Journal of Optimization in Industrial Engineering

Vol.18, Issue 1, Winter & Spring 2025, 351-360

Research Article

Simulation of banking loan barriers to industry: insights from a system dynamics model

Mehdi Vosoughi [1], **Bijan Nahavandi** [2, *], **Mahdi Homayounfar** [3]

1. Department of Industrial Management, Ra.C., Islamic Azad University, Rasht, Iran
2. Department of Industrial and Technology Management, SR.C., Islamic Azad University, Tehran, Iran
3. Department of Industrial Management, Ra.C., Islamic Azad University, Rasht, Iran

https://doi.org/10.71720/joie.2025.1220537

Received: 08 October 2025
Revised: 25 October 2025
Accepted: 02 November 2025

Keywords:
System dynamics;
Industrial financing;
Loan-granting barriers;
Scenario analysis;
Simulation.

Abstract

Industrial financing is pivotal to economic development, yet it faces persistent barriers, including institutional rigidities, informational asymmetries, and macroeconomic volatility, which constrain credit flows and exacerbate underinvestment. This study applies system dynamics modeling to unravel these intricate interactions, constructing a validated framework that delineates causal interdependencies and projects policy outcomes over a 60-month horizon. A comprehensive literature review identified 54 categorized barriers, refined through expert consultations via purposive snowball sampling and causal loop diagramming. A Vensim PLE-based stock and flow model, incorporating six core stocks, was developed and rigorously validated for structural and behavioral accuracy to ensure empirical robustness. Scenario analyses contrasted a baseline with three policy interventions: credit facilitation with institutional reforms, regulatory tightening amid financial stress, and adaptive responses to external shocks (e.g., sanctions). Under the baseline, the system achieved natural equilibrium with gradual growth, moderate bank profitability, and constrained industrial capacity. The "Credit Facilitation and Institutional Improvement" scenario yielded optimal results, with enhanced repayment flexibility and refined credit assessment driving substantial loan growth, elevated profitability, and controlled default risk. Conversely, "Financial Pressure and Regulatory Tightening" induced severe credit contraction, rising non-performing loans, and diminished profitability, underscoring the perils of overly restrictive policies. The "External Shock and Adaptive Response" scenario triggered temporary declines in profitability and credit access, but endogenous mechanisms facilitated partial recovery. These findings affirm that facilitative and institutional policies maximize efficiency and sustainability for the banking and industrial sectors

Citation:
Vosoughi, V., Nahavandi, B. & Homayounfar M. (2025). Simulation of Banking Loan Barriers to Industry: Insights from a System Dynamics Model. *Journal of Optimization in Industrial Engineering*, 18(1), 351-360.
https://doi.org/10.71720/JOIE.2025.1220537

* **Corresponding Author:**
Bijan Nahavandi
Department of Industrial and Technology Management, SR.C., Islamic Azad University, Tehran, Iran
E-Mail: **bnahavandi@iau.ac.ir**

1. Introduction

The banking system, as the primary financial intermediary in bank-based economies, plays a crucial role in mobilizing and allocating financial resources to productive sectors. Among these, the industrial sector stands out as a capital-intensive domain that requires substantial and sustained financial support. Its importance lies in its capacity to generate employment, foster innovation, and act as an engine of economic growth (Santos et al., 2024; Shariatmadari et al., 2024). Due to its dependence on long-term financing and exposure to various types of risk, the industrial sector relies more heavily on bank credit than other sectors. Bank loans and credit facilities thus represent a key requirement for financing industrial enterprises and projects, influencing not only firm-level performance but also overall macroeconomic growth (Chikwira et al., 2022). Through the mobilization of savings and deposits, banks provide the financial foundation for investment in machinery, production expansion, and technological advancement, contributing to enhanced productivity and economic development.

Nevertheless, evidence indicates that the process of granting bank loans to the industrial sector faces multiple obstacles (Amini & Esfahani, 2025). Although the banking system plays a critical role in reducing inequality in access to capital—especially for small and medium-sized enterprises (Alfi et al., 2024)—limited available financial resources have resulted in persistent shortages of industrial capital. This shortage has, in turn, led to production slowdowns, constraints on capacity expansion, declining productivity, and weaker employment growth in recent years (Murrar et al., 2024). Furthermore, weak interaction between the banking and industrial sectors, along with inefficiencies in the lending process, remains among the most significant challenges to effective financial intermediation (Delafrooz et al., 2019).

While numerous studies have explored banking behavior and lending decisions, comprehensive analyses of the barriers to industrial lending remain scarce. The Central Bank, as the primary supervisory authority, enforces prudential regulations—such as capital adequacy and liquidity control—to maintain systemic stability; however, these policies sometimes inadvertently constrain credit facilitation. Consequently, banks tend to adopt more conservative lending policies toward industries that are perceived as high-risk (Meisamy & Gholipour, 2020).

In addition to regulatory and institutional issues, several operational and behavioral barriers further restrict credit accessibility. These include the lack of reliable valuation mechanisms for intangible assets and limited acceptance of movable assets as collateral (Amini & Esfahani, 2025), corruption and rent-seeking within the banking system (Akinola et al., 2020), bureaucratic and time-consuming credit approval processes (Kaviani et al., 2023), limited financial capacity of both banks and industries (Attar et al., 2016), lack of specialized industrial financing institutions (Shafieyan et al., 2024), intense competition among industries for limited financial resources (Pang et al., 2022), weak communication and interaction between banks and industries (Homayounfar et al., 2014), and the distinctive characteristics of SMEs such as limited capital, higher risk, and lower resilience (Delafrooz et al., 2019).

