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Research Article

UPR Sim.DiffProc-Modeling in Non Life Insurance

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Abstract

The examination of UPR (Unearned Premium Reserve), which accounts for a significant amount of REC (Contractual Engagement Reserves) in insurance matters, is a crucial component of actuarial and financial management in insurance companies. We propose a solution based on the Solvency II system that uses an internal model based on a stochastic differential equation in order to apply the new international standard IFRS'17 linked to insurance contracts. We use the Sim.DiffProc package to produce statistical trajectories of the model by sampling. The analysis focuses on the problem of censoring obstacles in the process. Based on the model parameters, we investigate the barrier's sensitivity. Before the absorption barrier, we calculated the likelihood of ruin and the probability density of UPR life time.

Keywords: Unearned Premium Reserve, Gross Written Premium, Stochastic Differential Equation, Sim.DiffProc, censure, absorbent barriers, probability of ruin, sensitivity, life time.

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Introduction

The insurer's promises to the insured and contract beneficiaries are reflected in the RECs. These include, in particular, the clauses pertaining to the payment of claims, the mathematical provisions clauses in life insurance, and the provisions pertaining to current risks in non-life insurance [1]. We suggest a new modeling approach by diffusion process or stochastic differential equation [2], [3] of the volume of reserves in terms of dynamic structure in continuous time of the UPR(t) upper bound (e.g. a regulatory ceiling, for this final point), which is essentially for the case of a study of the UPR(t).

In terms of the dynamic structure in continuous time of the UPR(t), we provide a novel modeling approach for the volume of reserves using a diffusion process or stochastic differential equation. Since the UPR(t) cannot be negative, we incorporate a censorship into the model of the UPR(t) to enable the imposition of reasonable bounds, such as an upper constraint (such as a regulatory ceiling) or a lower bound at zero. We examine risk of failure when the UPR(t) or reserve hits a critical threshold, meaning the insurance can no longer meet its obligations. When the UPR(t) falls below a regulatory threshold, the insurer is required to inject capital since there is a risk of insufficient provision. We estimate the probability of ruin and see how sensitive it is to the ideal barrier. Additionally, the optimal barrier's sensitivity to drift and diffusion parameters is examined. The density of the random variable time of service till absorption by the barrier is estimated.

UPR Classical Model

GWP (Gross Written Premium)

GWP is the total gross premiums issued by an insurer over a specific time period, before provisions or reinsurance are subtracted.

GWP = direct premiums issued + premiums accepted in reinsurance (1).

Growing GWP indicates business volume, but since some premiums have not yet been paid, it does not always indicate actual revenue.

L' UPR (Unearned Premium Reserve)

The portion of premiums issued (GWP), that has not yet been recorded as revenue, is known as UPR. It guarantees that the insurer has enough money to pay claims in the future.

General formula :

$$\boldsymbol{UPR}=\sum\left(Underwritten\,premiums.\frac{Duration\ \ of\ remaining\ \ coverage}{Total\ duration\ \ of\ the\ policy}\right) \quad (2)$$

A high UPR indicates that a significant portion of the prices have not yet been earned, which has an immediate impact on rentability.

Financial results and technical provisions may be affected by an inaccurate UPR estimate.

Proposed Diffusion Model of UPR

We propose a more accurate mathematical model of the UPR in the form of a diffusion process U(t), t≥0, which is governed by the following stochastic differential equation, in order to account for the effects of the time factor and shocks on the financial market:

$$dU(t) = \alpha.\big(GWP - U(t)\big)dt + \sigma.U(t)dW(t) \quad (3)$$

Where:

α is an adjustment parameter from the UPR to the gross premium issued (GWP).

σ represents the volatility of the process.

W(t) is a Brownian motion modeling uncertainty.

U(t) Simulation Trajectories Using Sim.DiffProc

Before using the model with real data, simulation is a crucial step to evaluate its computational performance and sensitivity to the parameters α and σ, which we can determine once we have access to real data. The following graph illustrates the simulation of a flow of UPR(t) trajectories based on the model parameters.

