore, in order to provide useful information on the riskiness of the portfolio, a fundamental objective for the insurer is to keep at a relatively low level (equal to a threshold deemed as acceptable, ε) the probability of the event "random burden for compensation exceeds the sum of the global increase of pure premiums (P + r) and of the solvency margin (W) initially available to the insurer in relation to the portfolio".

This can be expressed as:

$\varepsilon = Pr\{G < -W\} = Pr\{X > W + P + r\}$

Therefore, the probability of the event {X> W + P + r} is aptly called the "annual probability of failure" of the insurer in relation to the portfolio and in our model ε = 0.005.

4.3 "Catastrophe Excess of Loss" Reinsurance

In order to reduce the annual probability of failure (ε), it is assumed that the insurance company decides to enter into a non-proportional reinsurance treaty of the "Catastrophe Excess of Loss" type.

This type of reinsurance refers to claims arising from a single catastrophic event, which affect multiple contracts in the portfolio.

With reference to a civil liability insurance portfolio, consisting of n contracts underwritten at the same time and with an annual duration, let S be the global compensation relating to claims; having set the LC priority (called full catastrophe), we will have that:

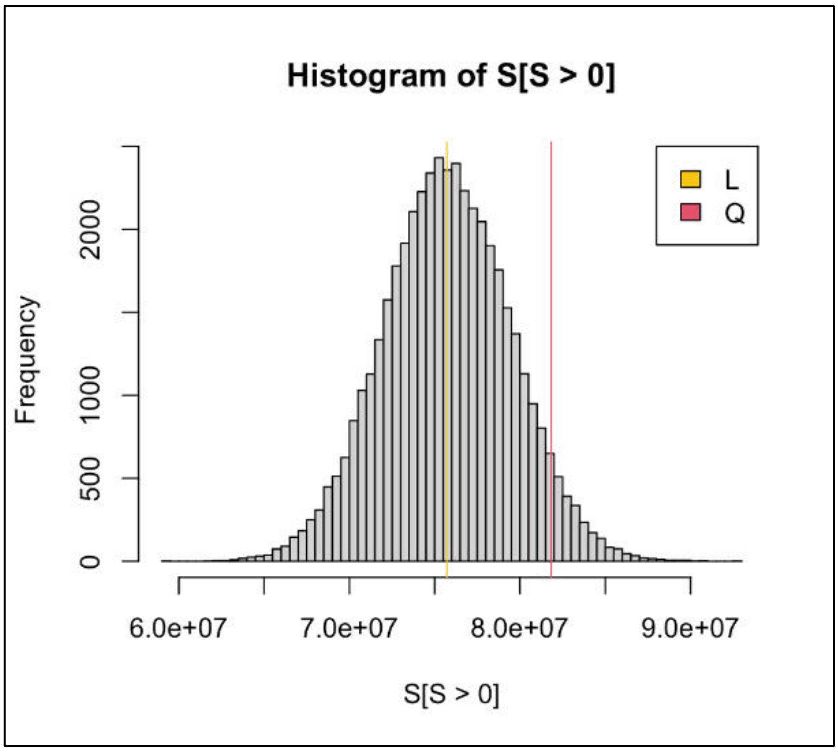
- the amount to be paid by the insurer will be equal to SA = min (S; LC);
- the amount transferred to the reinsurer, in the event that there is no upper limitation (scope), is equal to SR = max (S-LC; 0);
- in the event that there is a partial scope (which is realistic), the amount transferred to the reinsurer will be equal to SR = min [max (S-LC; 0); QC].

Let K be the random number of catastrophes affecting the portfolio during the year and let Sh (h = 1,2, ..., K) be the global compensation corresponding to the h-th catastrophe in chronological order, once the full catastrophe, Lc, is established, then the global compensation retained by the insurer will be equal to $XA = \sum_{h=0}^{K} \min (Sh; Lc)$, while the global compensation assigned to the reinsurer will be equal to $XR = \sum_{h=0}^{K} \max (Sh - Lc; 0)$.

In our specific case, in order to proceed with the definition of the priority[7], reference is made to the graph of the aggregate damage S given S> 0 (Figure 5): in this sense, we define the priority L as the average of this distribution, which turns out to be equal to € 75,714,971.

The priority in the reinsurance practice is generally partial; hence, it is customary to introduce a "scope" Q, i.e. the maximum amount within which the reinsurer undertakes to compensate the aggregate damage; in other words, the scope represents the upper limit of acceptance for the reinsurer which, in our case, is represented by the quantile of the distribution of S at 95%, for an amount of € 81,833,004.

Figure 5. Distribution of S [S> 0], Priority (L) and Scope (Q)



The value of the damage to be borne by the reinsurer is therefore equal to SR = min [max (S-L, 0), Q], while the "fair" premium (Pr) that the reinsurer will request in order to assume the risk will be equal to the expected value of SR [E (SR)], that is: Pr = E (SR) = € 661,525.40.

