IES 2022 Innovation & Society 5.0: Statistical and Economic Methodologies for Quality Assessment

BOOK OF SHORT PAPERS

Editors: Rosaria Lombardo, Ida Camminatiello and Violetta Simonacci

Book of Short papers
10th International Conference **IES 2022**
Innovation and Society 5.0: Statistical and Economic Methodologies for Quality Assessment

Department of Economics, University of Campania "L. Vanvitelli",
January 27th - 28th 2022

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Sede legale: Villa Marelli - Viale Thomas Alva Edison, 45 - 20099 Sesto San Giovanni (MI)
Sede operativa: Villa Marelli - Viale Thomas Alva Edison, 45 - 20099 Sesto San Giovanni (MI)
Ufficio Di Rappresentanza: Via Giacomo Peroni, 400 - 00131 Roma (RM)
CF / P.I. 03167830920 — www.pke.it; e-mail info@pke.it — Privacy

February 2022 PKE s.r.l.
ISBN 978-88-94593-35-8 on print
ISBN 978-88-94593-36-5 online

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THE INSURANCE PREMIUM STRUCTURE FOR A COVID-19 INSURANCE POLICY.

Struttura di un premio assicurativo per una polizza COVID-19.

Giovanna Di Lorenzo, Girolamo Franchetti and Massimiliano Politano

Abstract In the context of the Sars-CoV-2 virus pandemic, this paper deals with the analytical framework that involves a stochastic model to describe the probability of contagion and, therefore, of its outcome for a subject; subsequently, an actuarial model for an insurance policy against the risk of contracting the virus is proposed and the quantification of the related premium. It is assumed that the insurance coverage lasts for one year and that during the coverage it could happen the infection. The theoretical distribution of the contagion probability is of geometric type, in which every coverage day is a Bernoulli distribution of infection event. Four outcomes of the infection are considered below: hospitalization in home isolation, in hospital Medic Area, in intensive care and, finally, death. The Gamma distribution is taken into account as the theoretical distribution of number of days for each trajectory of recovery regarding the outcome of the infection, whereas for the outcome of death a lump-sum payment is defined to be paid as a single solution. A payment variable will be obtained whose mathematical expectation is the expected value of the expected benefits, assuming that in the event of death it remains the capital value. For each day of coverage, the expected payment is calculated and then weighted by the probability of infection on that given day; then, the expected payment is discounted to the effective date of coverage and, finally, it is calculated

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the fair premium of the policy. For this paper it is used the software R for statistical evaluation

Abstract *Nel contesto della pandemia Sars-CoV-2, questo lavoro affronta il quadro analitico che prevede un modello stocastico per descrivere la probabilità di infezione e, quindi, del suo esito per un soggetto; successivamente viene realizzato un modello attuariale per una polizza assicurativa contro il rischio di contrarre il virus e la quantificazione del relativo premio. Si ipotizza che la copertura assicurativa abbia una durata di un anno e che durante la copertura possa verificarsi il contagio. La distribuzione teorica della probabilità di contagio è di tipo geometrico, in cui ogni giorno di copertura è una distribuzione Bernoulliana dell'evento di infezione. Di seguito vengono considerati quattro esiti del contagio: il ricovero in isolamento domiciliare, in Area Medica ospedaliera, in terapia intensiva e, infine, il decesso. La distribuzione Gamma viene presa in considerazione come distribuzione teorica del numero di giorni per ogni traiettoria di ricovero in relazione all'esito della guarigione, mentre per l'esito del decesso si definisce un'indennità una tantum da erogare in un'unica soluzione. Si otterrà una variabile di pagamento la cui aspettativa matematica è il valore atteso dei benefici attesi, assumendo che in caso di morte rimanga il valore del capitale. Per ogni giorno di copertura viene calcolato il pagamento previsto e poi pesato per la probabilità di infezione in quel dato giorno; quindi, il pagamento previsto viene attualizzato alla data di decorrenza della copertura e, infine, viene calcolato il premio equo della polizza. Per questo lavoro viene utilizzato il software R per la valutazione statistica.*

Key words: Sars-Cov2, Covid-19 insurance, fair premium, vaccinated ad unvaccinated risk profile

1 The Model

The model is composed by two different sections strictly linked each other:
1 A stochastic model for the description of COVID-19 epidemic dynamics
2 An actuarial model to quantify a fair premium of a COVID-19 insurance policy.

