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Measurement of Credit Rating Levels in the Face of Internal Control Requirements with a Comparative Approach Using Particle Swarm Optimization and Genetic Algorithms

Akbar. Davaran [1], Kumars. Biglar [2*], Mehdi. Beshkooh [2]

[1] PhD Student, Department of Accounting, Qazvin Branch, Islamic Azad University, Qazvin, Iran
[2] Assistant Professor, Department of Accounting, Qazvin Branch, Islamic Azad University, Qazvin, Iran

*** Corresponding author email address**: Kumars.biglar@gmail.com

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A B S T R A C T

Objective: The objective of this study is to evaluate the impact of internal control requirements on the credit ratings of companies listed on the Tehran Stock Exchange.

Methodology: The research utilizes a comparative approach, employing Particle Swarm Optimization (PSO) and Genetic Algorithms to analyze the credit ratings of 101 companies listed on the Tehran Stock Exchange over a 14-year period from 2006 to 2019. The companies were categorized based on whether their independent auditors expressed opinions on internal controls. Descriptive and statistical analyses were conducted to examine the changes in credit ratings before and after the implementation of the internal control requirements.

Findings: The results of the analysis indicate no significant difference in the accuracy of the credit rating predictions made by the two algorithms. Additionally, no notable difference was observed in the credit ratings of the companies before and after the implementation of internal control requirements. This suggests that the internal control regulations did not significantly influence the credit ratings of the companies in the sample.

Conclusion: The study concludes that internal control requirements do not appear to have a substantial impact on the credit ratings of companies listed on the Tehran Stock Exchange. The findings suggest that credit rating agencies may not have experienced significant information asymmetry before the implementation of these requirements, leading to stable credit ratings even after the regulations were enforced. The study recommends a review of the current internal control standards to enhance their effectiveness in improving financial reporting quality and ensuring legal accountability.

Keywords: *Credit Rating, Internal Control Requirements, Genetic Algorithm, Particle Swarm Optimization Algorithm*

1 Introduction

The wave of corporate accounting scandals that emerged at the beginning of the millennium revealed significant weaknesses in the governance system. Managers of some of the largest companies committed corporate fraud and misrepresented information, and worse, these scandals were endorsed by the companies' financial gatekeepers, i.e., their auditors (Hatchett, 2011). The Sarbanes-Oxley Act, enacted in 2002, changed the landscape of finance, accounting, and corporate governance. This law was passed following scandals and bankruptcies of companies such as Enron and WorldCom to reduce managerial misconduct and deceptive accounting in an effort to ensure alignment between the goals of managers and shareholders (Nejadmalayeri et al., 2013). Similarly, in Iran, the Securities and Exchange Organization, following this law and to protect investors' rights, issued the Internal Control Guidelines for issuers listed on the Tehran Stock Exchange in 2012 by implementing Article 18 of the Tehran Stock Exchange Admission Guidelines.

Generally, the internal control structure of an organization, based on the definition provided by the Committee of Sponsoring Organizations of the Treadway Commission (COSO) and the Treadway Commission (1994), is a process implemented by the board of directors, management, and other personnel of the institution. Its purpose is to provide reasonable assurance regarding the achievement of effective and efficient operations, reliable financial reporting, and compliance with applicable laws and regulations (Soleimani & Moghadasi Nikje, 2014). Given that the internal control guidelines clearly define the regulations and specify them separately for all components of the internal control system, and since each company must implement effective internal controls according to its size and type of activity (Mahdavyan et al., 2022), the question arises whether these laws have been effective in reducing the problems they were designed to address. Can the process of documenting, evaluating, and testing all internal controls and reporting on them claim that these controls are operating effectively? Do internal controls provide useful information to informed capital market participants (creditors and credit rating analysts)?

It is evident that an internal control system is a policy designed by the company to provide assurance of the company's effective performance and compliance with all applicable laws (Younas & Kassim, 2019). Implementing effective controls can guarantee that the company conducts operational activities in accordance with applicable laws, including tax laws (Ji et al., 2017). In fact, internal control is a supervisory mechanism aimed at ensuring the financial statements are free of material misstatements (Gleason et al., 2017). Regarding credit rating, internal control requirements may impact credit ratings, as the purpose of internal control requirements is to quickly restore and maintain investor confidence in capital markets (Carter, 2011). On the other hand, the internal control process is designed to provide reasonable assurance regarding the achievement of organizational goals, including the efficiency and effectiveness of operations, reliability of financial information, and compliance with laws and regulations (Coso, 1994).