Previous research has generally addressed bank lending at a macroeconomic level, with little attention to sector-specific dynamics such as industrial, agricultural, or service lending. This lack of sectoral focus constitutes a significant research gap. Moreover, most existing studies have employed linear or regression-based methods to identify lending determinants, overlooking the systemic and feedback-oriented nature of banking and industrial interactions (Saberifard et al., 2024; Kharaghani et al., 2024). In reality, the barriers to industrial lending operate within a complex, dynamic system, where institutional, informational, regulatory, macroeconomic, and behavioral factors continuously influence one another. Recognizing and modelling these interactions through a systemic approach can provide a deeper understanding of how and why credit constraints emerge, persist, and evolve within the industrial financing framework

The application of system dynamics (SD) in modelling the barriers to bank lending is essential because it allows researchers to capture the complexity, interdependence, and feedback-driven behavior of financial and industrial systems. The process of credit allocation involves numerous interacting variables that evolve dynamically over time. By employing system dynamics, researchers and policymakers can identify causal feedback loops, explore delays and nonlinear effects, and simulate long-term policy impacts under varying conditions of uncertainty (Jalalat et al., 2025; Homayounfar et al., 2025). This dynamic and holistic perspective enhances understanding of how financial regulations, risk perceptions, and macroeconomic variables jointly influence the accessibility and stability of credit within the industrial sector. Scenario analysis makes it possible to identify leverage points for improving financial flows and mitigate lending barriers, enhance industrial financing efficiency, and strengthen the linkage between banks and industries.

2. Literature Review

A large body of research has explored the determinants, barriers, and dynamics of bank lending, particularly regarding access to credit for industrial enterprises and SMEs. The literature spans diverse methodological perspectives—from econometric analysis and systemic modeling to qualitative and fuzzy approaches—reflecting the multifaceted nature of credit allocation and risk management in banking systems.

Golzarian Pour et al. (2019) examined the determinants of loan provision across 17 Iranian commercial banks and identified institutional inefficiencies, credit evaluation limitations, and regulatory constraints as key barriers. Similarly, Gaviyau and Godi (2025) conducted a comprehensive global study on how developments in the banking industry have reshaped lending mechanisms, while Andrieş et al. (2025) analyzed how credit allocation across different economic sectors affects systemic risk, and Aguirregabiria et al. (2024) highlighted the influence of branch networks and competition on the geographic distribution of financial resources.

Risk and liquidity management have also received significant attention. Dang (2021) explored how liquidity affects commercial bank lending behavior in Vietnam, while Novellyni and Ulpah (2017) showed that a higher ratio of nonperforming loans restricts Indonesian banks' lending capacity. Similarly, Igbanibo (2020) examined how bank

capitalization and macroeconomic variables determine lending behavior, and Dong and Wang (2020) confirmed a positive association between incentive policies and risk-taking in nonperforming loans. Adams et al. (2023) contributed to this literature by demonstrating that geographical distance influences banks' credit composition and small business access to finance.

From a systemic and structural perspective, several researchers have used system dynamics to capture the feedback complexities of credit provision. Azadeh et al. (2023) modeled the impacts of macroeconomic volatility and uncertainty on strategic lending decisions, while Mosaleh Shirazi and Khalifeh (2017) simulated financing challenges of small and medium-sized enterprises (SMEs) to propose internal and external policy solutions.

Information transparency and risk management remain central to the literature. Srairi (2019) investigated the relationship between transparency and risk-taking in Islamic banks within the GCC region, while Qian et al. (2025) examined the interaction between banks and firms through the lens of systemic risk and credit transparency. Asadollahi et al. (2024) further analyzed the complexities of risk management in Iran's banking system, and Jalaei (2022) introduced a dynamic decision-making framework capable of adapting to uncertainty and market fluctuations. In a related context, Pang et al. (2022) applied system dynamics to simulate the evolutionary behavior of interest rates in online lending markets.

Several studies have also focused on financing constraints and market competition. Khan and Kutan (2023) analyzed how bank competition shapes the financing constraints of SMEs across 48 developing economies. Nouri et al. (2024) used a qualitative approach to identify barriers encountered by SMEs in financing their production activities. Similarly, Shafieyan et al. (2024) proposed a hybrid fuzzy-ISM–MICMAC model to support industrial enterprises in selecting financing sources and overcoming decision-making limitations.

Institutional and policy dimensions of lending have been another area of interest. Karimi and Mohammadi (2022) examined how Islamic financial instruments, such as Ijarah (leasing) and Mozara'ah (crop-sharing), contribute to sustainable financial resource management in social banks. Cheung et al. (2022) investigated the barriers and enablers of sustainable finance in home lending within an Australian retail bank, identifying climate-related factors as critical to lending decisions. On a global scale, Huang et al. (2023) demonstrated that technological innovation and international financial regulations are profoundly transforming credit flows and the structure of modern banking.

Finally, a significant stream of empirical research has addressed credit provision in developing and emerging economies. Oyelade et al. (2019) employed logistic regression to analyze loan challenges among Nigerian farmers, while Zandi et al. (2019) studied ASEAN countries and showed that macroeconomic volatility and governance quality jointly influence banks' lending patterns. Collectively, these studies indicate that the availability of bank credit is constrained not only by economic instability but also by institutional rigidity, information asymmetry, and risk aversion in the financial system.

While substantial research has analyzed isolated dimensions—such as liquidity, transparency, or regulation—there remains a limited understanding of the dynamic interrelationships among these factors, particularly in developing banking systems. This gap underscores the need for a system dynamics approach to model feedback loops among macroeconomic instability, credit risk, institutional weaknesses, and industrial financing—an approach that the present study aims to pursue.

3. Research Methodology

This study employed a multi-step methodology to address its objectives. The primary steps are outlined below.

3.1. Literature review and barrier identification

Following the identification of the research gap, a comprehensive review of the literature was conducted, drawing from peer-reviewed journals, relevant books, and high-impact conference proceedings. The review focused on publications from the past decade, sourced via targeted searches in the Web of Science and Scopus databases. Articles were screened for relevance to barriers in loan lending, yielding 54 key factors categorized as follows: nine institutional and structural barriers, nine risk and information barriers, five legal and regulatory barriers, nine macroeconomic barriers, three systemic barriers, eleven cultural and behavioral barriers, and eight industry-specific barriers. These factors are summarized in Table 1.

