Are we prepared to cover a future pandemic? Essay of a Portuguese health insurance portfolio

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Abstract

A pandemic is characterized by the development of a severe and unknown disease affecting many people, spreading over several regions. The COVID-19 pandemic brought new challenges for the entire health sector. In Portugal, health insurers used particular protective clauses since the risk is complex and high. Despite of legal protection, the pandemic situation led Multicare to study a coverage for that hand of risks in order to protect her clients in the future. Our manuscript studies and estimates the costs of medical treatments for potential future pandemics, using the COVID-19 one as reference. At the beginning of this pandemic, the insurer decided to cover hospital admissions for COVID-19, tests performed to track the disease, and Individual Protection Equipment (IPE), which began to be used frequently due to the pandemic disease. For estimating the cost of a pandemic, we considered the following variables: hospitalisations, tests and IPE using the data related to the COVID-19 pandemic. Our first challenge is to estimate the number of hospitalisations that the insurer may face. It is quite hard to predict the nature of a future pandemic, nevertheless we carry out stress tests to evaluate extreme situations. Interoccurrence time between pandemics has been decreasing, perhaps due to climate change, urbanisation, and globalisation. Great part of this manuscript is dedicated to inferring the risk of future pandemics. We also explain the challenges involved in managing low-frequency and high-cost coverage on an annual renewable insurance basis, without compromising the company's solvency.

Keywords: Health insurance; Pandemic; COVID-19; Simulation; Stress Tests.

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1. Introduction

This paper results from a work developed at the Actuarial Office from the Portuguese health insurer Multicare. We aim to infer the risk associated to the costs of medical treatment of a future pandemic.

According to the World Health Organization (WHO), a pandemic is a new disease that spreads exponentially around the world through human contact. Since the Black Death in 1347, there have been quite a few pandemics and epidemics reported. The Black Death was the deathliest after the Spanish Flu, in 1918, when 5% of the world's population died. In Portugal, 50 to 70 thousand casualties were estimated, as a result of the Spanish Flu.

The 2019 new coronavirus, SARS-CoV-2, is a human coronavirus that spread worldwide (see [1]). The first case of Coronavirus disease – in 2019 (briefly, COVID-19) in Portugal, was reported on the 2nd of March 2020. By the 30th of April 2021 Portugal reported nearly 834 thousand cases and 16,965 deaths. On this same day, 146,8 million people had been infected and 1,1million had died with COVID-19 in the world , see [2].

When the disease first appeared in Portugal, it was already known that some infected people might need moderate or severe hospital care. From that time up until today, almost every health insurer have a clause in their policies liberating them from covering costs related to pandemic diseases. Despite an increase in outbreaks, there is a small range of pandemic-related covers, worldwide, due to the complexity in pricing, since the risk is not well defined, as well as due to the possibility of extreme costs outbreak. The COVID-19 pandemic could help change that because it provided an important data source that may help insurers to handle better that kind of risk and develop in responding a vast range of covers.

During the COVID-19 crisis, Multicare, as the largest Portuguese health insurer, came forward and offered to cover her clients' costs. Therefore, the company co-paid for all the Polymerase Chain Reaction (briefly, PCR) tests carried out by her customers, Individual Protection Equipments (briefly, IPE) and also for the hospital customer admissions who have developed the most severe disease.

Despite not much was known about the disease in the beginning, nor its dimension, nowadays there is quite greater awareness of what danger pandemics and epidemics may represent, also about its (increasing) occurrence. Therefore, the aim of this manuscript is to infer about the risk associated with covering a future pandemic in the scope of health insurance.

The paper is organised as follows: Next section describes the data we used; Section 3 presents the analysis we did, the estimation of cases and hospitalisations in the company's portfolio considering bed capacity; Section 4 studies how costs vary with the duration of the pandemic; Section 5 estimates the time until the next pandemic; Section 6 explain the challenges involved in managing reserves; Section 7 sets some concluding remarks.

To infer the risk associated with future pandemics, we start by estimating the total cost of COVID-19 to the company in the first year of the pandemic. We assumed that the first year of the pandemic occurred from the 1st March 2020 to the 28th February 2021.

2. Data description

We collected the data from COVID-19 daily reports released by the Portuguese Health Authority (DGS, Direção Geral da Saúde). These reports include the daily number of accumulated cases, deaths, people recovered, active cases, inpatients and Intensive Care Unit (ICU) inpatients. The number of accumulated cases and deaths is also given by age group, sex, and region.

Age groups are defined in ten year intervals and split by sex: Male (M) and Female (F). We also consider seven Portuguese regions: *Lisbon, North, Centre, Alentejo, Algarve and the two Administrative Regions of Azores and Madeira*. At this point, we calculated the new monthly cases by age group, sex and by region.

From the PORDATA database (see [3]) we collected the distribution of the population and calculated the incidences per month by region, age group and sex.

In the first year of the pandemic, Portugal reported an incidence of 7.83%. The most affected regions were the urban centres, such as the *Lisbon* and the *North*, with 10.67% and 9.14%, respectively. As expected, the islands of Azores and Madeira were the least affected regions.