Therefore, for credit rating organizations that use these statements to assess a company's default risk, this is of great importance, as weak controls can harm the company's financial position and the interests of debt holders (Boulhaga et al., 2022). As a result, internal control requirements provide richer and more accurate information to credit rating analysts. Additionally, since the quality of internal controls is reported by independent auditors, these reports are of greater importance to credit rating analysts due to their accuracy (Cheng & Neamtiu, 2009; Vazifehdoost et al., 2016). Therefore, this research contributes to the existing literature by examining how changes in the information environment affect the credit rating of companies, which ultimately impacts the cost of capital. Moreover, this research contributes to the literature on internal control requirements by documenting the impact of these requirements on changes in credit ratings. Despite the importance of this issue, the impact of internal control requirements on credit ratings has not been given sufficient attention.

2 Methods and Materials

The presented research is of an applied nature and, from a methodological perspective, is of a causal-comparative and ex-post-facto type, as it examines events after they have occurred. Some of the analyses were performed using Excel software, and MATLAB software was used to analyze the optimal level. The data for this research were extracted from the audited financial statements of companies listed on the Tehran Stock Exchange, online databases such as the Codal website, and the official stock exchange database. The following limitations were applied to determine the research sample: (1) The financial period ends at the end of each

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Gregorian year. (2) The fiscal year has not changed during the study periods. (3) The company's shares have been traded for at least six months in a year. (4) The company is not involved in investment, brokerage, or financial activities. (5) The required information for this research is available during the study period. Finally, financial data related to 101 companies over a 14-year period from 2006 to 2019 were analyzed after applying the above limitations.

The main advantage of using metaheuristic methods lies in the limited assumptions required for model formulation, which is not the case in mathematical programming. Therefore, in this research, due to the ability of metaheuristic algorithms to handle various complexities related to practical problems and to reach an acceptable solution, as well as to recover local optimization and control uncertainty in objectives, two population-based algorithms, namely Genetic Algorithm and Particle Swarm Optimization, were used to discover the optimal solution. These algorithms, as one of the intelligent systems, can recognize the nonlinear relationship between inputs and outputs based on the data set and identify the fundamental relationships between them. The advantage of using these algorithms is that the researcher does not need to know the type of relationship between independent and dependent variables. In fact, metaheuristic algorithms are the best method for prediction because they learn from experience. Additionally, these algorithms provide more accurate predictions and do not have common modeling issues such as stability and instability. Therefore, they do not require financial variable preparation to address problems like autocorrelation, multicollinearity, and heteroscedasticity. In these algorithms, each particle in the search space represents a solution to the problem, and it changes its speed based on the best response obtained in the group of particles (the best individual in the group) and the best location it has ever encountered. This speed is added to the particle's position to obtain the new particle position. In subsequent iterations, the best particle in terms of fitness will adjust the movement of other particles, and after repeated iterations, the problem will converge towards the optimal solution. In metaheuristic algorithms, the larger the selected population size, the more accurate the solutions will be, but more computations will be required. In very small populations, the algorithm takes longer to reach a solution, and the solution quality is unsatisfactory. Therefore, to avoid prolonged model optimization execution time and to achieve accurate results, appropriate selection of the population size is essential. Moreover, these algorithms require an objective function to reach the optimal solution, making them applicable to a wide range of problems, from simple to complex. In this study, the Particle Swarm Optimization and Genetic Algorithm were used to examine the credit rating level of companies before and after the implementation of internal control requirements for companies listed on the Tehran Stock Exchange. In this research, each particle or chromosome represents a credit rating index in active companies listed on the Tehran Stock Exchange. Therefore, the goal is to find the optimal level of credit rating before and after the implementation of these requirements.

