JITCoS : Journal of Information Technology and Computer System
Vol. 2, No. 1; June 2026, e-ISSN: 3109-6182 (Online)
DOI 10.65230/jitcos.v2i1.80
Page 76-84
https://ejournal.multimediatekno.org/index.php/jitcos

Application of Deterministic Simulation Modeling for Capital Structure Robustness Testing: A Case Study in the Capital-Intensive Industry (AGII)

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Submitted **08-04-2026;** Accepted **08-05-2026;** Published **30-06-2026**

ABSTRACT

In the capital-intensive sector, the strategic management of capital structure is often constrained by cost rigidity, where high fixed costs magnify the impact of demand volatility on corporate solvency. This study addresses the methodological gap in static financial analysis by applying Deterministic Simulation Modeling to conduct a Robustness Test on PT Aneka Gas Industri Tbk (AGII). The primary objective is to measure the structural resilience of the firm against operational shocks specifically demand fluctuations attributed to the bullwhip effect and to evaluate the efficacy of refinancing as a risk mitigation strategy. Using audited financial data, the simulation executes specific "what-if" scenarios to project changes in Net Income, Interest Coverage Ratio (ICR), and Financial Distress probability based on the Springate S-Score. The empirical results reveal a significant structural vulnerability: a moderate revenue decline of 5% plunges the baseline performance into a net loss of IDR 5,027 million, confirming the detrimental impact of high operating leverage. However, the simulation demonstrates that a strategic refinancing intervention, reducing the cost of debt from 8.1% to 6.75%, effectively transforms the company's risk profile from fragile to robust. This optimization not only maintains profitability under stress but also significantly lowers the Break-Even Point (BEP), thereby widening the Margin of Safety. The study concludes that deterministic simulation offers a superior, forward-looking framework for management to identify financial "breaking points" and implement proactive liability management to ensure sustainability amidst economic uncertainty.

Keywords: *Deterministic Simulation; Capital Structure Robustness; Cost Rigidity; Refinancing; Financial Distress*

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1. INTRODUCTION

In the dynamics of the modern global economy, the strategic management of capital structure serves as a fundamental pillar for corporate sustainability, particularly within capital-intensive industries where debt financing is inherently characterized by a duality often described as a "double-edged sword." On one hand, leverage acts as a catalyst for welfare improvement and economic growth when utilized prudently and in moderation (Syifa, 2020). For companies with substantial fixed asset requirements such as those in the industrial gas sector debt provides the necessary liquidity to fund capacity expansion and technological upgrades that internal cash flows cannot support. However, historical empirical evidence from advanced OECD economies reveals a critical phenomenon where the unbridled accumulation of debt introduces severe structural vulnerabilities, indicated by the existence of specific debt thresholds; for instance, when corporate debt exceeds approximately 90% of GDP, it transitions from a driver of growth to a significant drag on economic performance (Lestari et al., 2025). This vulnerability is further exacerbated in capital-intensive firms by the phenomenon of cost rigidity, where a structure heavily weighted toward fixed costs interacts detrimentally with supply chain volatilities, such as the bullwhip effect, causing a slight decline in revenue to disproportionately squeeze liquidity and threaten solvency (Garayeta et al., 2022).

The robustness of a firm's capital structure is most critically tested during periods of refinancing or debt restructuring, where profitable firms, contrary to the Pecking Order Theory preference for internal funding, often must rely on external debt to sustain heavy operations (Song & Zhang, 2025).

Research indicates that while profitability typically has a negative correlation with leverage, this relationship weakens during refinancing events as firms actively restructure to realign with an optimal capital structure target (Andiya & Windijarto, 2021). Failure to execute this strategy effectively, especially under unfavorable macroeconomic conditions, can rapidly push a firm into a state of financial distress, defined as a stage of declining financial condition prior to bankruptcy characterized by the inability to meet obligations (Mohammed, 2024). The probability of such distress is influenced by internal factors like the Interest Coverage Ratio (ICR) and external macroeconomic variables such as inflation and exchange rate fluctuations (Dalilah Ulaya, 2022). Furthermore, while Financial Leverage and Operating Leverage serve as theoretical multipliers of earnings, their actual impact on Earnings Per Share (EPS) can be volatile and dependent on external market sectors (Aditya et al., 2025).