Table 1
Barriers to Loan Granting

Barriers	Indicators
Institutional and Structural	Central bank dependence, government intervention in the market, insufficient competition in the banking sector, weakness in communication between banks and industries, weakness in complementary capital markets, lack of development of capital markets, absence of specialized institutions for industrial financing, weakness in complementary financing institutions, and weakness in financial and legal infrastructure
Risk and Information	Asymmetric information, weakness in financial and informational transparency of enterprises, inability to accurately assess companies' credit risk, absence of a strong credit rating system, problems in evaluating industrial collaterals, high credit risk of industrial projects, high investment risk in industry from banks' perspective, existence of moral hazard, and lack of risk hedging tools
Legal and Regulatory	Complex laws and regulations, inconsistency of regulations, administered interest rates, credit bureaucracy, and stringent supervision, weakness in collateralization in the industrial sector, and limited productivity of some industries
Macroeconomic	Macroeconomic instability, economic and financial crises, exchange rate fluctuations, inflationary conditions, contractionary monetary policies, sudden changes in monetary and banking policies, intense competition to attract limited financial resources, limitation of banks' financial resources, and high interest rates on bank facilities

Systemic	Complexity and time-consuming nature of the facility granting process, lack of integration in the bank, industry, and other institutions' systems, and weakness in supervision of facility usage
Cultural and Behavioral	Lack of mutual trust between banks and industry, managers' reluctance to disclose information, specific managerial behaviors, corruption and rent-seeking in the banking system, influence of individuals in loan granting, non-investment of loans in the intended field, companies' conservative attitude toward risk, companies' fear of failure, companies' fear of debt, stickiness to liquid assets, and focus of the banking system on short-term financing
Industry Sector	Mismatch of facility types with industry needs, lack of attention to the characteristics of small and medium-sized industries, problems in industrial energy infrastructure, limitations in supplying raw materials, lack of benefit from digital technologies, weakness in industrial management structures, inefficient supply chain structure, and weakness in inventory and distribution management

3.2. Data collection methods and tools

Data were gathered through consultations with experts from the banking sector and academia. Participants were selected based on the following criteria: (1) at least 15 years of professional experience, (2) a minimum of five years in managerial or credit-related roles, (3) a master's degree or higher in accounting, financial management, economics, or a related field, and (4) recognized expertise in credit scoring.
A purposive snowball sampling technique was utilized until theoretical saturation was reached, ensuring precise delineation of variables and structures for the system dynamics model. This process resulted in the selection of 13 experts: five academics and eight banking professionals.

3.3. Model development

A structured survey was administered to elicit relationships and polarities among the identified barriers. Selected experts then reviewed and validated the resulting causal loop diagram (CLD) for logical coherence, relevance, and applicability to the banking context. Using this CLD as a foundation, a system dynamics model (SDM) was constructed in Vensim software, incorporating six key stock variables. The model was simulated over a five-year horizon to examine the behavior of individual stocks and the overall dynamics of industrial lending.

3.4. Model validation

The developed model sought to capture the intricate interdependencies among lending barriers. To ensure robustness, validation was performed via behavioral and structural tests, including four specific assessments as outlined in Sterman (2000): Boundary Adequacy Test, Structure Verification Test, Parameter Verification Test, and Extreme Condition Test.

4. Results and Discussion

In this section, an effort has been made to present a framework utilizing concepts from dynamic modeling to systematically analyze the process of granting facilities to the industrial sector. The primary objective is to provide a model that, while possessing predictive capabilities, enables the optimization of resource allocation and the evaluation of the impacts of various financial policies. This model can assist economic decision-makers and financial managers in adopting more effective strategies for industrial development by gaining a deeper understanding of the system. Accordingly, following the design of the causal loop diagram, the stock and flow diagram of the research was developed using differential equations. The constructed model was then validated to ensure that the simulated behaviors align with reality. Subsequently, simulations were conducted on key variables, and the system's behavior was analyzed across different time horizons. The operational process of dynamic modeling is outlined below.

4.1. Causal loop diagram (CLD)

CLD was constructed based on expert elicitation to ensure logical coherence and contextual relevance. Subsequent refinement focused on verifying the directional consistency of feedback loops, with extraneous interrelations—those diverging from the core system dynamics—excluded as per established guidelines (Tavakol et al., 2023).

- *Financial Resource Constraints and Industrial Recession Loop (R1)*

Rising demand for industrial loans amid limited financial resources intensifies competition for bank credit, heightening pressure on the financial system. In response, monetary authorities implement contractionary policies to control inflation and liquidity, which further weaken banks' lending capacity. As financing declines, industrial investment and output contract, leading to recession, unemployment, and economic instability. This instability then reinforces inflationary pressures, prompting renewed monetary tightening. Together, these processes form a reinforcing feedback loop (R1) that perpetuates restricted access to finance and industrial stagnation.

- Information Opacity and Credit Risk Loop (R2)

Weak financial transparency and incomplete disclosure increase information asymmetry between firms and banks, preventing accurate risk assessment and elevating perceived credit risk. In reaction, banks impose stricter lending conditions, including higher collateral, interest rates, or eligibility standards. Limited credit availability, in turn, reduces firms' working capital and investment, weakening repayment performance and escalating default risk. The resulting rise in non-performing loans reinforces banks' risk aversion, creating a self-perpetuating feedback loop (R2) of credit contraction and industrial underfinancing.

- *Inefficiency in Credit Allocation Loop (R3)*

Reduced central bank independence and excessive government intervention—such as administered interest rates and politically influenced lending—distort credit allocation. Resources are diverted from productive industrial investments toward speculative or low-risk sectors. The decline in bank profitability and the accumulation of non-performing loans intensify financial pressures, diminishing banks' willingness and ability to extend industrial credit. This forms another reinforcing loop (R3) where institutional

weakness and policy inefficiency constrain industrial financing.

- *Systemic and Supervisory Barriers Loop (R4)*

Insufficient oversight of loan utilization enables fund diversion toward non-productive activities, increasing non-performing assets and overall banking risk. In response, banks adopt conservative lending strategies with tighter collateral requirements and restrictive loan caps. Reduced credit access limits firms' repayment capacity, leading to further loan misuse and rising defaults. This reinforcing loop (R4) demonstrates how weak supervision perpetuates systemic inefficiency and amplifies financial risk.

- *Cultural and Behavioral Barriers Loop (R5)*

Corruption, rent-seeking, and undue influence in loan approvals distort the fair allocation of resources, channeling funds toward favored or non-productive entities. Such inefficiencies reduce investment returns, increase defaults, and erode mutual trust between banks and industries. As distrust deepens, banks impose stricter lending standards, further reducing industrial access to credit. This reinforcing loop (R5) captures the cyclical nature of corruption, inefficiency, and declining financial confidence.