Table 1

Parameters of the Particle Swarm Optimization Algorithm

Parameter	Value
Particle Population Size	nPop=707
Maximum Iterations	MaxIt=1000
Personal Learning Coefficient	c1=2
Global Learning Coefficient	c2=2.0
Inertia Weight Damping Ratio	wdamp=0.99
Initial Particle Speed	Zero
Replication Function	Repmat

Table 2

Parameters of the Genetic Algorithm

Parameter	Value
Initial Population	1000 Chromosomes
Stopping Condition 1	1000 iterations
Stopping Condition 2	No change in the best chromosomes after 30 iterations
Main Population Size	100

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Crossover Rate	0.8
Mutation Rate	0.2
Selection Method	Roullet Wheel Selection

3 Findings and Results

To determine the credit rating, the Emerging Market Score model, as proposed by Altman (2005), was used in four steps as follows (Altman, 2005): In the first step, corporate credits in emerging markets were analyzed in a manner similar to traditional analysis of U.S. companies using the Z-Score model. Then, the values were compared with Table 3, and the equivalent credit rating was obtained.

$EMS = 3.25 + 6.56X_1 + 3.26X_2 + 6.72X_3 + 1.05X_4$

Where:

X_1: Working capital to total assets ratio

X_2: Retained earnings to total assets ratio

X_3: Earnings before interest and tax to total assets ratio

X_4: Book value of equity to book value of total liabilities ratio

Table 3

Z-Score and Equivalent Credit Ratings

Equivalent Credit Rating	Z-Score	Region	Equivalent Credit Rating	Z-Score	Region
AAA	≥8.15	Financially Healthy	B-	3.75–4.15	Financially Distressed
AA+	7.60–8.15		CCC+	3.20–3.75	
AA	7.30–7.60		CCC	2.50–3.20	
AA-	7.00–7.30		CCC-	1.75–2.50	
A+	6.85–7.00		D	≤1.75	
A	6.65–6.85		BBB-	5.65–5.85	Doubtful Region
A-	6.40–6.65		BB+	5.25–5.65	
BBB+	6.25–6.40		BB	4.95–5.25	
BBB	5.85–6.25		BB-	4.75–4.95	
	B+	4.50–4.75		B	4.15–4.50

In the second stage, the rating is assessed based on the company's vulnerability to currency devaluation. Vulnerability is evaluated based on the relationship between foreign currency revenues minus foreign currency expenses compared to interest expenses and foreign currency revenues against foreign currency liabilities. Finally, the liquidity level is compared with the liabilities due in the coming year. If the company has high (weak) vulnerability, meaning it has low or zero foreign currency revenues or low or zero revenues and liabilities, or a significant amount of foreign currency liabilities with low liquidity, the equivalent rating in the first stage is reduced by three notches. For neutral vulnerability, a one-notch reduction is applied.

In the third stage, the equivalent rating (from the second stage) is compared with the industry-equivalent rating in Table 4. For a maximum one-notch difference up to two notches, the equivalent bond rating from the second stage is adjusted by one notch. For example, if the second stage rating is BBB and the industry rating is BBB, BB+, or BB, the adjustment is a one-notch downgrade. If the difference is more than one notch but less than two notches, a two-notch adjustment is applied. Finally, the industry environment in the specific emerging market country is considered in the analysis.

Table 4

Industry Average Credit Ratings

Industry	Average Credit Rating	Industry	Average Credit Rating
Telecommunications	A+	Energy	A-
Investments	A+	Paper Products	BBB
Oil and Gas Extraction	A+	Insurance & Pensions	BBB
Electrical Equipment	A+	Computers	BBB
Transportation	A+	Communication Devices	BB+

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Food Products	A	Auto Parts	BB+
Sugar	A	Textiles	BB+
Pharmaceutical Products	A	Hotels & Restaurants	BB
Banks	A-	Construction	BB
Multi-Sector Industry	A-	Cement	BB
Leasing	A-	Metal Ores	BB
Automotive	A-	Non-Metallic Ores	BB
Chemical Products	A-	Tiles & Ceramics	BB
Petroleum Products	A-	Basic Metals	B+

In the fourth stage, the rating is adjusted based on competitive position. The third stage rating is adjusted by one notch up (or down) depending on whether the company is dominant in its industry in terms of size, political influence, and management quality. If the competitive position is neutral, the credit rating remains unchanged. Following the research of Jafari and Ahmadvand (2015), this study uses market share (company sales to total industry sales ratio in each year) to examine the company's competitiveness in the industry.

