A Quantitative Measure for Financial Resilience of Firms: Evidence from Tehran Stock Exchange

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Abstract

Recent financial crises have strained the performance of different firms, and it has challenged investors to invest in these firms' stocks. Measuring firms' resilience from a financial standpoint in terms of crises is an important indicator for investors. Logically, investing in firms with higher historical financial resilience is more attractive for investors. In the literature, resilience is defined as anticipating, preparing, responding, and adapting to incremental change and sudden disruptions to survive and prosper. In this paper, the concept of financial resilience has been studied from various dimensions, and its quantification approaches are examined. The models developed in this paper are for calculating financial resilience in terms of key indicators, Value at Risk, and Conditional Value at Risk. Then, by comparing each of these methods, it has been tried to verify the methods by applying quantitative data of four bankrupt and four non-bankrupt firms listed on the Tehran stock exchange in recent years. The results show the proper performance of the proposed measure in expressing the concept of financial resilience in critical conditions.

Keywords: Financial crisis, Financial Resilience, Financial risk, Value at Risk, Tehran Stock Exchange.

1. Introduction

Investors are generally looking for profitable firms to investment. One of the factors that may tempt investors, along with technical and fundamental analyses to choose a stock is its historical performance in market shocks [1]. Naturally, all firms have experienced crises and risks at different times. In general, a risk is an event that affects the organization's goals, either positively or negatively [2]. In one classification, the risks inherent in a business are divided into three categories as follows. The first category includes risks that a firm has no control over and is only affected by them. The second category includes risks affected by the firm, but this impact is minor and most absorbed. The third category includes risks that affect the firm's financial aspects, but the firm also has the tools to control those risks. For investors, however, this risk will emerge as a financial risk. Financial risk is the potential to face a financial loss and the uncertainty inherent in developing a capital [3]. Investors need to look at financial risk management tools to control this risk and consider different risk-return scenarios [4]. Financial risk management consists of identifying and measuring financial risk, analyzing and evaluating it, formulating financial risk control strategies, responding and executing process,

and monitoring and controlling.

Traditional financial risk management has a rigid structure based on knowledge, analysis, strategy formulation, execution, and control. The review of previous studies show that the financial risk management strategies and responses are traditionally in the face of practicality has not a good experience. This weakness has existed because of disregarding the synergistic effects of risks on the network and the overlapping them, lack of unifying the whole risks, and the approach of integrating them [3]. The main focus of the financial risk management process is on identifying, measuring, responding, and controlling financial risks, as well as aspects of operational risk in this process. The overall financial risk management process does not measure the viability of an entity against external shocks and risks affecting a firm. In the global economic downturn of 2007, it has been observed that just having a plan and running a program cannot be useful and that performance needs to be measured. There must be an appropriate mechanism in place, having the least effect on performance reduction when changing financial performance.

Therefore, investors are looking for a concept that can express the firm's situation in the face of crises with a simple and accurate measure. This concept has been developed with the keyword of resilience in the literature. The concept of resilience is the ability to measure the effectiveness of risk response plans practically and to show the strength of a business in the face of risks or shocks. Indeed, it refers to a system's ability to return to the normal situation following a disturbance event [5]. Concepts such as stability, robustness, fault tolerance, flexibility, reliability, survivability, and agility are commonly mentioned alongside resiliency. These concepts are also found in the definition of Walker, Holling, and Carpenter [6]. In their view, resilience is the capacity of a system to absorb the effects of a shock as well as to return to its normal level when changes occur while its functions, structure, institutions, and feedback persist. From a financial viewpoint, resilience is the ability of a financial institution to absorb short-term shocks, including financial shocks, i.e., exogenous changes and types of business risks, and to maintain performance through long-term economic changes [7].

From Maurer [8], financial resilience has four aspects: consistency, redundancy, rapid recovery, and resource adequacy. A review of the articles in the field of resilience shows that as we get closer to recent years, an increasing number of articles aimed to provide an approach to calculate resilience. Resilience has been considered in different areas. A review of the trends shows that although the number of articles in various fields increases, there are still areas for the concept of entirely restricted resilience. In addition, there is a lack of quantitative integrated approaches in most areas. So, there is a need for a precise measure to calculate financial resilience quantitatively. Since firms' financial performance can be seen in the value of their stocks, a number of articles have used the market index to calculate resilience [9]. With the same idea in this paper, financial resilience has been calculated using firms' stock value. For this purpose, financial resilience has been measured in three cases. In the first case, resilience means a total decrease in financial performance from the beginning of the shock period. In this case, from the beginning of the stock's devaluation until the end of this period, the total amount of the decrease is obtained. In the second case, financial resilience is generally calculated as the number of stock prices, which is below the Value at Risk of those stocks at a given time after the crisis. The concept of Value at Risk (VaR) was developed to