1.1 Stochastic model

The stochastic model takes in account the data presented by the Instituto Superiore della Sanità (ISS) in his weekly report about the COVID-19 epidemics during the observation period from 14/07/2021 to 17/11/2021. It is calculated the probability of infection using the classic approach, taking in account the entire reference population, and the probability of a specific outcome of the infection itself taking in account infected people as the reference population:

Table 1: Infection and related outcomes probabilities

Non infection	*Infection*	*Home quarantine*	*Hospitalization*	*Intensive care*	*Death*

The Insurance premium structure for a Covid-19 insurance policy

$$p^S = \frac{S}{N} \quad p^I = \frac{I}{N} \quad p^C = \frac{C}{I} \quad p^O = \frac{O}{I} \quad p^{TI} = \frac{TI}{I} \quad p^D = \frac{D}{I}$$

Where

$p^S + p^I = 1$

$p^C + p^O + p^{TI} + p^D = 1$

Where *S* stands for people who are susceptible to the infection but not infected. Calculating these probabilities for every observation data it is possible to see the time series of this probabilities.

1.2 Actuarial model

Using the probabilities from the stochastic model seen before it is possible to quantify the fair premium of a COVID-19 insurance policy.

It is assumed that the policy coverage period is of 365 days and that the infection is represented by a bernoulli variable for every day of this period. Then, it is calculated the probability of being infected for every single day assuming that in the previous days the infection event has not happened.

$$\mathcal{B}(p^I) = \begin{cases} 0 & 1 - p^I \\ 1 & p^I \end{cases}$$

$$p^I(t) = \mathcal{G}(p^I) = (1 - p^I)^{t-1} * p^I$$

So, it is used a geometric distribution for representing this probability for every coverage day and, considering every single observation data, it is possible to obtain the dynamic of this probability during the observation period.

For every infection outcome (except death) it is calculated the expected benefit calculating the expected value of recovery days multiplied for the benefit paid every single recovery day. For death case it is paid a lump sum capital.

$$E[P] = E[rC] * p^C + E[rO] * p^O + E[rTI] * p^{TI} + 300 * p^D$$

Table 2: Benefit related to the infection outcomes (first three paid for every recovery day)

Home quarantine	***Hospitalization***	***Intensive care***	***Death***
1	1.5	2	300

It is used the probabilities related to the four possible outcomes to calculate the expected benefit of the policy by calculating the expected value of the expected benefits.

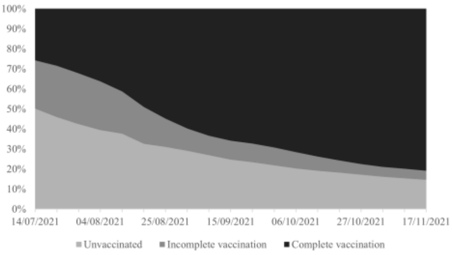
Finally, the expected payment is assumed the same for every day of the coverage period, weighted by the related infection probability and it is discounted at a technical interest rate of 1%.

$$Fair\ premium = \sum_{t=1}^{365} V_0(t) = \sum_{t=1}^{365} (1 + i)^{-\frac{t}{365}} * p^I(t) * E[P]$$

3 Data

It is used the data present in the weekly report about COVID-19 epidemic published by the Istututo Superiore della Sanità (ISS) about the infection and the related outcomes. This data are shown for three vaccination status: Unvaccinated, incomplete vaccination, complete vaccination.

Graph 1: Population partition by vaccination status



Regarding the recovery days, related to non-death outcomes, it is used the mean of the hospitalization and intensive care days presented by Azienda Sanitaria Toscana (ARS Toscana) and the mean of recovery days related to the home quarantine presented by the Health Ministry. So, the gamma distribution is considered as the theoretical distribution of number of days for each trajectory of recovery regarding the outcome of the infection with shape parameter equal to 2.