Finally, credit ratings reported in categories (A, AA, AAA, and etc.) are considered discrete ordinal variables and can be treated as a continuous scale called "Debt Repayment Capacity." Some researchers have converted credit ratings to numerical values for use in credit rating regressions. By doing so, a discrete ordinal variable is obtained. Converting credit ratings to numerical values balances the ratings published by various agencies. In some previous studies, the scores assigned to credit ratings have been categorized into seven classes. This classification is also used in the present study.

Table 5

Assigned Scores to Credit Ratings

Score	Credit Rating	Level (Region)	Score	Credit Rating	Level (Region)
7	AAA	Good Investment Level (Financially Healthy)	3	BB+	Low Investment Level (Doubtful Region)
6	AA+		3	BB	
6	AA		3	BB-	
6	AA-		2	B+	
5	A+		2	B	
5	A		2	B-	
5	A-		1	CCC+	Speculative Level (Financially Distressed)
4	BBB+		1	CCC	
4	BBB		1	CCC-	
4	BBB-		1	D	

In this study, companies listed on the stock exchange were divided into two categories based on the implementation of internal control requirements (Articles 12 and 17 of the Internal Control Guidelines):

Companies where the independent auditor has expressed an opinion on internal controls are coded as 1.

Companies where the independent auditor has not expressed an opinion on internal controls are coded as 0.

Table 6 provide descriptive statistics for the companies in the sample. The report on internal controls by the auditor was analyzed based on the content of the audit report for each fiscal year.

Table 6

Descriptive Analysis of Dummy Variable Values (Before the Implementation of Internal Control Requirements)

Time Period	Variable	Symbol	Dummy Values	Frequency	Percentage Frequency	Number of Observations
Before the Implementation of Internal Control Requirements	Report on Internal Controls by the Independent Auditor	DEF	0	667	0.943	707
			1	40	0.057	
After the Implementation of Internal Control Requirements			0	296	0.419	707
			1	411	0.581	

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Given that the variable representing the auditor's report on internal controls is a dummy variable before and after the implementation of internal control requirements, with means of 0.057 and 0.581, respectively, it shows that even with the requirement for auditors to report on internal controls, less than 60% of the companies in the sample during the study period received an independent auditor's opinion on internal controls.

Table 7

Descriptive Statistics of the Research Variable (Before the Implementation of Internal Control Requirements)

Time Period	Variable Name	Symbol	Mean	Standard Deviation	Kurtosis	Skewness	Minimum	Maximum
Before the Implementation of Internal Control Requirements	Credit Rating	CR	2.726	1.310	1.98	0.092	1	6
After the Implementation of Internal Control Requirements			2.782	1.530	1.871	0.308	1	6

Table 7 provide descriptive statistics for the companies in the sample. Given the calculated means for credit ratings before and after the implementation of internal control requirements (2.726 and 2.782), it can be concluded that, on average, the companies' credit ratings fall within the second category (B+, B, B-). In other words, on average, the companies are in the financially doubtful region.

As mentioned, these algorithms have a population-based nature, and the problem must be defined in such a way that these algorithms can optimize it as a population. The results obtained after running the algorithm for 100 generations led to suitable convergence, and Figures below illustrate the path taken by the evaluation function to reach the optimal point using the Particle Swarm Optimization and Genetic Algorithms.