determine an expected loss according to a predetermined confidence level. This concept makes it possible to warn an investor about the risk in the event of a loss in investment and inform investors of the necessary steps [10]. Since this value is considered a limit for loss, in this paper, crossing this point is considered to be a critical period of financial value, and financial resilience in the second model is considered according to it. In the third case, the financial resilience value is calculated using the conditional value at risk concept, assuming that the cause of the crisis has been identified, and its effect on reducing system performance is calculated. In fact, the concept of conditional value at risk (CoVaR) can be considered as VaR, with the exception that the share of external factors, which is the cause of a shock for financial performance, is considered as systemic risk in CoVaR [11]. In the third model of paper, the cause of shock and its effect is considered, and financial resilience is calculated based on financial performance, which overpasses the CoVaR.

Given that there is no precise approach in the literature that can show the financial resilience of firms quantitatively in a certain period of time, in this paper, a measure of financial performance has been developed based on five financial indicators of stock prices, earnings before interest and taxes, the ratio of total liabilities to the total value of the company's assets, working capital on total assets, and earnings per share. Therefore, as a contribution of this study, standard approaches of VaR-based (risk calculation), and CoVaR-based (systemic risk calculation) measures have been developed.

In the following sections, first, the background is presented. Next, a quantitative measure will be proposed, and the available historical data will be used to validate the proposed measure. For this purpose, by analyzing the data of eight stocks listed on the Tehran Stock Exchange from 2010 to 2018, firms' financial resiliency that has gone bankrupt in recent years will be compared with others. Finally, different methods in calculating financial resilience are discussed.

2. Background

Financial resilience was first defined by McDonough in 2003. In his view, the concept of resilience was the unaccompanied means of controlling the costs of an institution in the face of rapid inflation at that time in the United States [7]. In the 2000s, financial resilience was first explored at the household level as a way of controlling the financial crisis in a family. A number of other studies have also explored the financial resilience in the public sectors and economics of countries and referred to strategies for combating economic factors' turbulence, including inflation, exchange rate, and macroeconomic parameters.

The year 2008 can be considered as a turning point in the development of financial resilience research. There has also been a significant increase in the literature on the issue of resilience after the 2008 financial and economic crisis. The most important studies in this field are summarized in Table 1.

A review of the literature in this area shows that economic resilience is a tool for controlling the risks affecting a country's macroeconomics. On the other hand, financial resilience is a financial institution's ability to control its relevant risks. Given that evaluating financial resilience depends on particular indicators, we examine the relevant indicators introduced in the literature. These indicators are mainly derived from qualitative recommendations for the financial resilience of financial institutions. It is important to consider these indicators when

developing a quantitative measure for calculating and improving financial resilience. Some of these indicators are controllable by an institution, and some of them will merely result in the institution's passive performance. In general, resiliency assessment methods can be divided into two groups: qualitative and quantitative. The qualitative group includes methods that evaluate the resilience of a system using qualitative information. This group consists of two categories of conceptual frameworks and quasi-quantitative indicators. Conceptual framework development methods use approaches to develop a framework based on questionnaires for determining resilience (refer to Alliance [12] on Resilience of Socio-Environmental Systems). Quasi-quantitative methods usually calculate the resilience based on quantifying a questionnaire's results using fuzzy numbers or Likert scale (refer to Galyin et al. [13] research on social resilience). Other methods used in this area include developing logistic regression models and the degree of resilience classification for a financial institution. Another approach in this area could be to use clustering algorithms to compute a financial institution's degree of financial resilience [14].

Quantitative methods include two groups of general resilience methods and structure-based modeling methods. General resilience methods provide little tools for evaluating resilience by measuring the system's performance regardless of its structure. General methods of financial resilience are approaches that do not inherently involve probability in computation; however, these methods include the system resilience triangle based on the recovery time and system performance degradation developed by Bruneau et al. [5] and Zobel [15]. The probabilistic methods are the other type of general quantitative methods. In these types of methods, resilience is calculated through the probability of different levels of initial post-crisis system performance decline and the probability of different time intervals for recovery (refer to Chang and Shinozuka [16] refining an Electricity System).