This vulnerability is acutely magnified in the industrial gas sector, a unique subset of capital-intensive industries. Unlike general manufacturing, the industrial gas sector requires massive upfront investment in cryogenic air separation units, storage facilities, and complex distribution networks. This creates a cost structure heavily weighted toward fixed costs, leading to extreme cost rigidity. Consequently, these firms face heightened exposure to supply chain volatilities and the bullwhip effect, where even a slight decline in downstream demand (from healthcare, manufacturing, or energy sectors) disproportionately squeezes liquidity and threatens solvency (Garayeta et al., 2022). For companies like PT Aneka Gas Industri Tbk (AGII), which operates in a developing market, these operational risks are further compounded by macroeconomic volatility, specifically fluctuations in exchange rates and interest rates that directly impact the cost of imported technology and debt servicing.

Despite the extensive literature on capital structure and distress prediction, a significant methodological gap remains as existing studies generally fall into regression-based analyses that identify historical correlations or advanced probabilistic studies employing Monte Carlo simulations (Mardiati, 2020). While Monte Carlo simulations are powerful for aggregate risk assessment by generating thousands of random scenarios, they often function as "black boxes" that provide a probability of failure but lack the transparency required for stress-testing specific, causal scenarios relevant to strategic decision-making (Fitriani & Sihaloho, 2024). Furthermore, traditional deterministic tools like standard Break-Even Point (BEP) analysis, while essential for determining sales volume requirements and understanding the margin of safety, are often too static and fail to capture the complex, non-linear dynamics of a multi-variable financial crisis (Ananda & Hamidi, 2019).

To bridge this gap, this study proposes the application of Deterministic Simulation Modeling as a tool for Robustness Testing, representing a distinct novelty in the field. Unlike probabilistic models that rely on random sampling, this deterministic approach uses specific, pre-determined inputs to evaluate the definitive impact of distinct "what-if" scenarios on corporate solvency. This method allows for a granular analysis of how specific changes in fundamental drivers such as a spike in interest rates, a depreciation of the currency, or a shift in cost structure due to operational rigidity mechanistically propagate through the financial statements (Sorge, 2011). By integrating the logic of the margin of safety from BEP analysis with complex pro-forma financial modeling, this study creates a "stress test" framework designed to identify the precise tipping point or boundary condition where the firm's capital structure transitions from safe to distressed (Mohammed, 2024). Consequently, the primary objective of this research is to evaluate the structural resilience of PT Aneka Gas Industri Tbk (AGII) against deterministic economic shocks, aiming to determine how much shock the current capital structure can withstand before breaching solvency covenants. This research provides a practical contribution to management by moving beyond predicting the probability of failure to measuring the capacity for endurance, offering a clear "safety map" that facilitates more prudent refinancing strategies and risk management in a high-stakes operational environment.

2. LITERATURE REVIEW

2.1. Capital Structure in Capital-Intensive Industries: Growth vs. Vulnerability

In corporate finance literature, capital structure decisions are paramount for capital-intensive industries, such as the industrial gas sector. Firms in this sector possess a unique characteristic: the

need for massive fixed asset investment, which is frequently funded through long-term debt. Cecchetti, Mohanty, and Zampolli (2011), in their seminal study, highlighted the dual nature of debt. On one hand, debt functions as leverage for production capacity growth that cannot be funded solely by internal cash flows . On the other hand, debt accumulation creates structural risks. Their empirical study on OECD countries identified a critical debt threshold, where corporate debt exceeding 90% of GDP begins to negatively impact growth (Tandy & Budhi, 2025). For issuers like AGII, this finding implies that maintaining debt ratios below critical thresholds is a prerequisite for sustainability, rather than merely a strategic choice (Murdianto et al., 2025).