Similarly to the method adopted previously, a safety charge is made for the pure premium by applying the principle of the standard deviation, which in this case is greater than that carried out by the insurance company. The pure reinsurance premium (Πr), with $\gamma = 0.665$, will therefore be equal to: Πr = Pr + γ *s.d. (min (max(S-L,0), Q)) = € 1,746,382.

Likewise, we introduce a safety loading for expenses using the principle of "constant loading", which considers the loading as independent from the riskiness of the contract and is suitable for management expenses, including several items of overheads incurred by the reinsurer for the handling of the contract.

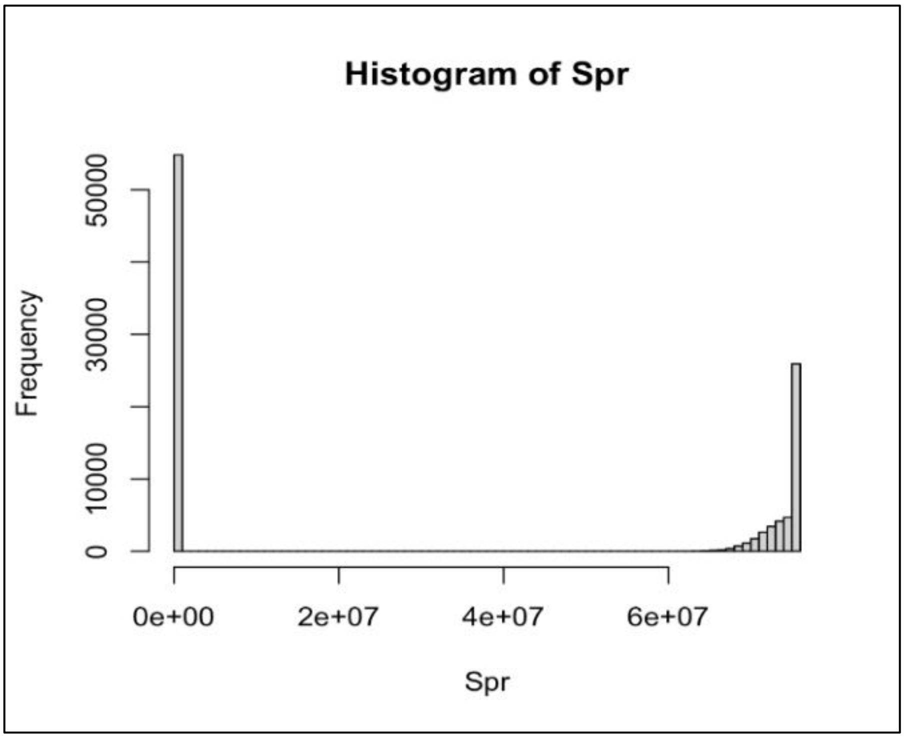
The reinsurance gross premium (Cr) is therefore equal to:

Cr = Πr + 200 * Nrisc = € 2,637,582

Post-reinsurance, the compensation payable by the insurance will be: Spr = S - Sr; the new damage distribution S (Figure 6) will be like the previous one, but visibly truncated due to the effect of the Risk Catastrophe Excess of Loss reinsurance.

[7] Such priority represents the monetary amount such that if the aggregate damage exceeds this value, the compensation is paid by the reinsurer.

Figure 6. Distribution of S post Reinsurance



Regarding the volume of premiums that remain with the insurance company (Πpr), it will be as follows:

Πpr =Π - Πr = 57,530,985.33 € = Cpr = C - Cr

It is thus clear that the pure premium and the post-reinsurance tariff are the same, as both parties made the same loading for costs and the same technical bases were used for assessing the damage.

As regards the SCR to be set aside following reinsurance, considering the internal model[8], we obtain SCRpr_IM equal to € 19,075,186; the SCRpr_SF, obtained with the standard formula 3 * 0.17 * Cpr, on the other hand, is equal to € 29,340,802.52.

From the above, once again the convenience for the insurance company to adopt the internal model is confirmed.

As expected, the amount of premiums collected has decreased, although it is noteworthy that the capital to be set aside for solvency requirements has recorded a greater decrease compared to that relating to the amount of premiums collected.

In fact, analyzing the two percentage changes, we observe that post reinsurance, after a change in the expected profit (Πpr - Π)/ Π*100 of (-2.94612%), the SCRpr_IM has decreased by (-23.73123%).