Structure-based approaches examine how a system structure affects the system resilience for which the system's behavior is studied, and then its characteristics are modeled and simulated. In fact, this approach aims to analyze the change of the system performance and analyze its resilience (not the resilience calculation). The structure-based methods are divided into four groups of optimization models, simulation models, fuzzy logic models, and factor-based models. Optimization approaches develop mathematical models and analyze different scenarios on the system either decisively / fuzzily or randomly and seek to find the best strategy from the standpoint of resiliency (refer to Sahebjamnia, Torabi, and Mansouri [17] and Rezaei Soufi, Torabi, and Sahebjamnia [18] papers for organizational resilience).

Simulation approaches are based on developing a system with different events and analyzing its resilience in terms of time and scenario (refer to Adjetey-Bahun et al. [19], about resilience in transport networks). Factor-based approaches also model these behaviors by testing the role of various factors in controlling the resilience of a system while designing an architecture for the performance of these factors and testing its performance in various scenarios.

Please insert Table 1 about here

According to our literature review, there is a:

- ✓ Disregarding for financial resilience while most researches are focused on social, human, and organizational domains;

- ✓ Lack of attention to the concepts of financial risk in the development of business continuity management and crisis management systems in the area of financial resilience of organizations;
- ✓ Bunch of developed qualitative and descriptive approaches to financial resiliency, while quantitative approaches can provide investors with more accurate decisions;
- ✓ A lot of financial resiliency research using descriptive approaches that examined existing examples and experiences; financial institution managers need effective procedures to promote prescriptive financial resilience.

3. Methodology

This section proposes a quantitative measure to calculate the financial resilience of firms. Figure 1 shows the flowchart of the proposed methodology. Behind, the details about each step are proposed.

3.1. Calculating financial performance

Determining an appropriate function to calculate a firm's financial performance is one of the most important steps for our proposed approach.

In order to determine an appropriate measure for financial performance in this paper, a set of financial indices are used, which are reported in the periodic reports of firms. These indices are identified by examining the literature on the indices available in the financial insolvency review. Notably, the indices with the maximum available data are selected. These measures are stock prices [39], earnings before interest and taxes (EBIT) [40], the ratio of total liabilities to the total value of the company's assets [41], working capital on total assets [42], and earning per share (EPS) [43]. In order to integrate the metrics and create a function for each firm, the highest and the lowest numbers at a specific time are identified, and the numbers for each time are normalized. Then, by considering each measure's positive or negative nature in determining the financial performance, the weight of each measure obtained by the Shannon entropy method, and using the simple weighted sum method, the integrated value is obtained. The Shannon entropy method is as follows:
For a component X_i with M_X possible states, each having a corresponding probability of $p(x_i)$, the average amount of information gained from the component measurement ($x_i = x_1, \ldots, x_{Ma}$) is defined by the Shannon entropy [44] w_i as:

$$w_i = -\sum p(x_i) \log p(x_i) \qquad \text{in each time period} \tag{1}$$

Accordingly, the weighted sum formula is as follows:

$$A_j^{WSM-Score} = \sum w_i a_{ij} \qquad \text{in each time period} \tag{2}$$

where w_i is the weight of each financial index i (calculated based on equation 1), and aij is the normalized value of financial performance index i for firm j in each time period.

Please insert Figure 1 about here

3.2. Calculating the shock periods

The second step to calculate the resilience is to determine the shock periods. For this purpose, by calculating the financial performance function and drawing the financial performance status chart in a time period, the periods of change in the financial situation trend will be examined. When a trend is reversed and negative during a period of increasing or stabilizing financial performance, the period of financial distress begins. Also, when a trend is positive and begins after a negative trend period, the period of financial distress ends. In fact, this section is the main difference between calculating financial resilience and organizational resilience that has already been developed in the literature. In organizational resilience, the performance rate is usually constant (for example, the production capacity of 1 million units per day) and reaches a lower level after the crisis. At the end of this period, the amount of performance returns to the previous level or exceeds. This value may never return to the previous value in financial performance, although experiencing positive trend patterns with a lower slope. For this purpose, the trend-changing pattern has been used in this paper to determine shock periods.

3.3. Calculating the financial resilience

The proposed measure for financial resilience should distinguish between good and bad firms based on their financial performance and define the impact of shocks on firms. So it should have a bad time period (disaster period) and a good time period (the time that the firm does not face any particular crisis). Since a firm's financial resilience should also be reflected in the balance sheet of the firm, considering the literature review, the measure should be designed to include balance sheet information. The financial resilience measure should be designed to apply to any financial institutions, and with minor modifications, it could be used to calculate other firms' financial resilience. Figure 2 presents a general diagram of the measure designed in this paper. According to Figure 2, it can be seen that a firm financial performance reduces dramatically after the shock. A firm is resilient if it has less damage due to occurring a shock (performance degradation) and if it returns to the normal situation rapidly (resuming time).