GWP= 10 (Gross premium issued (millions of €)) α= 0.5 (Adjustment rate toward GWP)

σ = 0.2 (Volatility)

U0 = -5 (Initial UPR (millions of €)) T= 1 (Simulation horizon (1 year))

N = 365 (Number of time steps (days)).

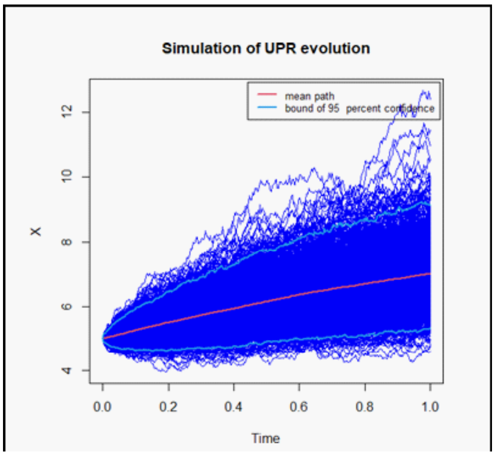

Figure 1. *Simulation of U(t) process*

If α is high, the U(t) converges quickly to the GWP. If σ is high, the trajectories are more dispersed, which means greater uncertainty.

Modeling by U(t) Diffusion Process With Censoring

By including the censoring limitations, we alter equation (3):

Reduced censorship: U(t) ≥ 0 (the UPR cannot be negative). Upper bound (optional): U(t) ≤ Umax (regulatory ceiling, for example).

The graph in Fig.2 shows a simulation of 1000 trajectories, corresponding to the size of a portfolio, with a regulatory limit set at 7 million euros.

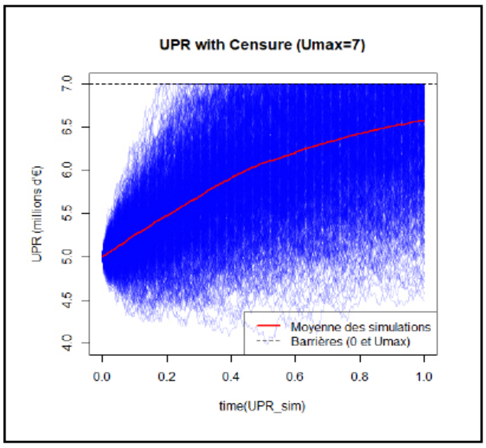

Figure 2. *U(t) wth censure, Umax=7*

This model offers better administration of technical obligations by considering regulatory and actuarial restrictions.

Diffusion Process Modeling of U(t) with Absorbing Barrier L

The model of equation (3) is modified with the following condition: If U(t) ≤L, then the process is stopped (the U(t) falls below the critical threshold).

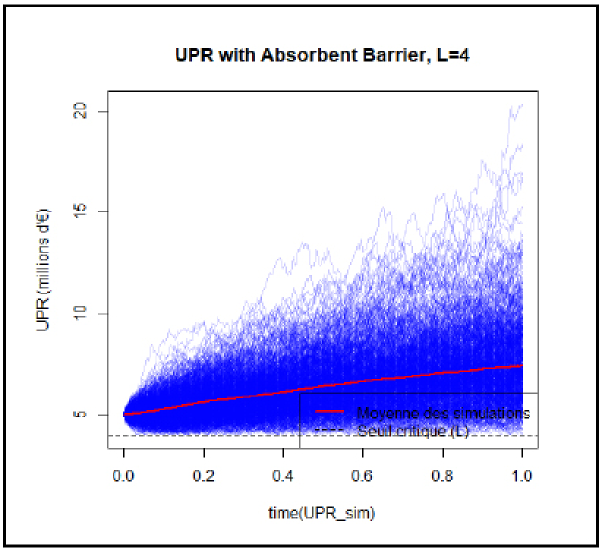

Figure 3. *U(t) with absorbent barrier, L=4*

A trajectory is arrested (absorbed) when it reaches L.

If σ is high, more trajectories will reach L quickly (risk of disaster).

Estimation of the probability of absorption

$Pabs\ (T)$ is defined as the likelihood that U(t) will reach L before T by:

$Pabs\ (T) = P(inf\, t\in[0,T]\ U(t) \le L)$

This probability depends on the parameters:

σ: Both the volatility and the absorption risk are not very high.