Incidence in female is slightly higher than male, respectively 8.12% and 7.51%. Incidence is higher for people aged intervals of 20 to 29 years and those older than 80. In this last group numbers high can be explained by the several outbreaks in nursing homes.

Regarding the hospitalisations, the COVID-19's daily reports provide no information besides the number of inpatients in each day. Therefore, we could only calculate the occupancy rate of hospitals. In addition, it was necessary to carry out some research in order to have enough information to estimate the risk if all customers went to private hospitals.

Some metrics from other sources are being used in this section. It is important to note that at the time of the study COVID-19 was a pandemic that had not ended yet, therefore, all information disclosed could be constantly updated. That is, the metrics used might not be those most up-to-date.

During our project, we received data, a sample of 2311 patients, from a Portuguese hospital in an urban area. For each patient, we have information about sex, age, length of stay at hospital excluding ICU and length of stay at ICU. We could estimate some probabilities of hospitalisations, these figures are shown in Table 1. As expected, we see that hospitalisations are seriously high in the higher age group when compared to the others, with more incidence in males.

	Age Group	**Hosp. W/ICU**	**Hops. W/o ICU**
Female	<40	0.25%	3.20%
	40-69	1.31%	6.22%
	>70	3.02%	34.11%
Male	<40	0.53%	1.38%
	40-69	3.59%	10.57%
	>70	4.78%	47.68%

Table 1 *– Probabilities of an infected individual needing hospital care using the data of a Portuguese hospital.*

3. Annual Cost of a pandemic

In this section we estimate the annual cost, assuming that all clients use their health insurance to cover COVID-19 hospitalisations, in the first year of the Pandemic. The data used here were those summarised in the previous section plus those provided by the company that contains the personal information about the policyholders and the amount paid for IPE, PCR Tests and hospitalisations in the period between March 2020 and February 2021.

3.1 Infections and hospitalisations

We needed to estimate infections and hospitalisations in the portfolio. First, we assumed that all the policyholders are susceptible to testing positive for COVID-19. Therefore, using the incidences calculated for Portugal and the probabilities of getting the most severe disease, we estimated the cases and hospitalisations per month.

In the first year of the Pandemic, we estimated an incidence of 8.88%. It makes sense that it is higher than the incidence for Portugal because most policyholders live in the urban areas.

We estimated that 6.49% of cases in the portfolio needed to be hospitalized. This figure is lower than the hospitalization rate in Portugal because the portfolio population is much younger than the Portuguese population, on average.

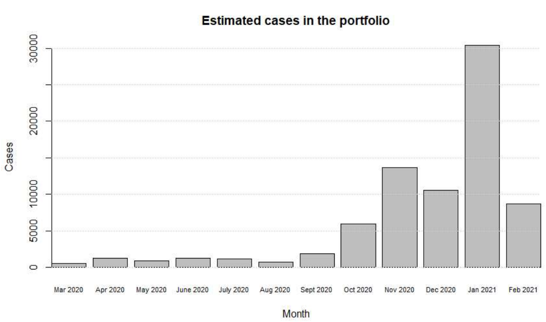

Figure 1 - Estimated cases in the portfolio per month

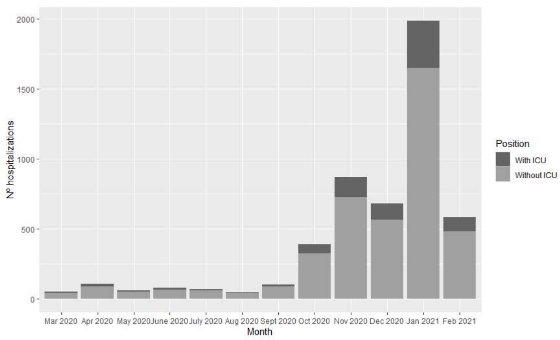

Figure 2 - Estimated hospitalisations in the portfolio per month

3.2 Bed Capacity

About bed capacity, up to this point, there was no limit set on the number of hospitalisations paid by the company. However, it is obvious that there is the possibly that the amount of beds allocated to Multicare in the private sector, or even in the entire private sector, may not respond to all patients in need of hospital admission. So, the costs of hospitalisations would be overestimated.

To know Multicare's responsiveness when her customers are admitted to the private sector, it was necessary to know the percentage of beds allocated to Multicare and the daily occupancy rate of these over time. If a patient arrives at the hospital with no beds available, we considered he goes to another hospital until he finds a bed, if there is no bed in any hospital then he goes to the public sector, without the company's share.

So, if the number of customers in need of hospitalization due to COVID-19 is similar to this reference scenario, it is very likely that Multicare would not respond to all patients. Therefore, the costs related to hospitalisations would be lower than those when admitting that the insurance company pays all the hospitalisations.

In this section we study the maximum amount that the insurer would pay for COVID-19 hospitalisations. According to some assumptions, we do a simulation, using the distributions of the “Length of Stay” (LoS) at the hospital and of the number of beds occupied at each moment. When the beds allocated to the insurer are all busy, we consider that the insurer does not bear the costs of the following patients to appear.

In 2019 the health private sector had 11,812 beds and 212 ICU beds, see [4]. We assumed that a maximum of 30% of those beds are allocated to pandemic related hospitalisations of Multicare clients.

