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Solvency Assessment of Insurance Companies in Algeria Using a Dynamic Model during the Period (2013-2022)

Ait Ouali Toufik[1], Mendil Djamila[2]

[1]*Research Laboratory in Management of Organizations (LAREMO), University of Mouloud Mammeri (Tizi Ouzou), Algeria; toufik.aituali@ummto.dz*
[2]*Economics and Development Laboratory (LED), University of Abderrahmane Mira (Béjaia), Algeria. djamila.mendil@univ-bejaia.dz*

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Corresponding Author
Ait Ouali Toufik
toufik.aitouali@ummto.dz

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Abstract: An insurance company must constantly ensure its solvency in order to be able to fulfill its obligations to policyholders and creditors under the established contracts.

The objective of this article is to assess the solvency of insurance companies in Algeria.

To achieve this, we applied a dynamic model based on stochastic differential equations. The results of this study reveal a significant disparity in solvency among the different companies examined.

Keywords: Insurance; Solvency; Risk Management; Stochastic Differential Equations; Algeria.

1. Introduction

In the insurance business, the phrase "soluble" describes an entity's capacity to fulfill long-term commitments, especially to policyholders. For an insurance business to be able to pay claims and benefits to policyholders, among other obligations, it must be solvent.

The goals of prudential regulation in the insurance industry are to safeguard policyholder interests and guarantee the financial viability of insurance businesses. The introduction of capital requirements that insurers must adhere to is one of the fundamental features of this law.

The regulatory bodies that set minimum capital requirements for insurance businesses are usually independent or government agencies. This capital, which is the gap between an insurance company's assets and liabilities, is meant to pay policyholder obligations and cover possible losses.

Insurers can guarantee they can meet regulatory requirements and thresholds that could compromise their solvency by adhering to these capital standards. The goal of this strategy is to win over the trust of investors, policyholders, and government agencies. But considering the risks they take to keep their promises, one would wonder if this is enough to address all the uncertainties that could jeopardize their financial stability.

Using a stochastic differential equations model, we shall evaluate the solvency of insurance companies in Algeria in this study. The goal is to put a number on these businesses' financial resilience to the risks that come with doing business, especially when it comes to managing the risks of others. In this context, the following problem has been identified:

How can we grasp the solvency of insurance companies in Algeria through the use of stochastic differential equations?

We will take an analytical approach to this problem. There are three sections to this article. Through a review of the literature, the first section seeks to describe the research that have examined risk management in insurance businesses and the many approaches used to determine solvency. The model's presentation is covered in the second section. The final segment will include a presentation of the study data and findings.

2. Literature Review

The following literature review brings together academic research on risk management practices in insurance businesses, the need for insurance market regulation, and several approaches to determining an insurance company's solvency.

In 1955, modern risk management began to take off. The 1970s saw a major change in the way the notion of risk management evolved in the financial industry, especially in insurance businesses (Castel, 2011). In reaction to changes in interest rate and market profit volatility, risk management became a top concern for companies during this time. The primary functions of risk management in an insurance company are risk identification, measurement, monitoring, and control. Insurance companies are required by law to identify, measure, monitor, and control risks promptly and accurately (Dionne, 2013).

In the insurance industry, risk management necessitates careful ethical thought in order to strike a balance between business profitability and policyholder rights and interests protected (Simonnet, 2015). If an insurance company's bankruptcy creates a large enough systematic risk, markets may be disrupted (Carmichael & Pomerleano, 2002). Ohlsson & Lauzeningks (2009) used the value-at-risk approach to evaluate risks in a variety of industry sectors for their study on underwriting risk analysis within the framework of the Solvency II regulation applied to a non-life insurance firm. This study emphasizes how crucial it is to make clear the differences between ultimate and short-term (one year) viewpoints when assessing risk in the non-life insurance market.

Gatzert & Reichel (2022) assessed how insurers' financial value was impacted when they took climate concerns into account. Effectively managing a variety of risks, including actuarial, systematic, credit, liquidity, operational, and legal risks, is also a critical responsibility for an insurance company (Laporte, 2002). The deployment of particular ratings by rating agencies beginning in 2005 demonstrated the practical significance of integrated risk management (Hoyt & Liebenberg, 2011). According to theory, integrated risk management enables better risk management choices, more appropriate capital structure selections, more effective capital allocation, and internal process improvement for decision-making (Nocco & Stulz, 2006).