Please insert Figure 2 about here

Given these two concepts (performance degradation and resuming time), the following function as the basic Loss of Financial Resiliency model has the ability to integrate these values with both parameters and express them as a loss of financial resilience.

$$\text{Loss of Financial Resiliency (LOFR)} = \int_{t_1}^{t_2} f(FP)dt - \text{Local}\min(FP) \times (t_2 - t_1) \quad (3)$$

Note that in equation 3, the f(FP) shows the performance of the firm at different time, Local min (FP) shows the minimum of performance after occurring the crisis, t1 is the time of performance degradation after a positive trend, and t2 is the time that the firms start to recover after the shock and the performance is reversed after a negative trend. According to figure 2, the highlighted yellow area is the total loss of financial resilience (LOFR). This area

is related to two variables of recovery time and the reduced level of financial performance. The recovery time is the time between occurrences of a shock and recovering a firm's financial performance to its baseline level. Therefore, the lower level of reducing financial performance and the shorter time to recovery leads to a higher level of financial resilience. Furthermore, we can see that a set of geometric shapes can fit the performance reduction area, such as a combination of triangles and trapezius in Figure 3. This performance reduction area can be used as a good approximation for the estimation of the LOFR. Therefore, in this paper's remainder, the approximate approach is used to calculate financial resilience.

Please insert Figure 3 about here

Our second model for calculating the LOFR is based on Value at Risk (VaR) of financial performance.

In the previous section, we said that VaR is used to measure an investing loss limit. In fact, crossing this level indicates entry into the critical range of losses based on a predetermined confidence level. In this section, the amount of financial resilience is calculated by using VaR as a critical threshold. Notably, there have been a variety of approaches to computing VaR, and various supplements have been developed for it. However, this paper uses a simple type using historical data to calculate it. The modified model for different risks is as follows. The relevant function is presented in equation 4. Similar to the basic LOFR model, the approximate models can be applied here.

$$LOFR = \int_{t_1}^{t_2} f(FP(t) \mid FP < VaR^{FP}) dt \tag{4}$$

It is notably, t_1 is the times which the financial performance level goes from a higher value to a lower value than the VaR, and t_2 is the times in which the financial performance level goes from a lower value to a higher value than the VaR. According to equation 4 the amount of financial performance in which the performance is below VaR level will be effective in calculating financial resilience (See figure 4).

Please insert Figure 4 about here

The next model is the modified LOFR for a special risk in a market. To this point, we use the CoVaR of functionality. In this phase the cause of the shock has been identified which is considered as a systemic risk (see figure 5).

CoVaR can be considered as one of the approaches related to VaR. In this measure, the contribution of an external factor in creating the shock is calculated and the new value of the VaR is calculated. The issue of the external event which is generating shock in a system has existed in systemic risk literature, and CoVaR is one of the measures used to calculate systemic risk. There have been various approaches to calculating CoVaR in the literature, all of which have been developed based on correlation due to the need to calculate the contribution of external factors and its effect on the main variable of the study.

To consider the systemic risk, in this study, we use CoVaR measure referred to in Girardi and Ergun [45] in order to investigate the shock variable's fluctuations effects on the capital markets of the Middle East countries. For this purpose, assume that x_t is the financial

performance indicator at the time *t*, and x_t^o is the return of systemic risk affected the financial performance at the time *t*. Accordingly, the CoVaR measure at a (1-β) level of assurance can be calculated as follows based on the β^{th} Percentile of the conditional distribution of x_t^f:

$$\Pr(x_t^f \le CoVaR_{\beta,t}^{f|o} \mid x_t^o \le VaR_{\alpha,t}^o) = \beta \quad (5)$$

In this equation, the expression $VaR_{\alpha,t}^o$ shows the VaR value of the variable which affects the system, explained as the maximum loss experienced in this market at a 1-α% level of assurance in the time of *t* . Using conditional distribution rules, we will have:

$$\Pr(x_t^f \le CoVaR_{\beta,t}^{f|o}, x_t^o \le VaR_{\alpha,t}^d) = \alpha\beta \quad (6)$$

Please insert Figure 5 about here

With these explanations, the loss of resilience for this model will be as equation 7.

$$LOFR = \int_{t_1}^{t_2} f(FP(t) \mid FP < CoVaR_{Systemic\ Risk}^{FP}) dt \quad (7)$$

It is notably, t_1 is the times which the financial performance level goes from a higher value to a lower value than the CoVaR, and t_2 is the time in which the financial performance level goes from a lower value to a higher value than the CoVaR.