3.3 Length of Stay distributions

To model the distribution of hospitalization, LoS, we used the sample of 2,311 patients from the Portuguese hospital referred above in the section. With the information, we created two groups of patients:

1. Those who stay at ICU (*U*);
2. Those who do not stay at ICU (*N*).

Of these groups, we created three samples for LoS:

- LoS at the hospital for patients who do not need ICU treatments (N_N);
- LoS at the hospital excluding ICU for patients who also need ICU treatments (N_{NU});
- LoS at ICU for these patients (U_{NU}).

Using the Wilcoxon-Mann-Whitney test, We tested the grouping of the LoS at hospital excluding ICU, N_N and N_{NU}, into one sample, i.e., setting:

$$H_o: N_N \text{ and } N_{NU} \text{ derive from the same population.}$$

It is a 2-sided test, from there a p-value of 0.0002783 resulted. Clearly, we should reject H_0, we mean, the two samples should not be grouped.

As said in [5] and [6] LoS distributions are positively skewed because only a few patients have long LoS, perhaps even with heavy tailed. Distributions often adjusted are from the Gamma, Log-Normal or Weibull family.

Using the "R Satistical package MASS", we adjusted the distributions to each LoS sample described above. For each sample, we tested a Weibull, Gamma, Log-Normal and, particularly, an Exponential distribution. Also, for the adjustment we used four tests: Chi-Square (CS), Kolmogorov-Smirnov (K-S), Anderson-Darling (AD) and Cramér-Von Mises (CVM) tests. The CS test was only used when the tests performed did not allow us to make a final decision about the LoS distributions.

To decide on the distribution best fit, we set the following criteria:

- It must not be rejected in two or more tests.
- Observe the histograms and curve fit.

Thus, we can state, with a significance level of 5%, that N_N follow a Log-Normal distribution with mean 2.156640 and variance of 1.035127^2.

Dist./Test	LoS for patients who don't need ICU			
	KS Test	AD Test	CVM Test	CS Test
Weibull	3,45E-08	0,523184	0,205147	9,94E-91
Log-Normal	0,001681	0,947863	0,913177	0,026832
Gamma	2,6E-09	0,349987	0,03499	2,89E-24
Exponential	1,1E-07	0,508873	0,538139	1,03E-21

Table 2 - P-Values of KS, AD, CVM and CS Tests - LoS for patients who don't need ICU.

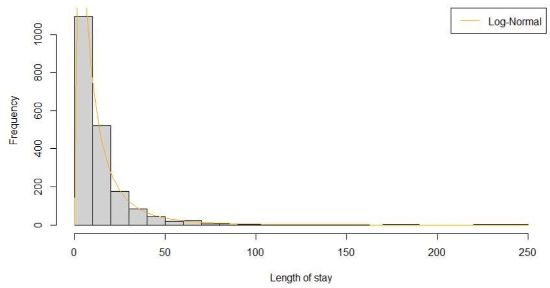

Figure 3 - Histogram of LoS for N_N

For the other two durations times (N_{NU} and U_{NU}), get the best adjustment would not be so easy. Figures 4 and 5 show the histograms and the distribution curves of two possible distributions for each sample of LoS. Although with a significance level of 5%, we can state that N_{NU} may follow a Weibull or a Gamma distribution. By observing the histograms and curves, we can conclude that the Weibull distribution fits better the data. Similarly, we can assume that U_{NU} also follows a Weibull distribution.

Dist./Test	LoS at hospital excluding ICU for patients who need ICU			
	KS Test	AD Test	CVM Test	CS Test
Weibull	0.093977	0.893323	0.890724	0.734738
Log-Normal	0.012735	335595	0.006342	
Gamma	0.165414	0.651666	0.152991	0.997979
Erlang	0.015355	0.007041	0.657118	
Exponential	0.000349	0.49628	0.910375	

Table 3 - P-Values of KS, AD, CVM and CS Tests - LoS at hospital excluding ICU for patients who need ICU.

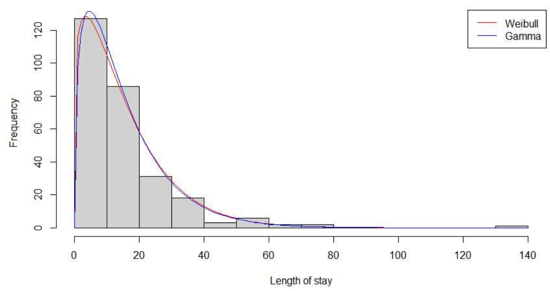

Figure 4 - Histogram of LoS for N_{NU}

Dist./Test	LoS at ICU for patients who were not only in the ICU			
	KS Test	AD Test	CVM Test	CS Test
Weibull	0.330425	0.616656	0.568664	0.012988
Log-Normal	0.074131	0.266312	0.144593	0.000741
Gamma	0.309	0.377838	0.802735	0.025228
Erlang	3.05E-06	0.000909	0.104788	
Exponential	0.208647	0.639239	0.252509	0.010324

Table 4 - P-Values of KS, AD, CVM and CS Tests - LoS at ICU for patients who were not only in the ICU