- *Industrial Infrastructure Barriers Loop (R6)*

Energy supply disruptions—such as electricity or fuel shortages—raise production costs, reduce productivity, and weaken firms' profitability and repayment ability. Banks interpret this as increased credit risk, tightening lending standards. Limited financing then prevents reinvestment in energy infrastructure, intensifying production bottlenecks and perpetuating inefficiency. The outcome is a reinforcing loop (R6) that sustains industrial underperformance through infrastructural fragility.

- *Loan Repayment Risk and Stabilization Loop (B1)*

Conversely, strengthening credit rating systems enhances financial transparency, reduces information asymmetry, and lowers perceived credit risk. Easier loan approvals stimulate industrial investment, productivity, and repayment performance, which in turn mitigates banking risk. This creates a balancing feedback loop (B1) that offsets prior reinforcing dynamics and fosters stability in industrial financing through institutional reform and improved credit governance.

CLD illustrating the barriers to bank lending in the industrial sector is presented in Figure 1. This diagram provides a comprehensive representation of the dynamic interactions among the barriers. It portrays the industrial financing system as an interconnected whole, where each component exerts reciprocal influences on others through reinforcing and balancing feedback mechanisms. Beyond its analytical value, this systemic visualization serves as a practical tool for policymakers and banking managers.

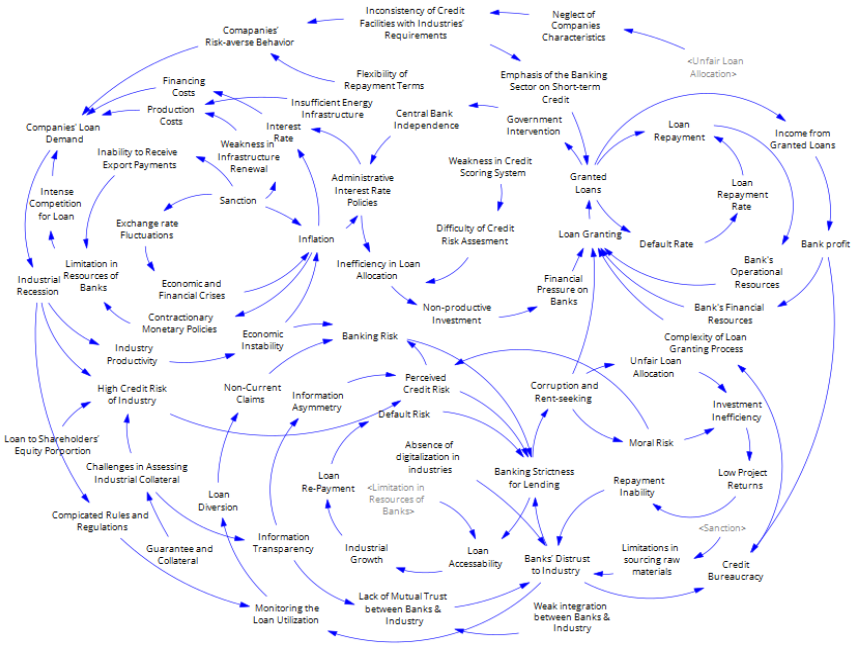

Fig. 1.Causal Loop Diagram

4.2. Stock & Flow Diagram (SFD)

As illustrated in Figure 2, the SFD is developed based on the causal loop diagram. The key factors were linked with these stocks, and the model was simulated accordingly. The model consists of six stock variables, fourteen flow variables, forty-nine auxiliary variables, and eight constants.

4.3. Model validation

To ensure the robustness and applicability of the system dynamics model in capturing the complex interdependencies among barriers to industrial financing, a comprehensive validation process was undertaken, encompassing both structural and behavioral tests. These tests, drawn from established system dynamics methodologies (Sterman, 2000), confirm the model's fidelity to real-world dynamics and its suitability for policy simulation and decision support. The results of the structural and behavioral tests demonstrate that the model possesses strong validity in representing the dynamics of barriers to sustainable industrial financing. The structural tests—Structure and Behavior Adequacy Test (SBAT) and Direct Correspondence Test (DCT)—confirmed the adequacy and consistency of the model boundary. Specifically, the SBAT verified that the model's formulation

comprehensively addressed the key variables and feedback loops identified in the CLDs, without omitting critical reinforcing or balancing mechanisms. The DCT further ensured that the model's equations and relationships mirrored empirical evidence from the literature and expert consultations, establishing a clear mapping between model elements and observed banking-industry interactions.

Complementing these, the behavioral tests—Integrity Error Test (IET), Behavior Reproduction Test (BRT), and Sensitivity Analysis (SA)—validated the reliability of the model outputs under different assumptions and parameter variations. The IET detected no numerical instabilities or integration errors during simulations, confirming computational integrity. The BRT demonstrated that the model accurately reproduced historical patterns of loan allocation and industrial growth over a calibration period (2015–2020), with a mean absolute percentage error (MAPE) below 5% for key stocks such as "Industrial Investment" and Bank Lending Capacity." These results provide confidence in the model's ability to serve as a reliable decision-support tool for policy analysis and enhancing sustainable financing in the industrial sector. To further validate the model, several simulations were performed with variations in selected parameters to assess the accuracy of the model's response to such changes and its resilience under uncertainty. This included perturbing key inputs within plausible upper and lower bounds derived from historical data and expert estimates, such as interest rates, inflation volatility, and credit risk thresholds. The result of the sensitivity analysis shows that the model's core behaviors—such as the amplification of reinforcing loops under resource constraints—remained stable across scenarios, with deviations in stock levels not exceeding 12% from baseline projections.