Figure 1

Credit Rating Results Before (Right) and After (Left) the Implementation of Internal Control Requirements (Particle Swarm Optimization Algorithm)

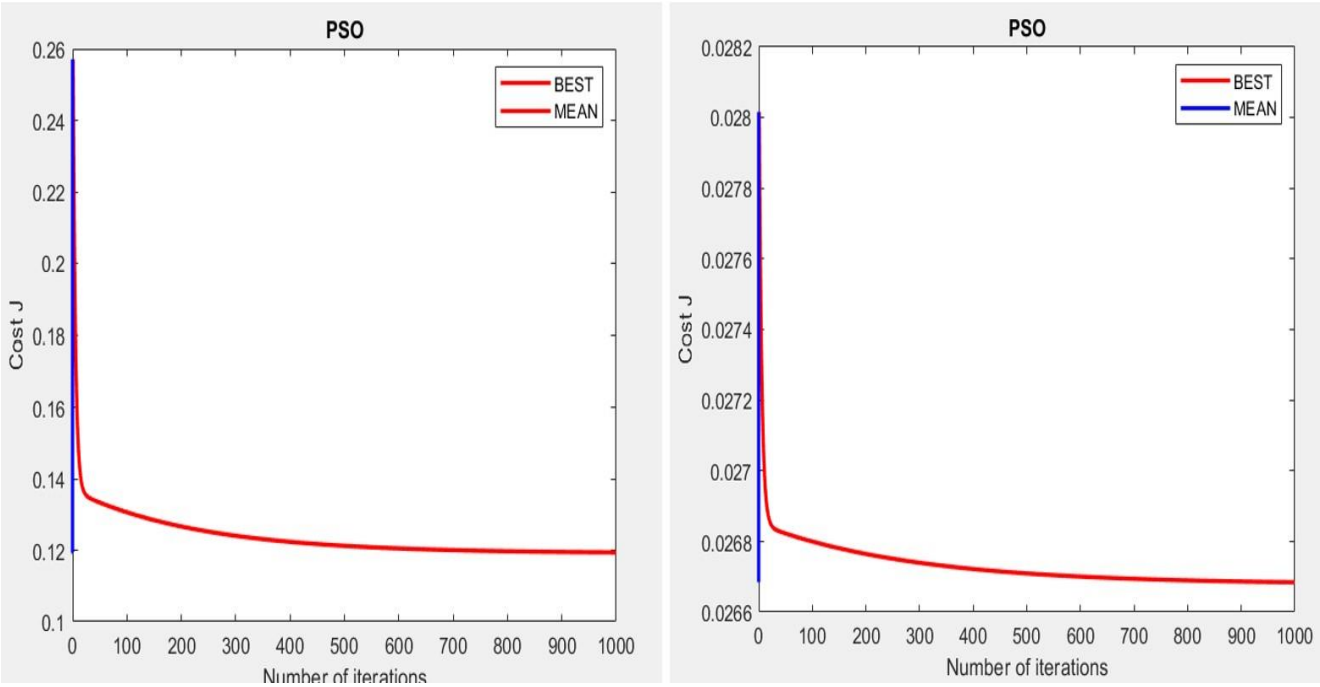

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Figure 2

Convergence Level Results for Credit Ratings Before (Right) and After (Left) the Implementation of Internal Control Requirements (Particle Swarm Optimization Algorithm)