This vulnerability is exacerbated by internal cost structures. Song and Zhang (2025) introduced the concept of the interaction between the bullwhip effect in supply chains and cost rigidity. Capital-intensive industries possess rigid cost structures dominated by fixed costs (machine depreciation, infrastructure maintenance) that do not decrease even when sales decline. Song and Zhang found that firms with high cost rigidity face exponential operational risks during demand volatility. In the context of AGII, this implies that a moderate decline in revenue can drastically erode net income, threatening the firm's ability to meet its debt obligations (Song & Zhang, 2025).

2.2. Refinancing Dynamics and Financial Distress Risk

To maintain capital structure robustness amidst cost rigidity, firms often undertake refinancing. Windijarto and Andiya (2021) investigated this phenomenon in Indonesian manufacturing firms and found that refinancing activities significantly alter a firm's risk profile. Refinancing allows firms to restructure expensive debt into cheaper alternatives or extend tenors, thereby weakening the negative relationship between debt burden and profitability. However, this strategy is not without risk. Failure to execute refinancing in a timely manner, especially during deteriorating macroeconomic conditions, can push a firm toward financial distress (Andiya & Windijarto, 2021).

Financial Distress is defined by Syifa and Idawati (2024) as a stage of declining financial condition prior to bankruptcy, often characterized by failure to pay interest or principal. Their study on the transportation sector (also capital-intensive) found that the Interest Coverage Ratio (ICR) is the most significant predictor; the lower the ICR, the more vulnerable the firm is to shocks . Ulaya and Nurfauziah (2022) added an external dimension, finding that inflation and exchange rates significantly impact distress probability in the mining sector. For AGII, which likely has exposure to foreign currency debt or high energy costs, these macroeconomic fluctuations are key stressors that must be tested for robustness.

2.3. Limitations of Conventional Models and the Need for Robustness Tests

Although the literature on capital structure and bankruptcy prediction is extensive, a methodological gap exists regarding how to measure "robustness." Most previous studies, such as Aditya, Rudin, and Suprapty (2025), utilize statistical regression to observe the historical influence of Financial Leverage (DFL) and Operating Leverage (DOL) on performance. While this method explains the past well, it is less effective for answering strategic forward-looking questions like: "Is AGII's capital structure robust if revenue drops 20% tomorrow?".

On the other hand, probabilistic methods like the Monte Carlo Simulation discussed by Hutabarat et al. (2025) offer an approach based on random distributions to predict various possible outcomes. Despite being sophisticated, Monte Carlo simulations often produce outputs in the form of probabilities (e.g., "15% risk of default"), which can sometimes be difficult to translate into concrete action plans for management requiring certainty on the impact of specific scenarios.

2.4. Deterministic Simulation Approach as a Solution

The deterministic simulation in this study expands the BEP concept into a dynamic financial model that tests cause-and-effect relationships definitively (what-if analysis). Unlike Monte Carlo which randomizes inputs, deterministic simulation uses specific "stress" scenario inputs (e.g., interest rate hike of 2% or sales decline of 10% due to the bullwhip effect). This approach allows for precise Robustness Testing to identify the breaking point where the firm's capital structure can no longer support operations, by integrating the understanding of cost rigidity, refinancing risk, and distress prediction into a single deterministic simulation model, this research offers a novel framework for evaluating the financial health of capital-intensive firms comprehensively and actionably.

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3. METHOD

3.1. Research Design

This study employs a quantitative approach using Deterministic Simulation Modeling. Unlike probabilistic methods such as Monte Carlo simulation which utilizes random sampling distributions, this research applies a deterministic framework where input variables are fixed and predefined to test specific cause-and-effect scenarios (what-if analysis). This method is selected to perform a Robustness Test on the capital structure of PT Aneka Gas Industri Tbk (AGII). Specifically, this design serves as a "White-Box" testing mechanism, allowing for the precise tracking of how financial shocks propagate through accounting statements to measure the firm's resilience limit against cost rigidity and refinancing risks.