Moreover, we can notice that the profitability index (Upr / SCRpr_IM) has increased from 1.002535 (pre-reinsurance) to 1.222924 (post-reinsurance)

The proof of the reinsurance benefit can also be appreciated by observing the decrease in the annual probability of failure (ε), post-reinsurance (εr): actually, in the 100.000 simulations carried out post reinsurance, the losses were never higher than the SCRpr_IM. This can be described as follows:

εr = sum (Πpr - Spr < (-SCRpr)) / Nsim = 0.

Finally, the simulation of the frequency-severity model algorithm was repeated, with 40.000 risks in the portfolio[9].

Lastly, observing the values of the new simulation, the technical bases (in yellow), the insurance actuarial values (in green), the post-reinsurance actuarial values (in orange) as shown in Figure 7, it is evident that they are sensitive to the size of the portfolio.

In particular, it is interesting to notice that as the size of the portfolio increases, the convenience to adopt the internal model for calculating the SCR also increases. In fact, despite the increase in the value of the SCR of the internal model, the result of the SCR_MI / NRA relating to each individual risk decreases, going from € 5,612.76 (in the analysis seen above with 4,456 risks) to € 5,248.40.

On the contrary, the SCR calculated with the standard formula proportionally increases with the increase in premiums[10]: therefore, going from 4,456 risks in the portfolio to 40,000, the value of the SCR_FS / NRA relating to each individual claim also increases (it has increased by approximately € 80 per risk).

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8 In this case, we consider the VaR of the post-Reinsurance distribution, plus the expected value of the costs.

9 40,000 SMEs are supposed to be insured, supposing that the insurance company in question has about 27% of Italy's SMEs in its portfolio.

10 This is a direct consequence of the standard formula $3 * \sigma * V$.

Figure 7. Technical basis and significant actuarial values on 40.000 risks

NRA	40000,00	P = E(S)	311.489.885,00 €	L	682.044.854,00 €	U/SCR	1,076233
E(N)	0,60	Sd(S)	340271361,00	Q	726.233.580,00 €	U_pr/SCR	1,28357
E(M|N>0)	0,7	π	537.430.068,70 €	Pr	5.018.453,00 €		
VAR(M|N>0)	0,21	C	545.430.068,70 €	πr	13.158.447,00 €		
E(Y1)	21239,75	VaR(99,5%)	755.366.089,00 €	πpr	524.271.621,70 €		
VAR(Y1)	1366810833,00	SCR_IM	209.936.020,30 €	SCRpr_IM	165.773.232,00 €		
Ds(Y1)		SCR_SF	278169335,04	SCRpr_SF	267.378.527,07 €		
Mix	9,2668	C/NRA	13.635,75 €	E(U)pr	212.781.736,70 €		
SigmaX	1,18056	SCR_IM/NRA	5.248,40 €				
		SCR_SF/NRA	6.954,23 €	Eps_pr	0		
		E(U)	225.940.183,70 €				
		Eps	0,0032				

5. Conclusion

Covid-19 has profoundly changed the world we live in, with disruptive effects at various levels, including particularly the health, social, economic and financial perspectives. The insurance sector has not been spared: insurance companies are therefore urged to adopt new and more effective tools for managing catastrophe risk, in order to ensure greater resilience while operating in a market that proves to be increasingly uncertain.

The analysis we conducted highlights the importance of the role played by NDBI policies both for the entrepreneurs, allowing them to cover the loss of profit following a business interruption, and for the insurance companies, which can achieve profits also thanks to the possibility to reinsure part of their business (with "Catastrophe Excess Of Loss" contracts).

In the near future, it seems increasingly appropriate to identify innovative pandemic risk transfer solutions contemplating lockdown scenarios and a closer cooperation between the public and the private systems. Pandemic risks, such as Covid-19, are difficult to insure, due to the fact that they are characterized by large accumulations of risks and multiple factor losses, simultaneously involving multiple types of activities in many regions. The scarcity of historical time series and statistical data prevents insurers from developing correct pricing. In fact, as pointed out in Section 4, the methodological approach proposed in this paper relies on the strong hypothesis that the distribution of the global compensation S is not inferred by empirical evidence. So our model will be definitely validated only if enough real data would be available. Nonetheless, the use of methodology proposed in this paper, may be replicated in other possible cases, bearing in mind that some hypotheses must be drawn down in order to be properly implemented. For instance, this method can be perfectly replicated using data of advanced economies (i.e. EU countries and US) to assess the potential impact of the pandemic event. Furthermore, it can be used to estimate the NDBI coverage advantages when extreme (and catastrophic) events other than the covid-19 are likely to occur, keeping the hypotheses of a mandatory policy for "lockdown" (even potentially addressed to specific industrial sectors) and that no other companies, apart from those already insured, signs any NDBI insurance contract for "lockdown" with the examined insurance company during the selected year. Lastly, the probability of lockdown occurrence may be adjusted in relation to the identified case of application.

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