α: A high adjustment rate lowers the risk of absorption.

U(0) and L: Absorption is probable if U(0) is near L.

The estimated probability of ruin for σ=0.4, L=4, M=5000, and other unchanged parameters $Pabs\ (T) = 0.2324$.

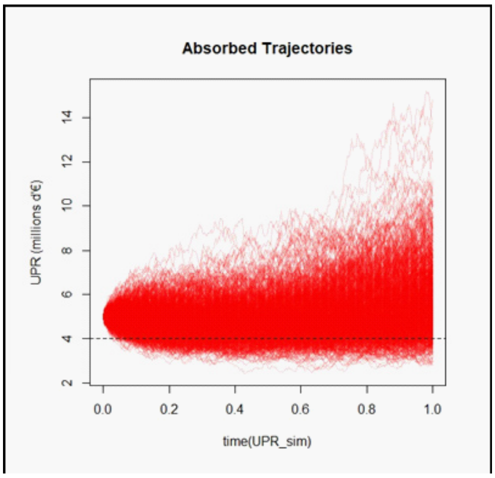

Figure 4. *Absorbed trajectories*

We will investigate the effects of the absorbent barrier L on

$Pabs\ (T)$.

The effect of L on $Pabs\ (T)$

To see the relationship, $Pabs\ (T)$ can be expressed as a function of L.

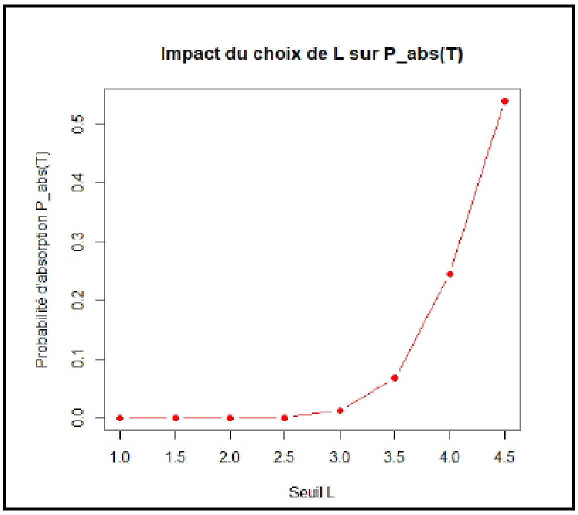

Figure 5. The effect of L on $Pabs\ T$

When L is small, $Pabs\ T$ is close to 0 (absorption peak).

$Pabs\ T$ Increases significantly if L is close to U(0).

$Pabs\ T = 0$ when L deviates from U(0).

This enables the determination of the ideal critical threshold for reducing the absorption risk.

Effect of α (adjustment parameter) and σ (volatility) on the absorbance barrier L*(optimal barrier)

We're all set:

a) Change α and see the impact on the optimal L*; b) Change σ and see how it affects L∗.

c) Displaying the results in a graphic format.

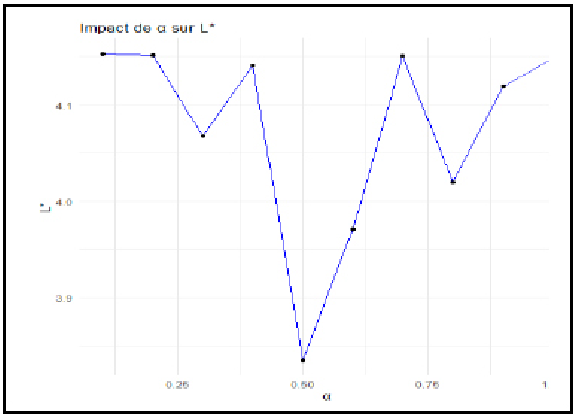

Figure 6. Effect of α on L*

Effect of α: A higher α causes the process to return to GWP more quickly, decreasing $Pabs\ T$

In order to make up for the lack of adjustment, a low α requires a higher L∗.

Effect of σ :

A higher volatility increases the likelihood of absorption, which increases L∗.

A low volatility makes it possible to select a lower L∗ without taking too much risk.