3.2. Data Sources and Collection

The study utilizes secondary data obtained from the Audited Annual Financial Statements of PT Aneka Gas Industri Tbk (AGII) for the period 2019-2023. Data collection was conducted through documentation from the official Indonesia Stock Exchange website (www.idx.co.id). The data is extracted to populate the simulation's base case, specifically focusing on income statement components (revenue, operating expenses, interest) and balance sheet items (total assets, current liabilities, total debt). Key financial ratios and cost structures from this historical period are averaged to establish the "Base Case" parameters before stress is applied.

3.3. Simulation Model Specification

The simulation program is constructed based on a set of mathematical equations derived from the literature. These formulas function as the computational engine to project the company's financial position under stress.

1. Operational Performance Model (Cost Rigidity Function)

   To simulate the impact of the bullwhip effect and cost rigidity, the model separates total operating costs into fixed and variable components. The projected Earnings Before Interest and Taxes ($EBIT_{sim}$) under a stress scenario is calculated as:

$$EBIT_{sim} = S_{stress} - (VC_{ratio} \times S_{stress}) - FC_{actual}$$

   Where:
   S_{stress} = Revenue under the simulation scenario (e.g., $S_{actual} \times (1 - \alpha)$).
   VC_{ratio}= Historical ratio of Variable Costs to Sales.
   FC_{actual}= Existing Fixed Costs, assumed to be rigid in the short term.

2. Financial Distress Prediction (Springate S-Score)

   To quantify the risk of failure in each scenario, the simulation integrates the Springate S-Score method. This formula is selected for its relevance in predicting distress based on working capital and profitability . The program calculates the score using the formula:

$$S = 1.03A + 3.07B + 0.66C + 0.4D$$

   Where variables are updated based on simulation outputs:

$$A = \frac{\text{Working Capital}}{\text{Total Assets}}$$

$$B = \frac{EBIT_{sim}}{\text{Total Assets}}$$

$$C = \frac{EBT_{sim}}{\text{Current Liabilities}}$$

$$D = \frac{S_{stress}}{\text{Total Assets}}$$

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Decision Rule:

If S < 0.862: The capital structure is classified as Not Robust (Distress Zone).

If S > 0.862: The capital structure is classified as Robust (Safe Zone).

To assess Refinancing Risk, the model calculates the Interest Coverage Ratio (ICR). A lower ICR indicates a higher probability of default during refinancing events.

$$ICR_{sim} = \frac{EBIT_{sim}}{\text{Interest Expense} + (\text{Total Debt} \times \Delta\text{Interest Rate})}$$

Additionally, to measure the buffer against losses, the model calculates the Margin of Safety (MoS) derived from Break-Even Point (BEP) analysis:

$$MoS = \frac{S_{stress} - S_{BEP}}{S_{stress}}$$

3.4. Simulation Scenarios

The deterministic simulation executes three distinct Stress Tests to evaluate robustness:

1. Scenario I: Demand Shock (Operational Stress). The simulation applies a stepwise decline in revenue (e.g., -5%, -10%, ..., -20%) to represent downstream demand volatility caused by the bullwhip effect. This scenario tests the firm's resilience against cost rigidity.
2. Scenario II: Refinancing Shock (Financial Stress). The simulation applies a spike in interest rates (e.g., +100 bps, +200 bps) assuming the company must refinance its maturing debt. This tests the sensitivity of the capital structure to external financing costs.
3. Scenario III: Simultaneous Shock (The Breaking Point). This scenario combines revenue decline and interest rate hikes to identify the specific boundary condition where the Springate S-Score breaches the 0.862 threshold.