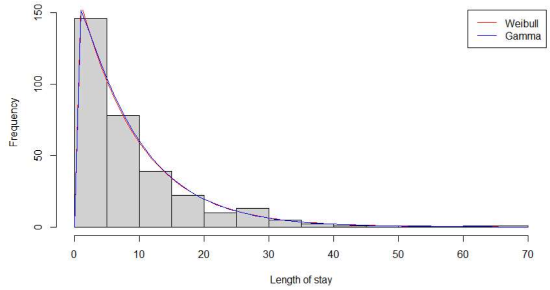

Figure 5 - Histogram of LoS for U_{NU}

3.4 Simulation

We built a simulation procedure to determine the cost of policyholders who tested positive to COVID-19, hospitalisations to which the insurer could respond considering the limit of the number of beds available for the purpose.

Using the number of hospitalisations estimated it is possible to know the admission day for each patient, how many of them were in ICU and the LoS, by the adjusted distribution. In order to know how many beds are available each day, it is necessary to simulate the LoS for each patient using the distributions adjusted above.

For each patient, 1000 pseudo uniform numbers, u_i, were generated, and depending on the type of hospitalisation, the following variables were obtained:

Patients who need ICU:

- 1000 pseudo Weibull, for LoS at ICU:

$$X_i = [-\ 7.908105 \cdot \ln ln\left(1 - u_i\right)]^{1/1.023288}$$

- 1000 pseudo Weibull, for LoS at hospital excluding ICU:

$$X_i = [-\ 16.29178 \cdot \ln ln\left(1 - u_i\right)]^{1/1.185651}$$

Patients who do not need ICU:

- 1000 pseudo Log-Normal, for LoS at hospital:

$$X_i = exp(1.035127 \cdot \Phi^{-1}(u_i) + 2.15664)$$

In the first phase, it is verified whether the patient needs ICU or not. In both cases, we see if there are available beds. If there is, the patient occupies +1 bed until the day of his discharge; otherwise, go home. In case of need for ICU treatment, the patient needs to be transferred to the sickbay. At this stage, we will see again if there are beds available. If there is not, the patient, go home. It should be noted that the patient goes home only at this stage and not at the beginning of the process.
From the observation of Figure 6 we see that only in January 2021 the insurer would not be able cover the hospital expenses of all her customers due to the number of beds allocated. In this scenario, patients without the need for ICU treatments, i.e., those in the sickbay, have always responded. However, in those who need to go through the ICU, the capacity is more limited.

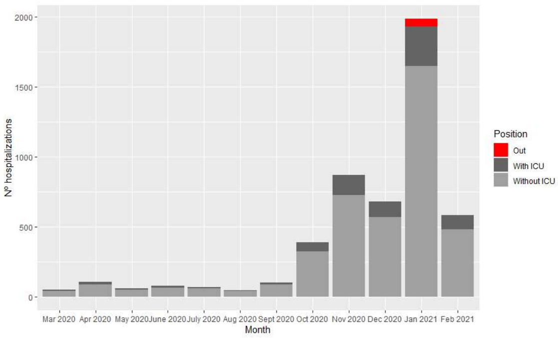

Figure 6 - Estimated hospitalisations in the portfolio per month considering the number of beds available.

After the simulation was completed, we did bootstrap percentile confidence intervals for the number and the costs of hospitalisations.

3.5 Total estimated Cost

The total annual cost was calculated considering the PCR tests performed, the IPE, and the estimated hospitalisations. Considering all these variables we arrived at a scenario of the cost associated with a one year of pandemic with the characteristics of the first variant of COVID-19, hereafter referred to as the Reference Scenario.

From now on the following notation was used: Number of estimated infections in the reference scenario (*I*); Nº of estimated hospitalisations in the reference scenario (*H*); Number of estimated hospitalisations w/o ICU in the reference scenario (Hw/o ICU); Number of estimated hospitalisations with ICU in the reference scenario (Hw ICU). Considering all these variables we arrived at a scenario of the cost associated with a one year of pandemic with the characteristics of the first variant of COVID-19, hereafter referred to as the Reference Scenario.

Therefore, we obtained Estimated total cost in the reference scenario (C) and Estimated aggregated risk premium in the reference scenario (P).

3.6 Stress Tests

It is impossible to predict the characteristics of a future pandemic, so in addition to the characteristics of COVID-19, we have also carried out stress tests to evaluate quite extreme situations.

At first, we though that it would be interesting to see the situation of other countries. We conducted a survey to see which countries had more cases than Portugal (relative to per million people). Second, some assumptions were changed, making two extreme scenarios with higher hospitalisation rates and elderly population. To conclude, rehearsals with the worst characteristics of other pandemics (Measles, MERS-CoV and SARS-CoV) were taken.

To calculate the total cost of the following scenarios we consider that the number of PCR tests is directly proportional to the estimated cases. A simulation procedure was also made for each of these scenarios in order to limit, from hospitalisations, those that the insurer pays.