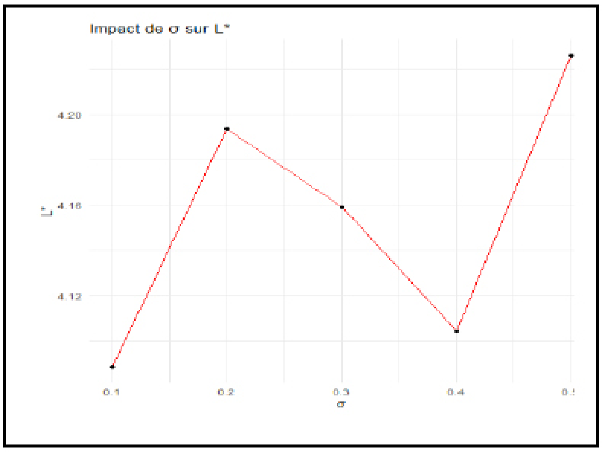

Figure 7. Effect of σ on L*

Estimation of the density of the absorption time of the barrier L: fptse1d() of Sim.Diffproc

The time it takes for the processus U(t) to be absorbed by the barrel L is a crucial aléatoire variable that indicates the likely life time of the processus until it is absorbed by the barrel L or L* (optimal). The module Sim.DiffProc's fptsde1d() function is well suited for estimating this random variable.

$\tau = inf\ t > 0\ U(t) \leq L$ (4)

An analytical form of the average absorption time is provided by [2], [5]:

$E\ \tau = 2\sigma 2 y U(0) L e\ -2\alpha\sigma 2\ y - GWP\ dy$ (5)

which is the Kolmogorov forward equation's solution:

$\alpha\ GWP - u\ df du + 12\sigma 2 u 2 d 2 f du 2 = -1$ (6)

With the conditions at the bords:

f(L)=0 (Absorption en L)

and

f'(U(0))<∞)) to ensure a well-defined solution.

The integral (5) does not have an accurate analytical expression. We can to evaluate it numerically, with high computational cost and unstable results.

In order to solve this problem, we use statistical estimation by the function —fptsde1d()‖ of Sim. DiffProc.

For this choice of parameters:

GWP = 10, α=0.5, σ=0.2, U(0)= 5, Tamx=10, L=4

M=1000 (Number of simulated trajectories),

Table 1. *gives a statistics summary of τ random variable distribution*

Mean	**0. 2199643(2years et 72 days)**
Variance	0.0065811
Median	0.2199643
Mode	0.2765417

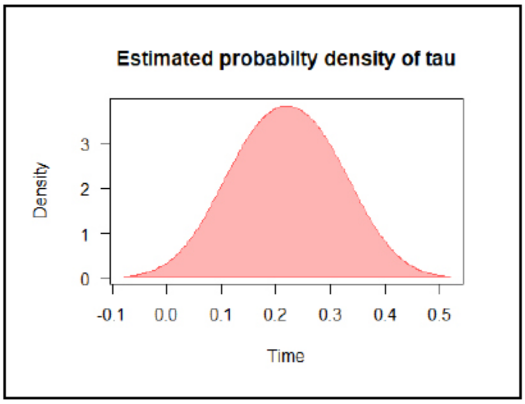

Figure 8. Estimated probability density of τ

Conclusion

Big Data and volatile financial markets are ideal for the suggested technique of complicated temporal dynamic modeling by diffusion for UPR. The analysis of UPR (Unearned Premium Reserve), a significant portion of the volume of REC (Contractual Engagement Reserves) in insurance matters, demonstrates the effectiveness of the model proposed by Sim. DiffProc in terms of the computational aspect of actuarial and financial management in insurance firms..

The likelihood of ruin could be calculated through statistical analysis of the process under barrier limitations. Additionally, the barrier's sensitivity to the two factors α of the drift coefficient and σ of the volatility is examined.

We compute the probability distribution of the duration of the provision until it is absorbed by a barrier that complies with regulations. This high-performance statistical analysis and modeling approach uses actual data after statistical inference regarding the two parameters α and σ, which are subsequently replaced by their estimators. The results can be applied to the company's UPR(t) provisioning process as a portfolio management strategy and as a tool for informed decision-making.

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