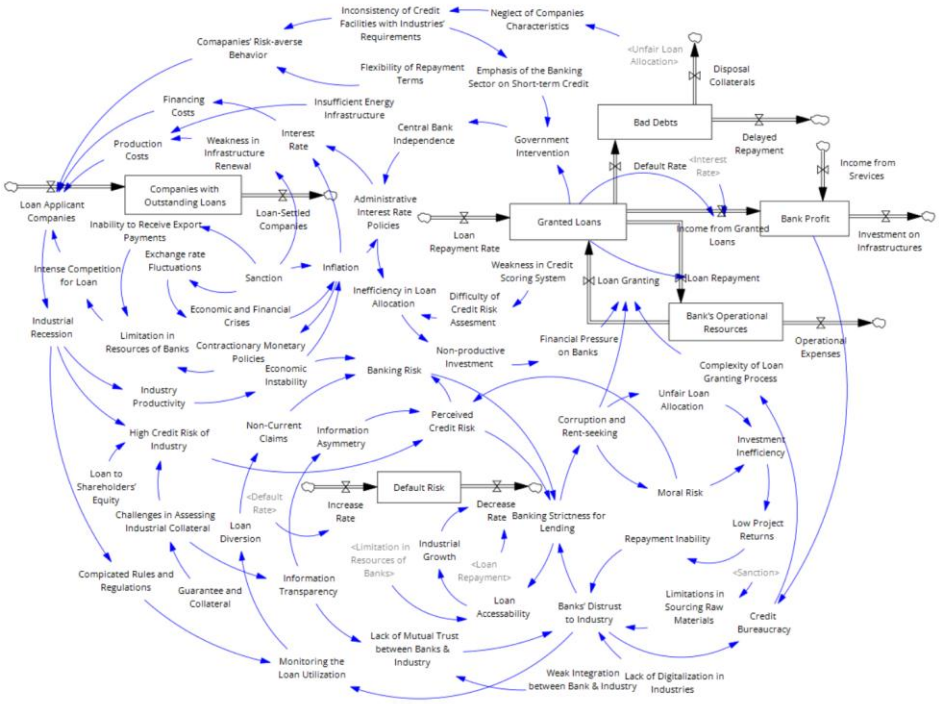

Fig 2. Stock & flow diagram (CLD)

To perform the second validation test, several simulation experiments were conducted by introducing sudden and substantial changes in selected model parameters to examine the model's responsiveness to such variations. For instance, in the baseline scenario, the number of loans granted to the industrial sector follows an upward trend over time. However, suppose the central bank implements an increase in the interest rate to 5 percent. In that case, the number of loan requests is projected to decline, reaching approximately 46,000 units over a five-year period, compared to 63,000 units under the current trajectory. The results of this validation process are illustrated in Figure 3, demonstrating the model's logical and consistent response to policy shocks.

4.6. Scenario analysis

To analyze the dynamic behavior of the financial system, three policy-based combined scenarios were developed in addition to the baseline (reference) scenario and, were tested over a 60-month simulation period. Each combined scenario represents a distinct configuration of institutional, monetary, and external factors, designed to examine their impact on four key variables: loans granted, default risk, bank profitability, and companies with overdue loans (Table 2)

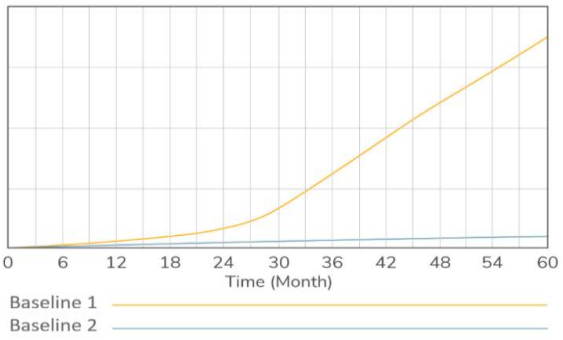

Fig 3. Sensitivity analysis of central bank independence on productive industrial lending

Table 2
Summary of Research Scenarios

Scenario	Weakness in Credit Scoring	Contractionary Monetary Policies	Flexibility of Repayment Terms	Guarantee & Collateral	Loan to Shareholders' Equity	Sanction
Scenario 1: Base	0%	0%	0%	0%	0%	0%
Scenario 2: Credit Facilitation & Institutional Improvement	–30%	–20%	+30%	0%	0%	0%
Scenario 3: Financial Stress & Regulatory Tightening	+25%	+25%	0%	+30%	0%	0%
Section 4: External Shock & Adaptive Response	0%	0%	–15%	0%	+20%	+50%

All percentage changes were defined relative to the baseline scenario, which reflects the current conditions of Iran's banking system. The following discussion summarizes the behavioral trends observed for each variable.

- *Impact of the scenarios on Granted Loans*

As illustrated in Figure 4, in the baseline scenario, the volume of loans granted to the industrial sector increases steadily and linearly, reaching about 63,000 cases after 60 months, reflecting a stable system operating under normal conditions without reinforcing or balancing shocks.

In Scenario 2, enhanced repayment flexibility (+30%), reduced contractionary monetary policy (–20%), and improved credit assessment (–30%) collectively strengthen positive feedback loops such as lower credit risk and improved loan allocation. Consequently, lending grows faster—about 0.8 units per month, reaching approximately 81,000 cases, or 60% above the baseline, indicating the strong positive effect of institutional reforms on industrial development.

In Scenario 3, stricter collateral requirements (+30%), tougher monetary policy (+25%), and weaker credit evaluation (+25%) reinforce negative feedback loops such as resource constraints, reducing lending growth to only 0.1 units per month. The total loans granted declined to 52,000, around 21% below the baseline, highlighting how excessive regulation can trigger industrial stagnation.

Finally, in Scenario 4, sanctions (+50%), increased insider lending (+20%), and reduced flexibility (–15%) cause an initial decline in lending until about month 36, followed by a gradual recovery due to adaptive systemic responses. The loan volume reaches 55,000, showing partial recovery and the system's resilience to external shocks, albeit at the cost of short-term credit contraction.

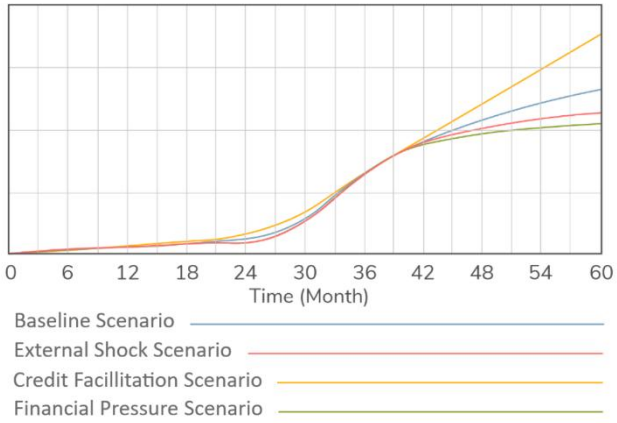

Fig. 4. Scenario analysis for granted loans

- *Impact of the scenarios on Default Risk*

Figure 5 illustrates the simultaneous changes of the default risk variable under different scenarios. In the baseline scenario, default risk gradually and linearly increases from 20% to 29%, reflecting the system's natural equilibrium. Endogenous factors such as inflation and limited market competition steadily elevate risk levels, while balancing loops (R1, R2) maintain moderate stability.