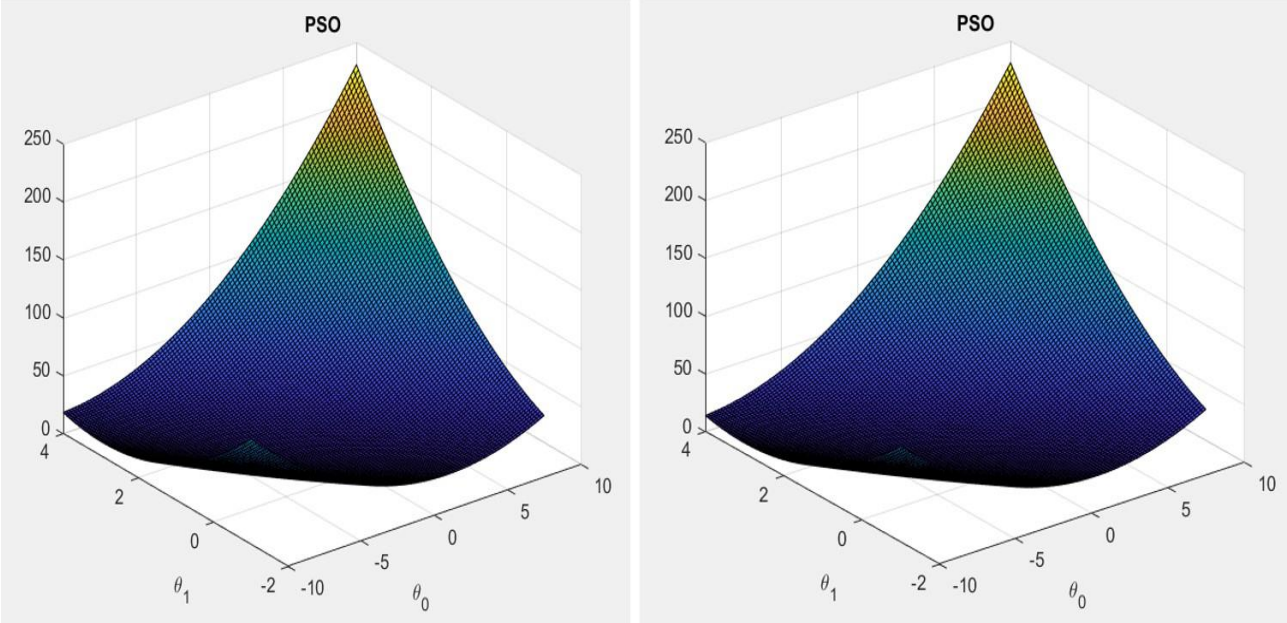

Figure 3

Credit Rating Results Before (Right) and After (Left) the Implementation of Internal Control Requirements (Genetic Algorithm)