The relationship between integrated risk management and business success has been examined in other empirical research. (Hoyt, Moore, & Liebenberg, 2008) looked at how 125 insurance companies implemented a "Enterprise Risk Management" (ERM) framework between 1997 and 2005, and they found that having a Chief Risk Officer (CRO) in place is a sign of an organization's ERM maturity. Using Standard & Poor's (S&P) ERM ratings, (Mcshane, Nair, & Rustambekov, 2010) investigated the impact of integrated risk management on performance and discovered a positive relationship—albeit one that was not as strong as in previous research. According to (Bohnert, Gatzert, Hoyt, & Lechner, 2018), establishing a robust integrated risk management strategy has a considerable positive impact.

Many studies have looked into risk measurement indicators, which are also used to determine capital requirements. Hardy (2006), for example, highlights how crucial it is to allocate capital optimally for each business sector in risk management.

The literature on insurance industry regulation presents a range of viewpoints and issues. According to De Mori (1965), the primary responsibility of regulatory bodies is to guarantee the solvency of insurance businesses through the verification of the coherence of mathematical reserves, premium reserves, and loss reserves. Plantin & Rochet (2007), who contend that regulation grants public authorities important control powers over insurers' financial and strategic decisions, support this requirement.

Theories regulating the regulation of the insurance market are divided into two groups by economists (Klein W., 1995). As per the "Public Interest Theory," the high expenses linked with information collection and information asymmetries are the reasons behind the necessity for regulation. In the absence of regulation, firms would become more insolvent due to agency issues and information asymmetries. However, the "Economic Theory" contends that regulation is essentially driven by people's and companies' desire to further their own agendas, prioritizing private economic interests over the interests of the general public.

(Munch & Smallwood, 1980) emphasize the necessity of securing minimum equity capital and the beneficial effect that solvency regulation plays in lowering insolvency. Prudential authorities have a duty to stop any reckless or exaggerated action that would jeopardize policyholder safety. The main argument for regulation in the insurance industry is the information imbalance that exists between the insurance firm and the insured (Carmichael, 2002).

While enabling the insurance industry to fulfill its macroeconomic function, prudential regulation must guarantee the best possible handling of policyholder deposits (Gollier, 2006). In order to increase the effectiveness of the insurance markets, solvency control is crucial, according to Cummins (2000).

Melyon (2007) has pointed out that the availability of sufficient capital has a direct bearing on the solvency of insurance businesses. Insurance companies are forced, by changing legislation, to manage their solvency in a proactive manner. A variety of sophisticated mathematical techniques for risk modeling and management in the insurance industry are revealed by the literature review. Researchers use methods like stochastic control theory and Backward Stochastic Differential Equations (BSDE) to investigate different aspects of financial risks and the solvency of insurance companies.

Numerous facets of insurance company solvency management are emphasized, highlighting the difficulties and vital tactics required to guarantee these organizations' financial stability. Of particular note is the significance of risk management with regard to stored funds (Ko & Lin, 2008). Using a different methodology, Floryszczak, Levy Vehel, & Majri (2018) highlighted the importance of solvency in strategic decision-making by treating required solvency capital as a constraint and using deterministic control theory to find the optimal premium strategy.

Based on eminent studies, it is imperative to adhere to new regulations, which touch on critical topics including capital importance, risk management, investment strategies, regulatory compliance, and equity optimization. The utilization of economic capital to maximize performance is demonstrated by Exley & Smith (2006), and the distinction between the difference between expected and actual results as a crucial measure of financial health is examined by Cocozza, Di Lorenzo, & Sibillo (2004). Tsanakas & Barnett (2007) stress the significance of figuring out the ideal equity level and identify optimization as a key problem for insurance businesses.