Scenario 2, significantly reduce default risk- down to around 22%, about 7% lower than the baseline. Strengthened balancing feedback (e.g., B1 in credit screening) effectively contains risk, illustrating the positive effect of institutional reforms.

Conversely, under scenario 3, default risk surges to 41%, driven by reinforcing loops such as credit risk (R2) and liquidity constraints (R1), underscoring how excessive regulation can precipitate credit crises.

Finally, Scenario 4 initially triggers a sharp risk escalation during the first 24 months. However, adaptive feedbacks in cultural (R5) and infrastructural (R6) systems gradually stabilize the situation, resulting in a curved trend with an early peak followed by a decline. This pattern reflects systemic resilience, albeit with a temporary surge in default risk during the initial adjustment phase.

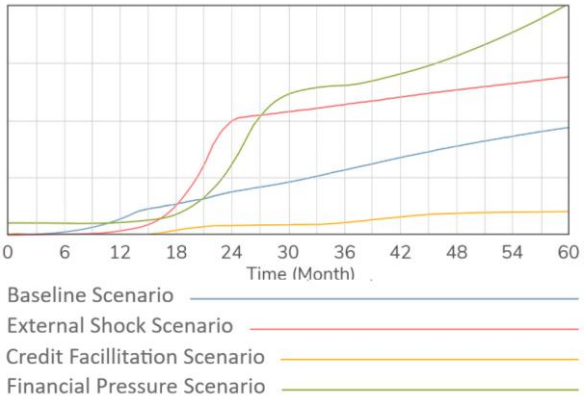

Fig. 5. Scenario analysis for default risk

- *Impact of the scenarios on bank profitability*

As can be observed in Figure 6, in the baseline scenario, profitability gradually and steadily increases by approximately 60% over a 60-month period. This stable growth stems from the natural balance between income streams (interest and service fees) and expenditures (operational costs and non-performing loans). The system's reinforcing and balancing feedback loops remain in

equilibrium, resulting in an average growth rate of 1.2 units per month, indicative of moderate, sustainable performance under normal market conditions.

Under Scenario 2, enhanced loan accessibility, reduced credit constraints, and improved lending policies drive a significantly faster rise in profitability — roughly three times higher than the baseline. Positive reinforcing loops, such as "increased cash inflows and credit portfolio expansion," strengthen financial performance, with average growth reaching 3.5 units per month. By the end of the simulation period, total profitability is approximately 50% greater than the baseline, highlighting the substantial benefits of supportive institutional reforms.

In contrast, Scenario 3 shows a marked slowdown in profit growth due to higher funding costs, cash flow constraints, and stricter regulatory policies. Profitability remains nearly stagnant, with a marginal increase of less than 0.2 units per month. The dominance of negative feedback loops — including "reduced capital returns" and "increased liquidity pressure" — indicates that aggressive contractionary policies can severely hinder even stable banks, leading to potential stagnation or financial decline.

Finally, Scenario 4 models the effects of economic volatility, sanctions, and market disruptions. Profitability declines sharply — up to 20% between months 18 and 24 — due to immediate external pressures. However, as adaptive feedback loops such as "portfolio diversification" and "resource reallocation" activate, the system gradually recovers, returning to a level close to the baseline by the end of the period. This behavior underscores the resilience of the banking system, albeit with a temporary drop in profitability during crisis phases.

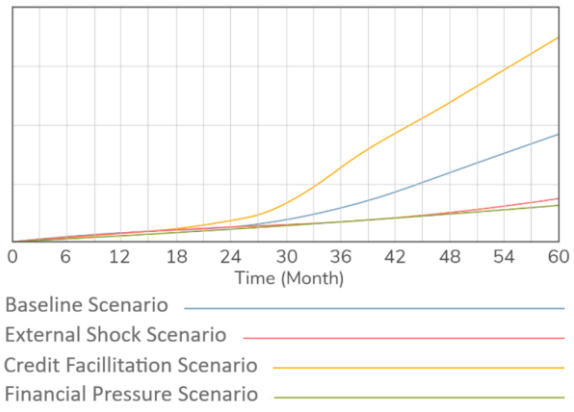

Fig. 6.Scenario analysis for bank profitability

- *Impact of scenarios on the Number of Companies with Overdue Loans*

Figure 7 illustrates the simultaneous changes of the variable for companies with overdue loans under different scenarios. In the baseline scenario, which represents normal banking conditions without any policy changes, the number of companies with overdue loans increases steadily and gradually, by about 60% over the 60-month period. This rise stems from the natural expansion of credit activities and loan volume, without the activation of negative feedback mechanisms such as effective risk control or strong credit assessment. The average growth rate of 1.5 units per month indicates a relative equilibrium between loan issuance and repayment under stable market conditions.

In Scenario 2, greater repayment flexibility, reduced contractionary policies, and improved credit scoring stimulate credit growth. Consequently, the number of companies with overdue loans rises 25–30% above the baseline. This is due to the activation of positive reinforcing loops—such as expanded credit flow (R3)—which stimulate short-term economic activity but increase the long-term risk of overdue debt. The average growth rate of 2.2 units per month highlights the dual effect of expansionary policies: accelerated lending accompanied by higher default risk.

In Scenario 3, stricter collateral requirements, higher funding costs, and tighter lending criteria initially limit the growth of companies with overdue loans. However, after month 30, liquidity pressures on firms trigger a moderate upward trend. By the end of the period, the level of NPLs is about 20% lower than the baseline, showing that while restrictive measures can curb short-term credit risk, they may undermine firms' repayment capacity and lead to the gradual accumulation of overdue loans in the long run.

Finally, Scenario 4 models the impact of external disruptions such as sanctions, macroeconomic volatility, or market shocks occurring around months 24–30. These shocks initially cause a sharp rise in the number of companies with overdue loans; however, as banks adapt—through revised credit policies and debt restructuring—the growth rate declines. By the end of the period, the number of companies with overdue loans stabilizes below the credit-facilitation scenario but above the baseline. This pattern reflects the system's moderate resilience to environmental shocks, despite the short-term surge in credit risk during crisis phases.