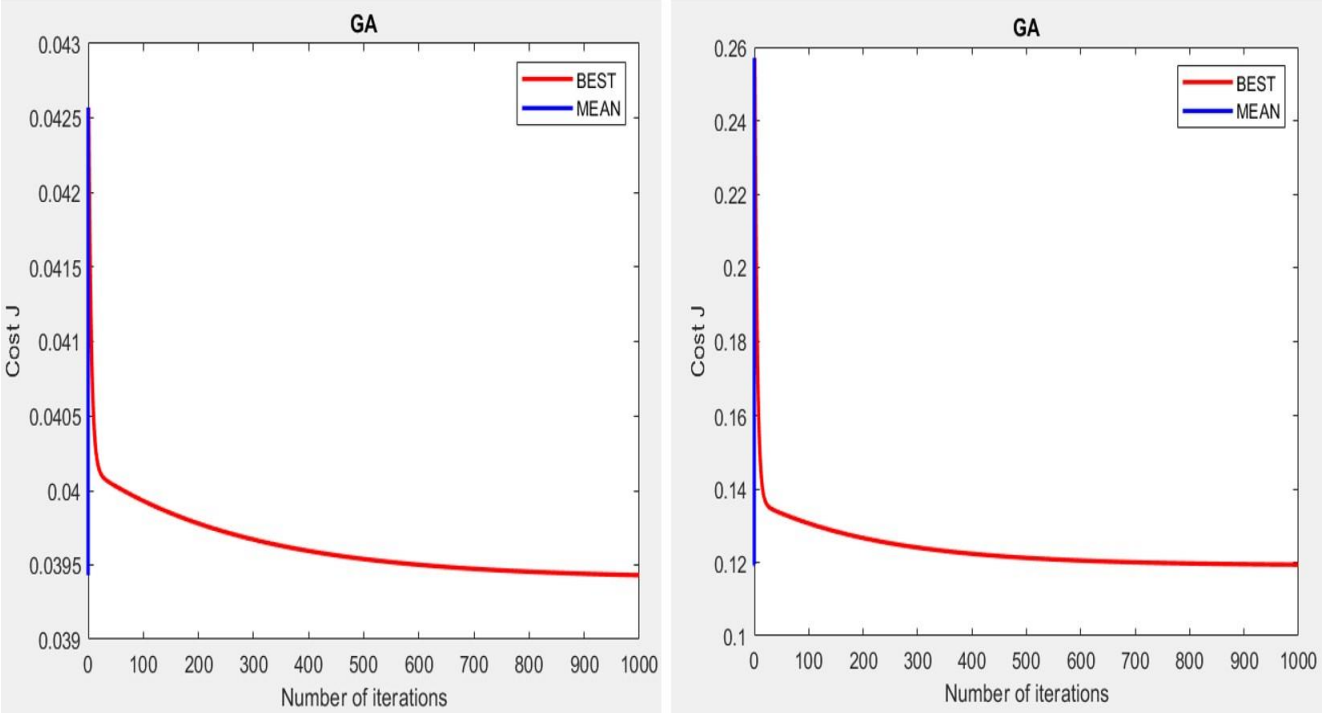

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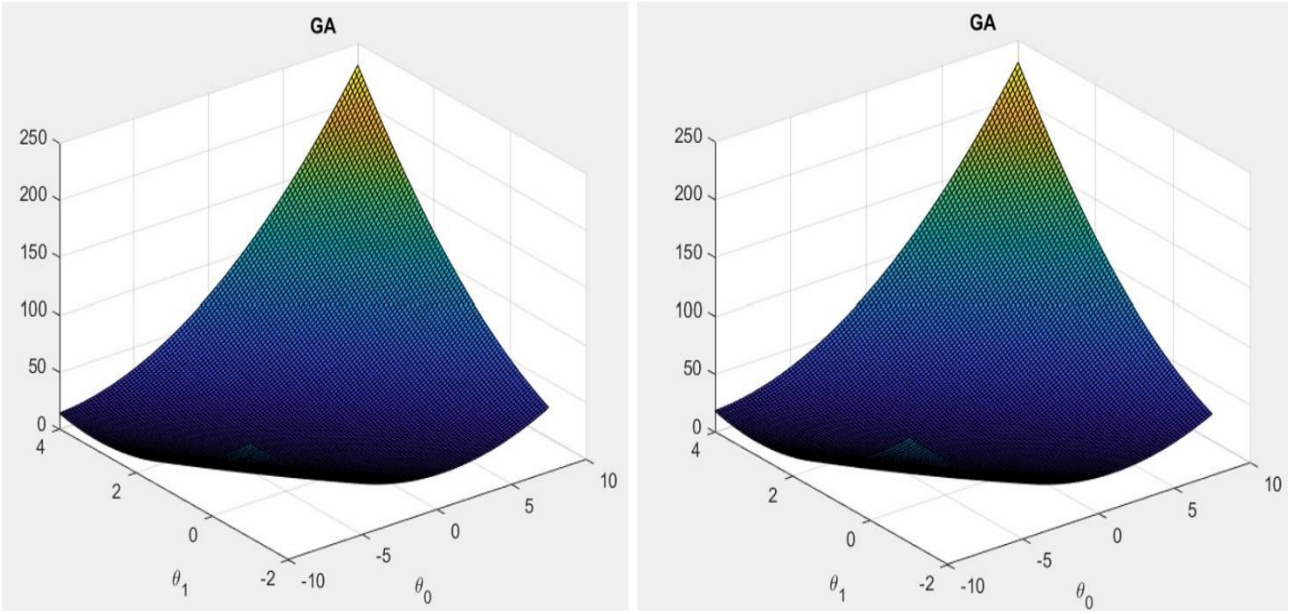
Figure 4

Convergence Level Results for Credit Ratings Before (Right) and After (Left) the Implementation of Internal Control Requirements (Genetic Algorithm)



To evaluate the accuracy and precision of the predictions, the indices of the coefficient of determination (R^2) and root mean square error (RMSE) were used. A lower RMSE value and a higher R^2 indicate acceptable accuracy and superiority over the other algorithm and its ability to predict better according to the criterion. The RMSE and R^2 values for the mentioned algorithms are presented in Table 10. The research question concerns examining the level of credit ratings before and after the implementation of internal control requirements, considering the capability of Particle Swarm Optimization and Genetic Algorithms in predicting the credit ratings of companies listed on the Tehran Stock Exchange. The results obtained from the optimization test show that the Particle Swarm Optimization Algorithm predicts the credit ratings of companies before the implementation of internal control requirements with 99% accuracy and an optimal coefficient of 2, and the Genetic Algorithm with 96% accuracy and an optimal coefficient of 2. Similarly, the Particle Swarm Optimization Algorithm predicts the credit ratings after the implementation of internal control requirements with 98% accuracy and an optimal coefficient of 2, and the Genetic Algorithm with 95% accuracy and an optimal coefficient of 2. Therefore, it can be concluded that no change in the algorithmic prediction pattern is observed before and after the implementation of internal control requirements, and it can be said that there is no significant difference in the accuracy of the algorithms, and the optimal level of credit rating remains constant.