The stochastic differential equation was used by (Delong & Gerrard, 2007) to simulate the shift in claim intensity. Stochastic control theory was utilized to ascertain the best course of action in the event that the insurance company's wealth diverges from its predetermined profitability and solvency aim. This strategy offers ways to preserve the business's financial stability. (Delong, 2012) concentrated on longevity risk as well as systematic and non-systematic insurance loss risk. His application of the predictable representation property and BSDE equations produced an ideal asset allocation, proving the usefulness of this strategy in insurance portfolio management.

(Shi, De-li, & Li-min, 2008) innovated by fusing utility attitude and risk tolerance with goals for decision-making. They showed how to incorporate psychological factors of decision-making into the pricing process by creating a model for the actual pricing of unit-linked life insurance policies using BSDEs. The diffusion model and its use in risk theory and insurance were examined by (Xiong, 2011). He shows how stochastic differential equations can be useful tools for determining default probability in the insurance industry by demonstrating that the expected discounted penalty function is an extension of the probability of ruin while satisfying an elliptic partial differential equation under specific initial boundary conditions.

In the end, using stochastic differential equations in the insurance industry offers bright futures for risk modeling and management. These sophisticated mathematical techniques make it possible to take into account the stochastic and dynamic elements of insurance-related processes, giving professionals in the field useful tools for efficiently managing portfolios, setting product prices, and preserving the solvency of insurance companies.

3.The solvency assessment of insurance companies according to the stochastic differential equations model

3.1 Model presentation

We have decided to use a stochastic differential equation-based dynamic model for our research, which focuses on the solvency evaluation of insurance firms in Algeria. We took inspiration for our model from the research done by (Wang & Zhu, 2021).

These researchers have undertaken a comprehensive analysis of the solvency framework within China's insurance industry. Their approach involves utilizing a model based on stochastic differential equations to determine the essential conditions for sustaining the dynamic solvency of an insurance company.

In addition to proposing strategies to uphold solvency in the context of potential shifts in the external environment, they also conducted examinations and simulations of these scenarios.

This model relies on analyzing capital flows to evaluate the solvency of insurance companies. Rather than solely establishing capital criteria, this approach takes into account financial dynamics across various phases: health, risk, and reserve. The model conceptualizes an insurance company as a system fueled by funds. While insurance premiums contribute essential resources, claim payments serve to protect policyholders. Concurrently, the company leverages its capital for generating returns through investments. To comprehend this intricate process, a compartmental model divides the company's funds into three distinct states: health fund, risk fund, and reserve fund. The transitions of funds among these states represent the capital flows.

In the health state, capital experiences fluctuations based on incoming premiums and underwriting expenses, with premiums susceptible to random interferences. The model accounts for fund transfers to the risk and reserve states, as well as fund outflows to cover underwriting expenses. The risk state involves capital investments, with returns subject to random variations. Fund outflows encompass investment expenses and transfers to the reserve state, the latter contingent on the claims payment rate.

The reserve state manages funds designated for claims and associated expenses. Fund outflows address indemnification costs and are subject to random variations. Fund transfers to the reserve state originate from the health and risk states, influenced by the claims payment rates.

The model, grounded in the analysis of the insurance company's capital flows, employs stochastic differential equations to delineate the dynamic process. In the health state, the capital at time t, denoted as S(t), undergoes two distinct changes: the capital input component and the capital output component.

Assuming a premium growth rate of λ with a cap of K, a fraction of the health state funds covers underwriting expenses and is transferred out of the system, characterized by an underwriting expense rate of d_1. Another portion of the health state funds is allocated to investments and transferred to the risk state, with a transfer rate of β. Additionally, a segment of the health state funds is directed to reserves and transferred to the reserve state, governed by a transfer rate of ω. Considering that these random interferences follow a Brownian motion, the dynamic change process of the health capital is adjusted as follows:

$$dS(t) = \left(S + \lambda S\left(1 - \frac{S}{K}\right) - \beta S - \omega S - d_1 S\right)dt + \delta_1 S dB_1\,(t)$$

where δ_1 is the standard deviation of the capital flow fluctuations in the health state.