Graph 2: Theoretical gamma distribution of recovery days

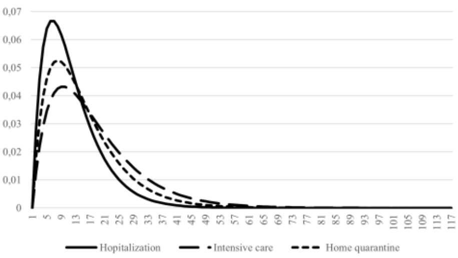


Table 3: Means of the recovery days

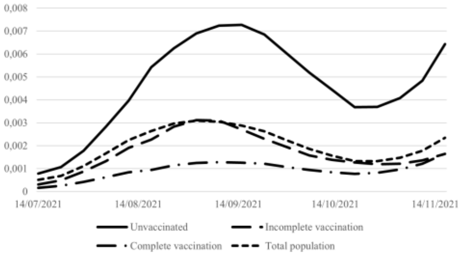
Home quarantine	***Hospitalization***	***Intensive care***
14	11	17.3

4 Analysis

In the analysis it is computed the time series of infection probability and the time series of the expected benefits by vaccination status. Then, it is calculated the fair premium for each class of people differentiated by vaccination status.

The Insurance premium structure for a Covid-19 insurance policy

Graph 3: Time series of infection probability by vaccination

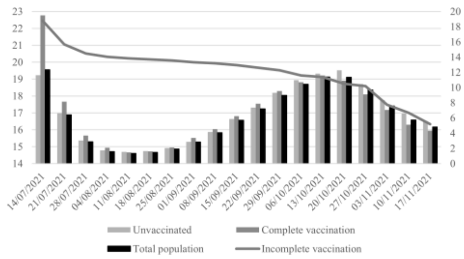


So, it is possible to see that during August and September the probability of infection increased due to the wave of infections and the same is happening during November.
Another statement is that the infection probability is higher than the other vaccination status and higher than the probability calculated on entire population. This data shows that the class of unvaccinated is the one with the highest risk about infection event.
Regarding the expected benefits related the infection outcome, they are shown in the graph except the lump sum capital in death case. The highest is the intensive care due to the mean of recovery days and the payment in each one that are the highest. The lowest is the home quarantine for the same reason presented before but the difference that in this case they are the lowest.

Table 3: Expected benefits for the infection outcome

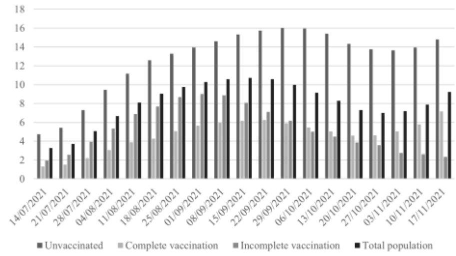
Home quarantine	*Hospitalization*	*Intensive care*
14,02368661	16,54542718	34,03564112

Graph 4: Expected payment of the policy by vaccination



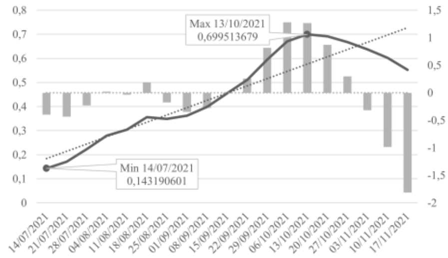
It is possible to state that during the wave of the infections, most of them are people that have the home quarantine as the infection outcome. So, this brings to see a reduction of expected payment during the wave, because it is more expected that it is paid the lowest benefit. Only by 20/10/2021 the expected benefit for the unvaccinated is higher than the expected for the entire population. Applying the actuarial model, it is possible to see that the class of unvaccinated is the one with the highest fair premium compared to the other vaccination status, confirming that this is the class of the highest risk related to the infection event and to the possible benefit. It is possible to see that the premium increases during the wave, as expected, and decreases outside it. Observing this result, it is possible to state that the vaccination status has a relevant impact on the quantification of fair premium.

Graph 5: Time series of the fair premium by vaccination



In fact, people who is unvaccinated has a higher risk to get infected and have a higher risk to be in more serious infection outcome.

Graph 6: Time series of the fair premium gap between unvaccinated people and total



In conclusion, if an insurance company sells a COVID-19 insurance policy to the entire population has a relevant risk to incur in losses due to the serious mismatch between the fair premium of the policy and the one that unvaccinated people should pay that is much higher that the one of the insurance policy offered to the entire population.
So, there is the necessity to apply a safety loading on the probability of infection and on the expected payment to cover the risk that the company could provide a payment higher that expected in the offered policy if the insured person who incurs in the infection has the unvaccinated status.

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February 2022 PKE s.r.l.
ISBN 978-88-94593-35-8 on print
ISBN 978-88-94593-36-5 online