3.5. Data Analysis Technique

The analysis compares the Base Case (actual data) against the Simulation Outputs. The robustness of AGII's capital structure is determined by the magnitude of shock required to breach critical thresholds, specifically comparing the results against the macro-level debt threshold of 90% GDP suggested by Cecchetti et al. and the micro-level distress threshold of 0.862.

4. RESULTS AND DISCUSSION

This section presents the empirical findings derived from the deterministic simulation modeling of PT Aneka Gas Industri Tbk (AGII). The analysis focuses on evaluating the robustness of the company's capital structure under stress scenarios and assessing the effectiveness of the refinancing strategy as a risk mitigation tool.

4.1. Shocks Analysis of Shock Impact and Profitability Recovery

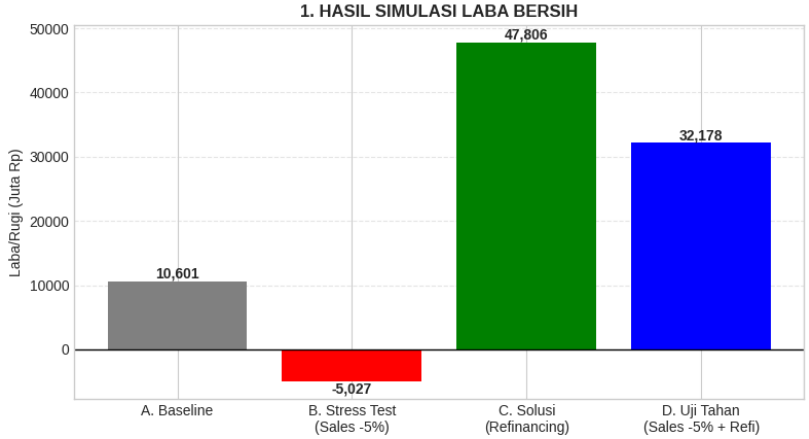

Figure 1. Net Income Simulation Results

The evaluation of AGII's capital structure robustness begins with the "Net Income Simulation Results" (Figure 1). In the Baseline condition, the company operates with a net income of IDR 10,601 million, indicating that the existing capital structure is adequate for supporting operations under normal stable market conditions. However, a fundamental structural vulnerability is exposed during the Stress Test, where a 5% decline in sales representing demand volatility caused by the bullwhip effect causes net income to contract drastically, resulting in a net loss of IDR 5,027 million. This phenomenon confirms the presence of high cost rigidity within the company's operational structure, where fixed costs cannot be adjusted as quickly as revenue declines, thereby exponentially increasing operational risk. This vulnerability serves as an early indicator of financial distress risk, where the inability to generate positive earnings during a market downturn threatens business continuity.

In response to this vulnerability, a refinancing strategy was implemented by reducing the effective interest rate from 8.1% to 6.75%. The simulation results show a surge in net income to IDR 47,806 million under normal conditions. This significant increase proves that interest expense was a dominant cost component burdening previous financial performance. Furthermore, the robustness of this new capital structure was re-tested under the same stress scenario (5% sales decline). The result demonstrates that the company is capable of maintaining a positive net income of IDR 32,178 million. The transformation from a loss-making position to a profitable one under identical pressure demonstrates that the refinancing strategy successfully weakened the negative relationship between debt burden and profitability, creating a "robust" capital structure.