Consider that C is the estimated total cost with pandemic in the reference scenario and T is the cost of all insurer claims without a pandemic, in a year. In Table 5 we can see the relationship between the total costs C and T for all the scenarios performed. In the reference scenario, we can observe that the treatment of the pathology would amount 14% of all claims while in the worst case scenario C equals $0.72\,T$. These figures can be seen in first line and last of first column. Last column shows corresponding Loss Ratios. The Loss Ratio could vary from 90% to 136% depending on the circumstances. Therefore it is not difficult for the Combined Ratio to reach 100%, and consequently, the insurer ceases to have profitability, even in the reference scenario.

	Infected	Hosp w/o ICU	Hosp w/ ICU	Total Cost(€)	C/T	$LR(\%)$
Reference Scenario	I	$H^{w/o\ ICU}$	$H^{w/ICU}$	C	0.14	90.26
W/incidences of Czech Rep.	1.47I	1.61 $H^{w/o\ ICU}$	1.58$H^{w/ICU}$	1.49C	0.21	95.74
W/incidences of Slovenia	1.18I	1.31$H^{w/o\ ICU}$	1.30$H^{w/ICU}$	1.26C	0.18	93.17
Higher Hospitalization rate	I	1.67$H^{w/o\ ICU}$	1.67$H^{w/ICU}$	1.36C	0.19	94.33
Elderly population in portfolio	0.96I	1.59$H^{w/o\ ICU}$	2.61$H^{w/ICU}$	1.45C	0.20	95.25
Characteristics of Measles	2I	7.32$H^{w/o\ ICU}$	5.55$H^{w/ICU}$	3.46C	0.49	117.71
Characteristics of SARS-CoV	I	3.69$H^{w/o\ ICU}$	2.5$H^{w/ICU}$	2.15C	0.30	103.13
Characteristics of MERS-CoV	I	11.30$H^{w/o\ ICU}$	5.83$H^{w/ICU}$	3.87C	0.55	122.33
Worst case	2I	22.60$H^{w/o\ ICU}$	11.65$H^{w/ICU}$	5.07C	0.72	136.05

Table 5 – Summary table of the case scenarios

4. Impact of pandemic duration

The WHO declared COVID-19 a pandemic between March 11th, 2020 and May 5th, 2023. However, over the 3 years of the pandemic, the different variants revealed very different behaviours and, consequently, very different results regarding the number of infected cases and hospitalisations. Considering some of the most representative variants in Portugal, the Delta variant, revealed to be more transmissible than the previous ones, but less so than Omicron, showed the greatest severity, see [11]. Delta was the predominant variant in Portugal from June 2021 to December 2021, being succeeded by Omicron. This scenario was repeated in most geographies. In order to illustrate this reality, we present two graphs representing: 1) One graphic representation of the most predominant variants in Portugal from the end of May 2021 (2021W22) until the end of October 2022 (2022W43), Figure 7; 2) Two graphics representing the behavior observed in England between May 2020 and February 2022 for the different variants, Figure 8 (based on [12]):

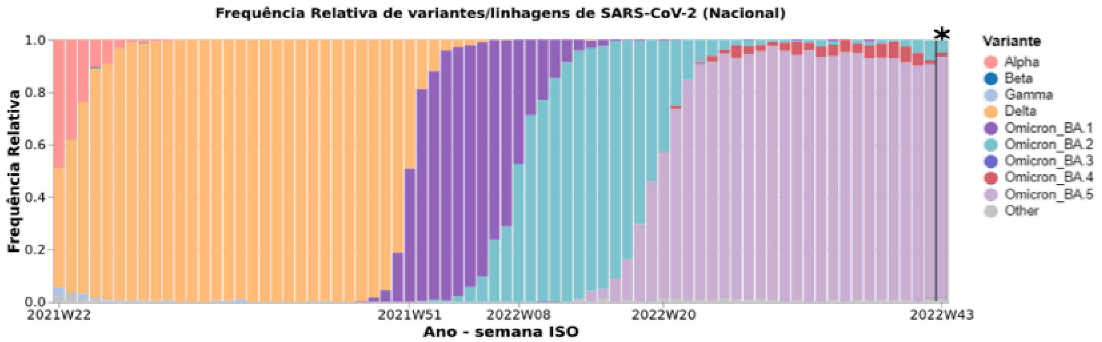

Figure 7 - Evolution of the weekly relative frequency of SARS-CoV-2 variants circulating in Portugal between ISO weeks 22/2021 (31/05/2021 to 06/06/2021) and 43/2022 (24/10/2022 to 30/10/2022). Author: DGS