In the risk state, the capital at time t, denoted as I(t), undergoes changes that are also bifurcated into two components: the capital inflow segment and the capital outflow segment. The dynamic change process of capital outflow in the risk state is delineated as follows: a portion of the capital outflow in the risk state is utilized to cover investment expenses and is transferred out of the system, characterized by an investment expense rate of d_2; another segment of the capital outflow in the risk state is earmarked to replenish reserves and is transferred to the reserve state, guided by a transfer rate of μ. The investment return rate is subject to random interference. Assuming that these random interferences follow a Brownian motion, the dynamic change process of capital in the risk state unfolds as follows:

$$dI(t) = (\beta S + rI - \mu I - d_2 I)dt + \delta_2 I B_2(t)$$

where δ_2 is the standard deviation of capital flow fluctuations in the risk state.

In the reserve state, the capital at time t, denoted as R(t), undergoes changes divided into both capital inflow and outflow. The dynamic process of capital inflow unfolds as follows: capital originates from both the health state and the risk state. If the fund outflow from the reserve state is designated for compensations and other related expenses and is subsequently transferred out of the system, the claims payment rate is denoted as d_3. In reality, the incidence of compensation events is stochastic, assumed to follow a Brownian motion. Given this assumption, the dynamic change process of the reserve fund is articulated as follows:

$$dR(t) = (\omega S + \mu I - d_3 R)dt + \delta_3 R dB_3(t)$$

where δ_3 is the standard deviation of capital flow fluctuations in the reserve state.

For the capital flow system of the insurance company, the dynamic process of the entire system's capital flows can be elucidated by integrating the dynamic changes in the healthy state, risk state, and reserve state. It is crucial to highlight that the proportion of funds transferred from the healthy and risk states to the reserve state hinges on the reserve payment rate, denoted as d_3. This rate is a function of ω and μ, expressed as $d_3\omega$ and $d_3\mu$, respectively. For simplicity, this function can be assumed as $d_3\omega$ and $d_3\mu$. In practice, $d_3\omega$ and $d_3\mu$ represent the actual loss rate, indicating the proportion of real compensation in the healthy and risk states, respectively. This approach aligns more closely with reality since the fund outflow in the healthy and risk states corresponds to expenses to be paid, while the reserve is an estimate for the future, and the accounting provision is not an actual expense. The transfer rate in the equations for the three states can be adjusted to $d_3\omega$ and $d_3\mu$, respectively, resulting in a stochastic dynamic equation for the insurance company's capital flow system:

$$dI(t) = \left(S + \lambda S\left(1 - \frac{S}{K}\right) - \beta S - d_3\omega S - d_1 S\right)dt + \delta_1 S dB_1(t),$$

$$dI(t) = (\beta S + rI - d_3\mu I - d_2 I)dt + \delta_2 I B_2(t),$$

$$dR(t) = (d_3\omega S + d_3\mu I - d_3 R)dt + \delta_3 R dB_3(t).$$

3.2. Equilibrium conditions of the model

The stability conditions of this model are met with the specified parameter values: $\lambda = 0.1$, $\beta = 0.4$, $d_3 = 0.9$, $\omega = 0.4$, $d_1 = 0.3$, $r = 0.05$, $\mu = 0.5$, $d_2 = 0.001$, and $\delta_1 = \delta_2 = \delta_3 = 0.05$, respectively. These values clearly adhere to the solvency requirements of the insurance company. The model conceptualizes the capital flow of an insurance company as a dynamic system, where solvency hinges on the stability of the capital flow in different states. Stochastic differential equations are employed to depict changes in the system. By establishing the existence of a positive equilibrium point in the stochastic system and determining the condition for stable fluctuations near the equilibrium point, the solvency condition of the insurance company is ascertained. This necessitates the premium growth rate, investment rate, loss rate, expense rate, investment return, volatility of investment income, and indemnities to satisfy three conditions:

(1) $\lambda + 1 - (\beta + d_3\omega + d_1) > 0$;

(2) $(\delta_2)^2 \leq -2(r - d_2) - \beta + d_3\mu$;

(3) $(\delta_3)^2 \leq d_3((1 - \omega) + (1 - \mu))$.