4.2. Risk Profile Shift and Shock Tolerance

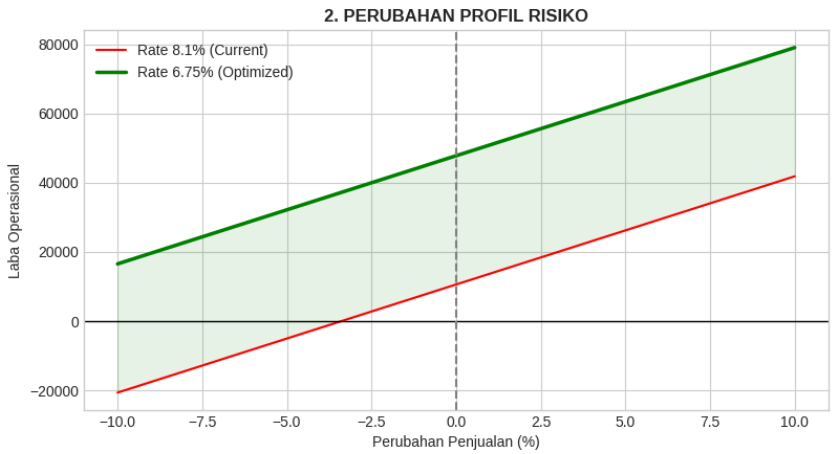

Figure 2. Risk Profile Change

The analysis of "Risk Profile Change" (Figure 2) visualizes the sensitivity of operating profit to percentage changes in sales. The red line represents the risk profile of the legacy capital structure (8.1% interest rate), which features a steep slope and intersects the break-even point (zero axis) at a sales decline of approximately 2.5%. This indicates a very thin risk tolerance, where a minor market contraction or upstream supply chain disruption could immediately push the company into the loss zone. Such a risk profile is highly dangerous for capital-intensive industries with high exposure to macroeconomic volatility.

Conversely, the green line representing the post-optimization capital structure (6.75% interest rate) exhibits a much safer position, consistently staying above the red line and remaining in the positive area (green zone) even when sales are simulated to decline by up to 10%. This upward shift signifies the formation of a liquidity buffer, which expands management's maneuvering space in facing uncertainty. With a flatter risk profile and a higher intercept position, the company possesses a greater capacity to absorb external shocks without breaching critical debt thresholds, thereby effectively lowering the probability of future financial distress.

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4.3. Margin of Safety Enhancement through BEP Reduction

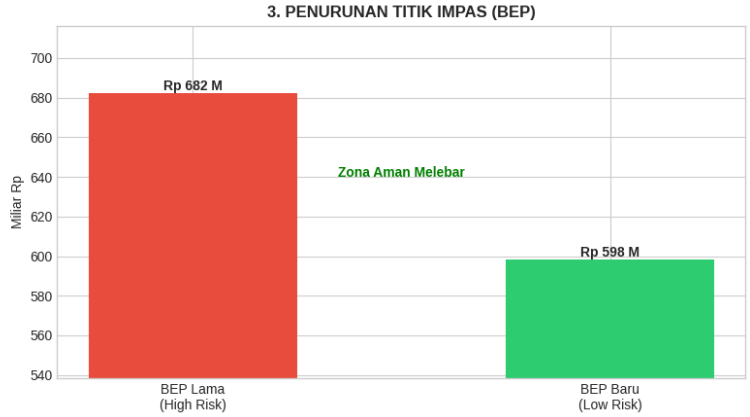

Figure 3. Impact of Budget Equity Simulation

The structural impact of this optimization is further highlighted in the "Break-Even Point (BEP) Reduction" analysis (Figure 3). In the initial condition, the company bore a very high break-even burden, requiring minimum sales of IDR 682 billion just to cover operational and financial costs. This high BEP reflects high capital structure risk, as the company is forced to continuously push sales volume to avoid losses, which is often difficult amidst fluctuating market conditions.

Following the capital structure optimization through refinancing, the break-even point was significantly lowered to IDR 598 billion. This reduction of IDR 84 billion automatically widens the company's Margin of Safety. A lower BEP provides crucial strategic flexibility for management, as the company is no longer under extreme pressure to chase high sales targets solely to maintain solvency. Consistent with the principles of cost-volume-profit analysis, this widening margin of safety is a primary indicator of improved financial health and corporate resilience against the risk of declining market demand.