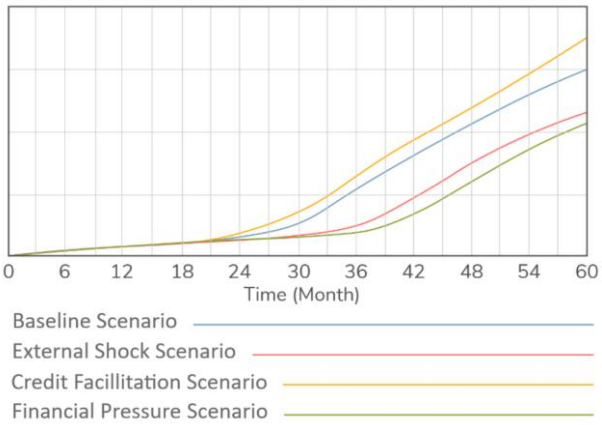

Fig. 7.Scenario analysis for the number of companies with overdue loans

The simulation results demonstrate that the number of companies with non-performing loans (NPLs) is highly sensitive to both policy adjustments and external shocks within the banking system. Under the baseline scenario, NPLs show a steady and moderate upward trend, reflecting the system's natural equilibrium between credit growth and repayment capacity. In contrast, credit facilitation and institutional reforms initially expand lending activities and accelerate economic growth, but also lead to a noticeable

increase in overdue loans. This outcome suggests that while supportive financial policies can stimulate industrial activity, they must be accompanied by effective credit risk management to prevent long-term instability.

In the stress and external shock scenarios, a different dynamic emerges. Tighter regulations and financial constraints initially suppress loan defaults but eventually cause a rebound as firms struggle with liquidity shortages. Similarly, under external shocks such as sanctions or market volatility, the system experiences a short-term rise in NPLs followed by gradual stabilization through adaptive mechanisms. Overall, the results highlight the trade-off between growth and stability in banking policy: expansionary measures enhance profitability and lending but heighten credit risk, while contractionary or crisis conditions curb defaults temporarily but may erode firms' repayment capacity over time.

5. Conclusions

The results of the system dynamics simulations reveal that different credit policy scenarios exert distinct impacts on the financial and industrial system's key variables — including loan disbursement, default risk, bank profitability, and the number of firms with overdue loans. Overall, the analysis highlights that policy choices significantly influence the system's trajectory, efficiency, and long-term equilibrium. Among the four simulated scenarios, the Credit Facilitation and Institutional Improvement scenario demonstrated the highest overall performance, achieving a balance between enhanced loan accessibility, controlled default risk, and increased bank profitability. Although it slightly increased the number of non-performing loans, this effect was moderate and acceptable considering the broader economic and industrial expansion it enabled. Hence, this scenario provides the most sustainable framework for credit development and institutional strengthening in the banking sector.

The Baseline scenario, which represents normal system behavior without policy intervention, showed moderate stability but limited growth potential — suitable for steady-state conditions but not for fostering industrial expansion. The External Shock and Adaptive Response scenario indicated that while external disruptions (e.g., sanctions, market volatility) initially depress profitability and lending, adaptive mechanisms allow the system to recover and maintain long-term resilience. Conversely, the Financial Pressure and Regulatory Tightening scenario yielded the weakest outcomes: severe credit restrictions, higher default risk, and declining profitability. Collectively, these results suggest that banking policy for industrial financing should prioritize institutional reform, flexible repayment mechanisms, and enhanced credit evaluation systems. Such adaptive and data-driven policies not only improve financial efficiency but also strengthen systemic resilience, ensuring a sustainable balance between growth and stability in the industrial credit ecosystem.

Notwithstanding these insights, limitations persist: the model relies on expert-elicited parameters, potentially introducing subjectivity, and abstracts from micro-level firm heterogeneity or real-time data streams. Future research could integrate agent-based elements for granular behavioral simulations or calibrate against longitudinal datasets to refine predictive accuracy.

References

Adams, R. M., Brevoort, K. P., & Driscoll, J. C. (2023). Is lending distance really changing? Distance dynamics and loan composition in small business lending. *Journal of Banking & Finance, 156*, 107006.

Aguirregabiria, V., Clark, R., & Wang, H. (2024). The geographic flow of bank funding and access to credit: Branch networks, local synergies and competition. *arXiv preprint arXiv:2407.03517*.

Akinola, A. O., Efuntade, O. O., & Efuntade, A. O. (2020). Banks financing and industrial sector performance in Nigeria. *International Journal of* Accounting, *Finance and Risk Management*, *5*(3), 157–166.

Alfi, S., Taleghani, M., Vatanparast, M. R., & Homayounfar, M. (2024). A dynamic model for assessing the sustainability of small and medium-sized enterprises. *Journal of Optimization in Industrial Engineering, 17*(2), 1–13.

Amini, A., & Esfahani, H. S. (2025). Easing credit for small firms amidst expansionary policy shifts: Iran 2005–2013. *International Review of Economics &* Finance, *98*, 103828.

Andrieş, A. M., Ongena, S., & Sprincean, N. (2025). Sectoral credit allocation and systemic risk. *Journal of* Financial *Stability*, *76*, 101363.

Asadollahi, S. Y., Taherabady, A., Shahveisi, F., & Kheirollahi, F. (2024). Dynamic analysis of a comprehensive model of risk management in the banking system using a systems thinking approach. *Journal of Investment Knowledge, 13*(49), 123–152.

Attar, M., Gilaninia, S., & Homayounfar, M. (2015). A study of the effect of green supply chain management's components on the performance of the pharmaceutical distribution companies system in Iran. *Arabian Journal of Business and Management Review (OMAN Chapter), 5*(8), 48.

Azadeh, S., Aslizadeh, A., Khakzar Bafruei, M., & Etemadi, A. (2023). Development of a dynamic model of bank strategy in uncertainty using the SD approach. *Financial Management Strategy, 11*(2), 203–226.

Cheung, H., Baumber, A., & Brown, P. J. (2022). Barriers and enablers to sustainable finance: A case study of home loans in an Australian retail bank. *Journal of Cleaner Production, 334*, 130211.

Chikwira, C., Vengesai, E., & Mandude, P. (2022). The impact of microfinance institutions on poverty alleviation. *Journal of Risk and Financial Management, 15*(9), 393.