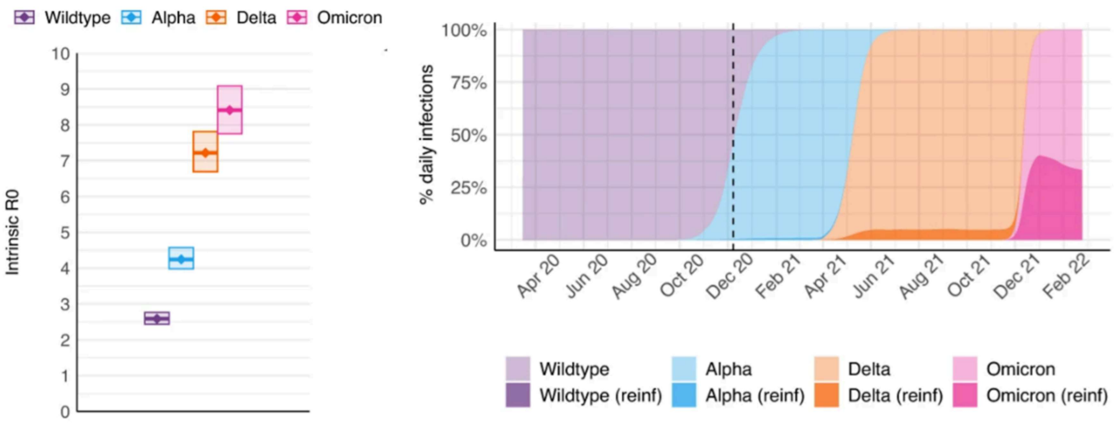

Figure 8 - Covid variants – England: Left) Intrinsic basic reproduction number (R0) estimates by variant (mean and 95% CrI); Right) Model-inferred average frequency of daily infections by variant and type of infection (either primary or re-infection following any prior infection, "reinf").

We had already mentioned characteristics of several variants and considering the periods of greatest predominance of each of them, it would be expected that the incidence of COVID-19 would increase over time. However, this was not the case, as can be seen from the Figure 9 below with the cumulative incidences over 7 days in Portugal from March 11th, 2020 to September 30th, 2022*.

*On January 10th, 2022 there was a break in the SARS-CoV-2/COVID-19 data series, due to changes in the notification of infection cases. With the end of the state of alert in Portugal, there was an end to mandatory isolation and the reimbursement of non-prescribed COVID-19 tests, which resulted in a significant decrease in the notification of positive cases, leaving subsequent records to be comparable with the previous ones.

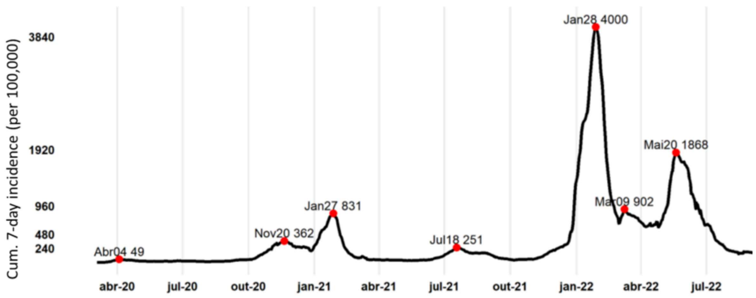

Figure 9 - Cumulative 7-day incidence (per 100,000 habitants), in Portugal, from 11/03/2020 to 07/11/2022. Source: BI SINAVE; Author: DGS

The difference between the observed values and those that would be expected during the predominance of the delta variant was mainly due to the success of the vaccination plan in Portugal. On June 2021 to December 2021:

With the Omicron variant appearance, the number of cases increased significantly. However, even with the severity of this variant, the protection effectiveness vaccination against more serious symptoms remained. Therefore, despite the incidence peaks at the end of January 2022 and May 2022, the cases that led to serious hospitalisations remained well below the values recorded at the end of the first pandemic year, as can be seen in Figure 10 below, with the evolution of ICU admissions in hospitals in mainland Portugal.

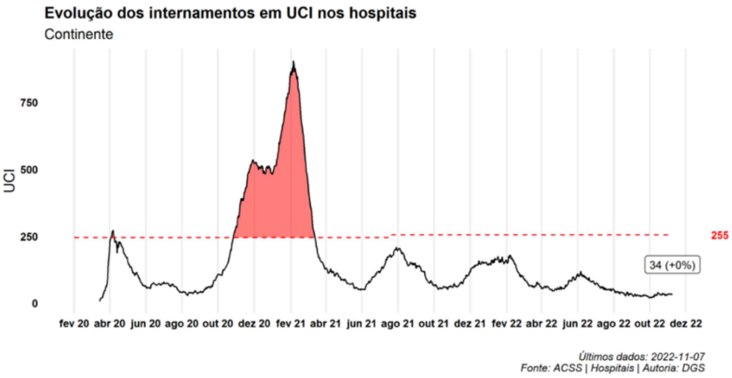

Figure 10 - Daily trend of COVID-19 patients admitted to Intensive Care Units in mainland hospitals between 11/03/2020 and 07/11/2022. Source: Hospitals; Author: DGS

Taking into account all that has been discussed regarding Multicare experience with the COVID-19 pandemic, the purpose of this section is to:

1) Simulate Multicare scenario during the first two years of the pandemic, a period marked by a high concentration of individuals requiring hospital care due to virus infection, and consequently, the associated costs of the disease.

2) Using the previous simulation, check whether the simplification considering the product between the cost of pandemic first year and the duration of an active disease would be a prudent estimation of the cost of all pandemic duration, i.e,

$$C_{1_{year}} \bullet n_{years} < C_{n_{years}}.$$

Where, $C_{1_{year}}$ is cost of the first year of the pandemic, n_{years} is number of years of an active disease duration and $C_{n_{years}}$ is the total cost of the pandemic during the active period.

We compared the 1-year cost with the 2-year cost for the sample available: COVID-19.