4.4. Financial Effectiveness of the Solution Strategy

Figure 4. Solution Effectiveness

Figure 4. quantifies the financial impact of the implemented strategy compared to initial expectations. The gray bar indicates a conservative savings target that management might expect, set at IDR 20.7 billion. However, the deterministic simulation results in the blue bar reveal that the actual impact of the refinancing strategy and capital structure efficiency generates an added value of IDR 37.2 billion.

The substantial positive difference between the simulation realization and the initial target confirms that intervention in the capital structure provides a strong leverage effect on profitability. The savings in interest expenses combined with operational resilience create substantial economic

value, which can be reallocated to strengthen working capital or fund other strategic investments. These findings validate that the use of deterministic simulation models is capable of providing accurate and actionable projections for strategic decision-making, transforming uncertainty into measurable and profitable risk calculations.

5. CONCLUSION

This study comprehensively concludes that the application of deterministic simulation modeling serves as a critical, forward-looking mechanism for assessing capital structure robustness within the capital-intensive industry, specifically for PT Aneka Gas Industri Tbk (AGII). The research successfully bridges the methodological gap between static historical analysis and complex probabilistic forecasting by demonstrating that deterministic "stress testing" can precisely identify the tipping points of corporate solvency. The synthesis of the simulation results validates the theoretical premise that firms with high asset intensity are inherently exposed to severe structural vulnerabilities driven by cost rigidity. In this environment, the interplay between fixed operational costs and financial obligations creates a multiplier effect where even moderate fluctuations in downstream demand representative of the bullwhip effect in supply chains can disproportionately erode profitability and threaten the firm's going concern status.

The empirical evidence derived from the simulation scenarios reveals the fragility of the company's baseline capital structure. The stress test indicated that a 5% revenue contraction was sufficient to plunge the company from a profitable position into a net loss, thereby significantly elevating the probability of financial distress as measured by the Springate S-Score. This finding underscores that for capital-intensive entities, the primary risk is not merely the magnitude of debt, but the rigidity of the cash outflows required to service it. When revenue declines, the inability to adjust fixed costs and interest expenses rapidly pushes the Interest Coverage Ratio (ICR) toward critical levels, confirming that high financial leverage acts as a detrimental force during economic downturns unless managed through proactive structural adjustments.

However, the research demonstrates that this vulnerability is not irreversible. The implementation of a strategic refinancing intervention which simulated a reduction in the effective cost of debt from 8.1% to 6.75% successfully transformed the company's risk profile from "fragile" to "robust." This optimization did not merely restore profitability under identical stress conditions; it fundamentally altered the company’s cost structure by significantly lowering the Break-Even Point (BEP). The reduction of the BEP created a wider Margin of Safety, acting as a necessary fiscal buffer that allows management to absorb macroeconomic volatility without breaching solvency covenants. This confirms previous findings that refinancing activities can effectively weaken the negative relationship between high leverage and corporate performance, allowing firms to maintain sustainability even while operating near the critical debt thresholds prevalent in the sector.

Based on these conclusions, this study offers several strategic recommendations for management and directions for future research. Practically, management is strongly advised to prioritize the flexibility of financial burdens over merely increasing leverage for expansion. Given that operational cost rigidity is difficult to reduce in capital-intensive industries, the focus must shift to active liability management; specifically, utilizing favorable market conditions to refinance high-interest debt and extend maturity profiles to maintain a safe Interest Coverage Ratio. Furthermore, management should institutionalize the use of deterministic simulation as a routine risk management tool to monitor the debt threshold of 90% GDP, ensuring that leverage remains a driver of growth rather than a drag on performance. For future academic inquiry, it is recommended to expand this simulation model by incorporating exchange rate volatility as a distinct stress variable, given the high sensitivity of industrial manufacturers to currency fluctuations affecting imported raw materials and foreign debt. Additionally, comparative studies across different sectors could further validate whether the robustness thresholds identified in this study are specific to the gas industry or applicable to the broader manufacturing sector.

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