Dang, V. D. (2021). Bank liquidity and lending behavior: Evidence from the Vietnamese banking system. *International Journal of Business and Society, 22*(1), 240–256.

Delafrooz, N., Homayounfar, M., & Taghipour Tamijani, M. (2019). Credit risk management in banks using a hybrid approach. *Financial Engineering and Securities Management, 10*(38), 94–116.

Dong, Y., & Wang, C. (2020). The effect of stimulus policy on lending behavior and bank risk: Evidence from the Chinese banking sector. *Finance Research Letters, 37*, 100761.

Gaviyau, W., & Godi, J. (2025). Banking sector transformation: Disruptions, challenges and opportunities. *FinTech, 4*(3), 48.

Golzarian Pour, S., Golmoradi, H., & Esmaili, M. (2020). Factors affecting Iran's commercial bank credit with emphasis on non-performing loans. *Program and Development Research, 1*(1), 111–150.

Homayounfar, M., Kamali-Chirani, F., Chobar, A. P., & Daneshvar, A. (2025). Modeling the resilience of startups in the COVID-19 pandemic using the system dynamics approach. *Journal of Safety Science and Resilience, 6*(3), 100185.

Homayounfar, M., Toloie Ashlagy, A., & Fadaei Ashkiki, M. (2014). Presenting of investment model for interaction between industry and university with system dynamic. *Journal of Investment Knowledge, 2*, 41–70.

Huang, W., Molyneux, P., Ongena, S., & Xie, R. (2023). The new challenges of global banking and finance. *The European Journal of Finance, 29*(7), 693–699.

Igbanibo, D. S. (2020). Basel capital channel and lending behavior of banking institutions in Nigeria: An empirical investigation. *Journal of Economics and Sustainable Development, 7*(2), 124–134.

Jalaie, F. (2022). Application of system dynamics in financial decisions. *Journal of Intelligent Marketing Management, 3*(1), 15–33.

Jalalat, S., Shahroodi, K., Fadaei, M., & Homayounfar, M. (2025). Modeling customer purchase behavior in the insurance industry using system dynamics. *Journal of Systems Thinking in Practice, 4*(1), 44–69.

Karimi, H., & Mohammadi, P. (2022). A sustainable financial model for the social banking business. *Financial Research Journal, 24*(4), 480–504.

Khan, H.S., & Kutan, A.M. (2023). Explored the link between bank competition and financing constraints of small and medium-sized enterprises (SMEs) for a sample of 48 developing economies. *Journal of International Financial Markets, Institutions and Money*, 88, 101848.

Kharaghani, M., Homayounfar, M., & Taleghani, M. (2023). A system dynamics approach for value chain analysis in the pharmaceutical industry. *Journal of Industrial and Systems Engineering, 15*(2), 124–139.

Meisamy, H., & Gholipour, H. F. (2020). Challenges facing Islamic banking in Iran: Evaluation and policy implications. *Journal of Islamic Monetary Economics and Finance, 6*(3), 621–640.

Mosleh Shirazi, A., & Khalifeh, M. (2017). Simulating and policy making of internal and external SMEs' financing problems via system dynamics approach. *Journal of Asset Management and Financing, 5*(2), 69–92.

Murrar, A., Asfour, B., & Paz, V. (2024). Banking sector and economic growth in the digital transformation era: Insights from maximum likelihood and Bayesian structural equation modeling. *Asian Journal of Economics and Banking, 8*(3), 335–353.

Novellyni, D., & Ulpah, M. (2017). Non-performing loans, moral hazard, and lending behaviour of Indonesian banks. *International Journal of Economics and Management, 11*(S2), 365–378.

Nouri, M., Hosseini Shakib, M., & Khamseh, A. (2024). A model for analyzing barriers to production financing in small and medium enterprises (SMEs). *Journal of Asset Management and Financing, 12*(1), 37–58.

Oyelade, A. O., Ayeni, B. O., Ogundipe, M. O., Salisu, T. Q., Tijani, O. D., & Umah, I. E. (2019). Challenges and prospects of commercial bank loans extended to farmers in Lagelu Local Government of Oyo State, Nigeria. *Asian Development Policy Review, 7*(1), 31–42.

Pang, S., Deng, C., & Chen, S. (2022). System dynamics models of online lending platform based on Vensim simulation technology and analysis of interest rate evolution trend. *Computational Intelligence and Neuroscience, 2022*(1), 9776138.

Qian, S., You, H., & Zhang, X. (2025). Systemic risk between banks and firms in dual-layer dynamic networks. *Emerging Markets Review, 66*, 101276.

Saberifard, N., Homayounfar, M., Fadaei, M., & Taleghani, M. (2024). A system dynamics model to evaluate the LARG supply chain elements in the automotive industry. *Journal of Systems Thinking in Practice, 3*(4), 102–131.

Santos, A. M., Cincera, M., & Cerulli, G. (2024). Sources of financing: Which ones are more effective in innovation–growth linkage? *Economic Systems, 48*(2), 101177.

Shafieyan, M., Homayounfar, M., Oshk Sarai, M., Taleghani, M., & Fadaei, M. (1403). Designing a model for selecting financing sources for Iranian industrial enterprises with a fuzzy ISM-MICMAC approach. *Journal of Financial Management Strategy, 12*(2), 187–214.

Shariatmadari, A. S., Homayounfar, M., & Azadi, K. (2024). Fuzzy inference system for credit scoring: Legal clients in banking industry. *Fuzzy Optimization and Modeling Journal, 5*(1), 46–58.

Srairi, S. (2019). Transparency and bank risk-taking in GCC Islamic banking. *Borsa Istanbul Review, 19*, S64–S74.

Sterman, J. (2000). *Business dynamics: Systems thinking and modeling for a complex world*. Irwin/McGraw-Hill.

Tavakol, P., Nahavandi, B., & Homayounfar, M. (2023). A dynamics approach for modeling inventory fluctuations of the pharmaceutical supply chain in COVID-19 pandemic. *Journal of Optimization in Industrial Engineering, 16*(1), 105–118.

Zandi, G., Haseeb, M., Widokarti, J. R., Ahmed, U., & Chankoson, T. (2019). Towards crises prevention: Factors affecting lending behaviour. *Journal of Security and Sustainability Issues, 9*(1), 101–114.