3.3. Model rebalancing

If an insurance company's premium growth rate (λ) is less than zero, indicating negative growth, then the investment proportion parameter (β) can be adjusted to maintain solvency and stability. In the event that other parameters are unchanged and the premium growth rate (λ) is -0.1, the insurance firm can preserve its solvency by reducing the control variable investment ratio from $\beta = 0.4$ to $\beta = 0.3$. Figure 3 shows that capital approaches to zero in every state when $\beta = 0.4$, indicating insufficient solvency. On the other hand, for $\beta = 0.3$, each state's capital fluctuates above zero, guaranteeing solvency..

Adjustments in the investment proportion parameter (β) can be made to meet stability standards and maintain solvency as an insurance company's loss ratio increases. For instance, if other parameters remain unchanged, a decrease in the investment proportion of the control variable from $\beta = 0.4$ to $\beta = 0.3$ can be used to offset an increase in the claim that causes the reserve ratio to climb from $\omega = 0.4$ to $\omega = 0.7$. Figure 4 illustrates how capital in each stage moves towards zero under $\omega = 0.7$ and $\beta = 0.4$, showing insufficient solvency. In contrast, capital in every state fluctuates above zero under $\omega = 0.7$ and $\beta = 0.3$, guaranteeing solvency.

It is possible to achieve stability standards and preserve solvency by simultaneously adjusting parameters β and μ in situations where investment or claim volatility increases. For example, if volatility rises from $\delta = 0.05$ to $\delta = 0.45$ while maintaining other parameters unchanged, the insurance firm can maintain solvency by increasing μ from 0.5 to 0.9 and decreasing β from 0.4 to 0.1 in the control variable. As seen in Figure 5, the first line with β

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= 0.4 and μ = 0.5 under δ = 0.45 indicates that capital in the reserve state may go below zero, indicating insufficient solvency. Nonetheless, capital in the reserve state stays above zero under β = 0.1 and μ = 0.9, lowering the possibility of inadequate solvency.

4. Presentation of of empirical study data and test results

4.1 Study data

Our study's goal was to assess insurance companies' solvency using stochastic differential equations, and it was centered on businesses that were involved in Algeria's insurance industry.

This approach was used to analyze 19 insurance firms, looking closely at each instance individually. All insurance businesses that operate in Algeria between 2012 and 2021 are covered by our study; these companies offer all types of capital (public, private, or mixed) and insurance (property, life, and mutual).

The insurance or reinsurance companies excluded from this study are: CAGEX, SGCI, CCR, MAATEC, and AGLIC. CAGEX and SGCI were excluded due to their specialization, while CCR was excluded as a reinsurance company. Regarding MAATEC, its license expired on May 16, 2017. AGLIC commenced its operations only from 2015 onwards.

The data analysis encompasses ten (10) years, spanning from 2012 to 2021, for every insurance firm and fiscal year. The data includes the following:

- Premiums issued (contributions).
- Claims (compensations).
- Investments (placements).
- Overhead expenses.
- Personnel expenses.
- Financial products.
- Technical provisions.

5. Results and Discussion

The following table, which summarizes the overall satisfaction rates by company, condition, and combination of conditions, is appropriate to display after looking at the satisfaction level of the three (03) equilibrium conditions for each of the researched insurance companies:

Table .1. Satisfaction Rates of Equilibrium Conditions

Conditions	Number of Satisfactions	Satisfaction Rate	Concerned Companies
Condition (1)	17/19	89%	All companies, except CAARAMA and LE MUTUALISTE
Condition (2)	5/19	26%	SAA, CAAR, GAM, ALLIANCE and CNMA
Condition (3)	15/19	79%	All companies, except AXA DOMMAGES, SAPS, CAARAMA, and AXA VIE
Conditions (1) and (2)	5/19	26%	SAA, CAAR, GAM, ALLIANCE and CNMA
Conditions (1) and (3)	14/19	74%	All companies, except AXA DOMMAGES, SAPS, CAARAMA, AXA VIE, and LE MUTUALISTE

Conditions (2) and (3)	5/19	26%	SAA, CAAR, GAM, ALLIANCE and CNMA
All conditions	5/19	26%	SAA, CAAR, GAM, ALLIANCE and CNMA
Two conditions	14/19	74%	All companies, except AXA DOMMAGES, SAPS, CAARAMA, AXA VE, and LE MUTUALISTE
At Least One Condition	18/19	95%	All companies, except CAARAMA
No Condition	1/19	5%	CAARAMA

Source: Compiled by ourselves, based on the model results.