Multicare Simulations:

As was previously done for the first year of the pandemic, for the simulation of the multicare reality, the national incidence rates and the multicare age structure were used to estimate the number of cases. In order to estimate the number of hospitalisations, we used the rates presented in section 2 for the variants prior to Delta. However, with the emergence of new variants exhibiting different behaviours and the impact of vaccination, it was necessary to consider some additional assumptions:

- A higher risk of hospitalization (double) for the Delta variant, see [11];
- A lower risk with the Omicron variant (30% of the risk for people under 50 years old and 50% for the rest), see [13];
- An 80% reduction in hospitalisations among vaccinated individuals, see [14];
- The percentage of the Portuguese population vaccinated, categorized by age group, on a month-by-month basis.

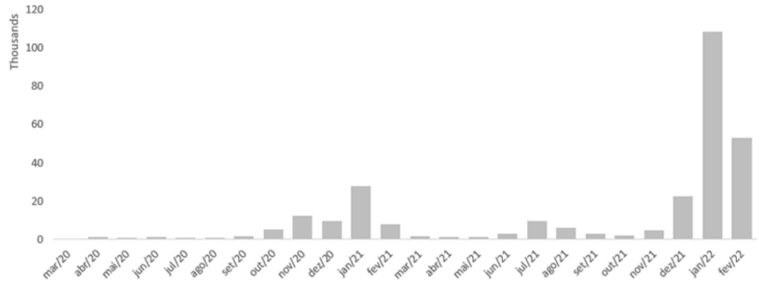

Figure 11 - Estimated cases in the portfolio per month for 2 years

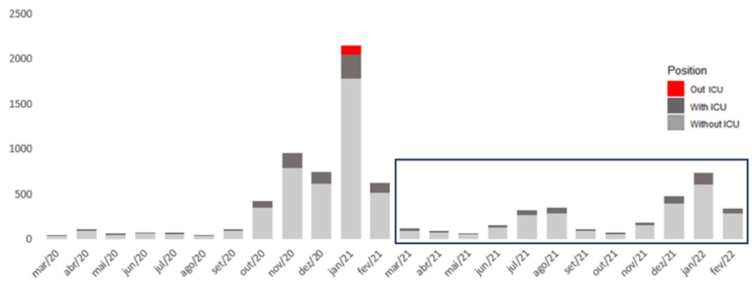

Figure 12 - Estimated hospitalisations in the portfolio per month for 2 years

In the first two years of the COVID-19 pandemic in Portugal, the 2nd year represents only 36% of the number of hospitalisations. As mentioned before, this is certainly due to vaccination programme that started on the 27th of December 2020. This behaviour was expected to continue or even decrease in future pandemics, since there are already many lessons learned such as approvals, mass production, and distribution, see [10].

In conclusion, the total cost of 1 year by 2 results in a more conservative estimate than considering the actual values of 2 years of pandemic.

5. Time between pandemics

The time between pandemics has been decreasing. This is mainly due to three factors: climate change, urbanisation, and globalisation, see [7] and [8]. For this reason, we found important estimating the time until the next pandemic. The dataset was composed by epidemics and pandemics with airborne transmission since 1600 and viral or bacterial epidemics/pandemics due to the increasing resistance of bacterial infections to antibiotics. Today's globalization makes easier an epidemic outbreak to become a pandemic.

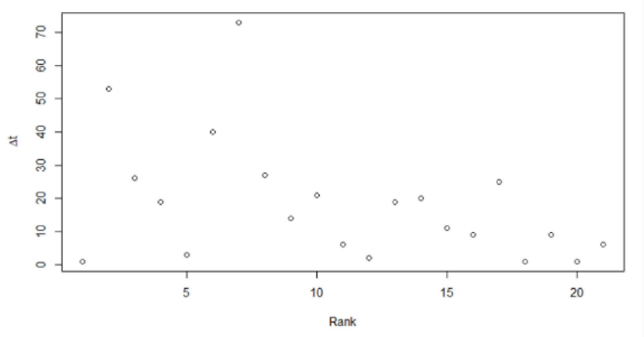

Figure 13 - Time between pandemics

In this section we make use of the Extreme Value Theory (EVT), see [9]. An extreme event occurs when a risk takes on tail values of the underlying distribution function. EVT is a methodology that tries to provide the best possible estimates of the tail of that distribution. It provides statistical inference techniques to study extreme, highly unusual, or rare behaviour of certain events occurring in the universe.

In [9] two main EVT methods were used to estimate tail distributions are considered: Block Maxima (BM) and Peaks-Over-Threshold (POT).

BM models the extremes using the limit distribution of the maximum. It studies the maximum that some variable assumes in successive periods, for example days, months or years. The sample is divided into blocks and the maximum value is extracted from each block. The biggest limitation is that an extreme value of one block can be smaller than non-extreme values of another block.

We considered periods of n years. For each period, we extracted the highest intensity value and sorted the sample. For each intensity, we calculated its probability of being exceeded. We adjusted a distribution of extremes Generalize Extreme Value (GEV) which units the Gumbel, Fréchet and Weibull distributions into a single family to allow for a continuous range of possible shapes. Then a probability function with the previously adjusted distribution were generated, $pgev_i$.