Table 8

Statistical Parameters Evaluated Using Particle Swarm Optimization (PSO) and Genetic Algorithms

Index	PSO R^2	PSO RMSE	Genetic Algorithm R^2	Genetic Algorithm RMSE	Optimal Coefficient (PSO)	Optimal Coefficient (Genetic Algorithm)
Credit Rating Before the Implementation of Internal Control Requirements	0.99	0.23	0.96	0.15	2	2
Credit Rating After the Implementation of Internal Control Requirements	0.98	0.32	0.95	0.28	2	2

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4 Discussion and Conclusion

In recent decades, with the simultaneous increase in failures and accounting scandals in organizations, new laws, standards, and guidelines have been introduced to improve corporate governance principles. To reduce the conflict of interest that plagued the accounting industry and facilitated abusive practices, the U.S. Congress passed the extensive Sarbanes-Oxley Act in 2002, and in Iran, internal control regulations were enacted in 2012 concerning the accounting industry. It is evident that accounting firms were not the only "gatekeepers" that remained silent during corporate financial crises. Rating agencies that monitored bankrupt companies also remained silent, despite internal awareness of the companies' instability. Therefore, rating agencies were publicly criticized for their inefficient performance. Following the sharp decline of companies during the dot-com crash and the 2008 financial crisis, they have come under close scrutiny. Essentially, credit rating agencies are responsible for assessing the likelihood that a company will fulfill its financial obligations. Therefore, their opinion on the safety of investing in a company or specific stock is conveyed to the public. Hence, a company's credit rating is an important part of its information profile, and by reducing issues of information asymmetry, it conveys additional information to market participants. Given the importance of this issue, this study measured the level of credit ratings in response to the implementation of internal control requirements using a comparative approach with Particle Swarm Optimization and Genetic Algorithms among 101 companies listed on the Tehran Stock Exchange from 2006 to 2019.

According to the results obtained from the statistical analysis, there is no significant difference in accuracy between the algorithms, and there is no difference in credit rating levels before and after the implementation of internal control requirements. It appears that companies' credit ratings are not influenced by internal control requirements, and no changes have occurred after the implementation of these requirements. Internal control requirements may not have a significant impact on the informational environment of credit rating agencies. This situation may occur because credit rating agencies may not have suffered from significant information asymmetry before the mentioned requirements. These results align with the second concept of Povel, Singh, and Winton (2007), which suggests that the quality of financial reporting may not worsen and may remain stable after the implementation of internal control requirements, leading to an unchanged credit rating (Povel et al., 2007). The findings of this study do not align with the research by Crabtree and Maher (2012), as they found that internal control disclosures provided positive information to credit rating analysts, which negatively impacted a company's credit rating (Crabtree & Maher, 2012). Additionally, the results do not align with the study by Liu et al. (2021). Their results showed that companies with internal control weaknesses are more susceptible to lower credit ratings compared to those without such weaknesses (Liu et al., 2021). The findings of this study also do not align with the study by Jeon (2021). His results showed that among environmental, social, and governance factors, the governance factor, such as internal controls, disclosure and transparency, and ethical management, has a significant relationship with credit ratings (Jeon, 2021).

Given the research results indicating no difference in credit rating levels before and after the implementation of internal control requirements, it is recommended that policymakers review the current internal control requirements and develop standards for assessing and expressing opinions on the effectiveness of internal controls governing financial reporting to enhance the effectiveness of internal control requirements. This is because the implementation of effective internal controls could have been a powerful tool for legal accountability and improving the quality of financial reporting.

Authors' Contributions

All authors have contributed significantly to the research process and the development of the manuscript.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

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Ethical Considerations

In this research, ethical standards including obtaining informed consent, ensuring privacy and confidentiality were observed.

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