By scrutinizing the satisfaction rates for conditions (1), (2), and (3) within the sample of 19 insurance companies, the following conclusions can be drawn:

Compliance with Condition (1): The satisfaction rate for condition (1) is 89%. This indicates that 17 out of the 19 insurance companies responded positively to the requirements of condition (1). In other words, the growth rates of their premiums are in line with the evolution of various expenses, including personnel costs, underwriting costs, and claims, while covering a portion of their investments.

Compliance with Condition (2): The satisfaction rate for condition (2) is 21%. Thus, only five insurance companies have successfully exercised control over the volatility risk of their respective investments. This stems from their different strategies, whether in terms of investment choices or portfolio diversification.

Compliance with Condition (3): The satisfaction rate for condition (3) is 79%. This means that 15 out of the 19 insurance companies studied responded positively to this condition. This implies that they have sufficient allocation to cope with fluctuations in their respective claims risks.

Compliance with Conditions (1) and (2) combined: The satisfaction rate for conditions (1) and (2) combined is 26%. This means that only five insurance companies have managed to simultaneously satisfy these two conditions.

Compliance with Conditions (1) and (3) combined: The satisfaction rate for conditions (1) and (3) combined is 74%. This means that 14 out of 19 companies have succeeded in simultaneously satisfying these two conditions.

Compliance with Conditions (2) and (3) combined: The satisfaction rate for conditions (2) and (3) combined is 26%. Thus, only 5 out of 19 insurance companies have managed to simultaneously satisfy these two conditions.

Compliance with All Three Conditions: The satisfaction rate for all three conditions is 26%, and the same companies that met this requirement are SAA, CAAR, GAM, ALLIANCE, and CNMA, which also satisfied condition (2).

Non-Compliance with All Three Conditions: The non-satisfaction rate for all three conditions is 5%, and the insurance company CAARAMA is the only one that did not satisfy any of the three conditions in this model.

In summary, it is observed that condition (1) has the highest satisfaction rate, followed by condition (3), while condition (2) displays the lowest satisfaction rate. Although satisfaction with condition (2) is less frequent, it is the most demanding in this model, as all insurance companies that satisfied this condition also managed to satisfy all three conditions.

6. Conclusion

The solvency analysis of insurance companies using the stochastic differential equations model reveals disparate results for different companies. The equilibrium conditions of the model are employed to assess the financial health of companies and their ability to meet obligations to policyholders.

Results vary from one company to another. Some companies have demonstrated satisfactory financial balance by meeting all three conditions, while others have failed to satisfy at least one of these conditions. Imbalances may result from inappropriate financial parameters, excessive risks, or disparities between income and costs.

This model, with its flow states and associated mechanisms, proves to be relevant but also demanding to fulfill. This is evident from the results obtained when evaluating the model based on the financial parameters of the examined insurance companies:

Only 26% of companies managed to meet the model's requirements by satisfying all three required conditions, namely: SAA, CAAR, GAM, ALLIANCE, and CNMA, while 95% satisfied at least one condition. This latter rate is not reassuring, as a quarter of insurance companies (26%) failed to meet two-thirds of the model's conditions. CAARAMA Assurance remains the weak link in this test, as it did not satisfy any of the three conditions.

What can be drawn from this model is its dynamic algorithmic nature, which can yield long-term benefits but certainly requires appropriate means to be implemented. It will likely require a robust and real-time information system to have a relevant and timely view, thus allowing for necessary adjustments if the situation demands it.

In conclusion, the solvency analysis of insurance companies according to the stochastic differential equations (SDE) model highlights significant disparities among different insurance companies. Companies failing to meet the model's equilibrium conditions must reassess their financial parameters to restore financial balance, reduce investment-related risks, and increase reserves. Prudent financial management and regular solvency assessments are crucial to ensuring long-term financial stability. It is essential for these companies to implement strong risk management strategies and closely monitor their financial performance.

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