POT models extremes using the distribution of excesses above a certain level. It only considers the set of observations, say X_i, $i = 1, 2...$, that lie above some defined level $X_i = u$. It is said more useful as it efficiently uses the highest observations. In this type of model the blocks have to have the same high dimension, which is a disadvantage when the sample is small such as ours.

We set a threshold of 0.001, calculated the frequency of events with an intensity of less than 0.001 or unknown, obtaining $p = 0.55$ and then sorted the sample. After this, we adjusted a Generalized Pareto distribution, which depending on the shape parameter, an Exponential, Pareto, or Beta distribution could be produced, and generated a probability function with the previously adjusted distribution, pgp_i.

The main difference between the two methods is that POT uses the highest observations while Block Maxima uses the maximums of each period.

After that we can conclude that a new pandemic will occur within 12 to 13 years after COVID-19 (assuming all limitations).

6. IFRS17 and accounting for provisions in insurance on an annual renewable basis

The Pandemic cover was studied to be included in the Multicare Portfolio's annual renewable insurance policies. Under the IFRS17 accounting rules, there is a restriction limiting the existence of provisions to cover the risk contained in the policy to the period it is in force.

Considering the already identified characteristics of the pandemic, both in terms of its frequency (low) and total cost (high), the insurer will always have to set aside a portion of the premium at each renewal to cover the costs associated with the pandemic when it arises. Therefore, we had to find instruments to guarantee that the savings made each non-pandemic year would be transferred to the year in which the pandemic occurs. We have identified two possibilities: Reinsurance or the constitution of Equity Reserves.

The choice of one over another will always be related to the robustness of the insurer and its appetite for risk. In the case of Multicare, which is part of an insurance group with solid financial stability, either instrument could be possible.

In the case of reinsurance, we designed an 80% quota-share treaty with an international reinsurer. Some difficulties were encountered, starting with the very definition of a pandemic, which will not allow for the usual dispersion risk effect associated with geographical distribution in reinsurers' portfolios: a pandemic is an epidemic that affects more than one continent. In addition, the experience gained with COVID-19 in markets where there were no pandemic exclusions proved to be very costly. And so, the price of the treaty presented to us by the reinsurer turned out to be high.

This situation became even more significant when, following the low use of medical care in the various providers - promoted by the various lockdowns and followed by the outbreak of the war in Ukraine - an inflationary movement increased the costs of medical care of national providers, thus forcing insurers to increase insurance premiums and, therefore, at the time, including the cost of this cover on top of the necessary increase in premiums would have become difficult or even unaffordable for our clients.

Another way of setting up the necessary reserves for a pandemic was then studied within the Direct Insurer's own accounts, as follows: Withdrawing the coverage margin from results, acquired from the unused premium paid and constituting it in the "Other Reserves" account in Equity. This method presents the following risks:

- If the portfolio's overall margin is less or equal than the hedging margin, we won't have enough to accumulate in the aforementioned account, a risk that we don't think is significant at Multicare.
- If the shareholder wants to distribute dividends without leaving us the amount corresponding to the coverage margin, once again we won't be able to accumulate this amount.
- And even if there is such a reserve, if there is a severe event, such as an earthquake of great magnitude, the shareholder may decide to use the sum set aside for pandemics to pay these claims and thus decapitalise the reserve. It is reasonable to think, however, that if this is the case, we can also assume that the same could happen in the opposite direction. We recommend that this reserve be limited to a maximum amount corresponding to the "Worst Case Scenario" of the population in force at the end of each financial year.

7. Some concluding remarks

This project was carried during changing times due to the COVID-19 pandemic crisis. The pandemic has brought new challenges for the entire health sector, including health insurance companies that did not cover expenses related to such pandemic risks. Given the lack of data from previous pandemics and epidemics as well as the complexity in charging pandemic related products, the risk of the occurrence of these events was not well studied. The current pandemic has made very relevant the discussion on the cover for these products. In Portugal, insurer Multicare came forward with covers in order to meet the needs of her policyholders. This research aimed the estimation of the total cost for health insurance, during a pandemic crisis, to remove the clause that safeguards insurers from this cost. COVID-19 brought us many data with which we could estimate the cost. Therefore, considering the incidences, the hospitalisation rate, the limit of available beds, and using a simulation process, we estimated the cost of one year of the pandemic. The medical treatment costs in a pandemic resulted in about 14% of all insurer claims of a year without a pandemic. Nothing guarantees us that the next pandemic will be similar as the current one, so when we perform the stress tests, we conclude that in the worst-case scenario, the cost related to a pandemic is 0.72 times the cost of all other insurance claims. Therefore, it is very likely that the Loss and Combined Ratios are higher than 100%, and the insurer business does not have profitability, which can risk the solvency of the whole insurance company. For that reason, the last steps taken include calculating a premium, or an additional premium if it is taken into another existing product. The main challenges of this calculation were to consider that pandemics do not occur every year and that the duration is not always the same. However, we used the estimated time interval (12-13 years) until the next pandemic and considered the duration of the pandemic as an additional variable. Finally, Multicare proposed a way to face pandemic risk, based on an annual renewable insurance basis, considering new accounting rules.

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