In the next sections, the proposed three approaches are considered in eight firms, and their capability is compared. Furthermore, the efficiency of the approaches in distinguishing between companies with good and bad financial performance is compared with Altman Z-score model [46].

It is notably Altman Z-score model is a model to predict the bankruptcy of the understudied firms. This model considers five financial ratios include: working capital / total assets (A_1), retained earnings / total assets (A_2), earnings before interest and taxes / total assets (A_3), the market value of equity / total liabilities (A_4), and sales / total assets (A_5) and develop a linear weighted sum model as: Z-Score= $1.2A_1+1.4A_2+3.3A_3+0.6A_4+0.999A_5$, When the value of the linear model is higher than 2.99, the firms are in the safe zone; when the value is lower than 2.99 and higher than 1.81, the firm is in the gray zone, and when the value is lower than 1.81, the firm is in distress zone.

4. Data and Results

In order to evaluate the proposed models and validate them in this section, we use data of eight firms listed on the Tehran Stock Exchange (TSE). Four of these firms had a good financial performance during 2010-2018, and the other four firms were in bankruptcy. Table 2 shows these firms' list, their industry groups, and their relevant periods of disruption.

Given the lack of transparency in the definition of bankruptcy in the Iranian market, we use the following definitions to distinguish between bankrupt and non-bankrupt firms.

> Bankrupt: firms with the accumulated losses which are in accordance with Article 141 of Commercial Code of Iran during 2010-2018.
>
> Non-bankruptcies: firms that made profits in the 2010 to 2018 period.

Please insert Table 2 about here

Using the proposed approach to generate each firm's financial performance in section 2, we use the available data and calculate eight understudied firms' financial performance charts. The eight firms' financial performance charts are presented in figure 6 as the required steps to determine financial resilience. According to these figures, the periods of disruption are identified.

All the data are gathered from the TSE website on a monthly basis. Furthermore, due to the fact that the financial data of companies is not reported in short periods, it was not possible to collect data in periods shorter than monthly. Also, short time periods (for example, daily) are so small that they will not show a shock effect due to high fluctuations.
The results of applying the first model (standard LOFR model) are presented in the second column of table 3. The results show that the application of this method is capable of separating firms with good and bad performance (bankrupted).

Please insert Figure 6 about here

In the second (VaR-based) model, there is a need to calculate VaR for each firm. So the maximum data is used to calculate this. In this approach, the degree to which the firm's conditions are lower than the value at risk is used. The results of the study show that firms that are more distant from their VaR and more time-consuming are more likely to go bankrupt and are less resilient. Results are presented in the third column of table 3.
It is notably, in order to calculate the VaR, we use historical simulation models and consider all confidence levels as 95%. The results of VaR are prepared in the third column of table 3.
Finally, for the third (CoVaR-based) model, a detailed study was conducted to identify the causes of the shocks. It is found that the fall of more than 20% of oil and gas condensate prices in October of 2018 for petrochemical firms and the change in the price of raw materials for food staff firms were the main reasons for this devaluation. By calculating the VaR of oil and sugar prices, the CoVaR of financial performance of each of the eight firms were calculated, and the new resilience value was calculated. The fourth column of table 3 shows the resilience values for the third method and other required information.
It is important to note that for firms with more than one period of a financial shock, the average of financial resilience in these periods is considered.

Please insert Table 3 about here

According to table 3, calculating financial resilience in the standard model has a lower value than the VaR-based and CoVaR-based models. Resilience in the first model is considered the total amount of lost performance and reduced efficiency. In the second and the third models, however, the reduction in performance is only for points less than VaR or CoVaR threshold, which in turn will result in less resilience. Also, in the third approach, the use of an effective factor in reducing financial performance to some extent modifies the calculations. In fact, if we reduce the effect of this shock, which acts as a systemic risk, by determining the risk factor and calculating its effect on the stock price, a new value will be obtained. Table 3 reveals that the amount of loss of resilience has been decreased by identifying the shock causes. Of course, this is especially true for bankrupt firms.

5. Discussion

In this paper, three different quantitative methods have been developed for calculating the financial resilience of firms. The standard method considers firms' financial performance and calculates financial resilience after decreasing financial performance. The second method defines the VaR and calculates financial resilience. The third method considers the origin of the risk factor and uses the CoVaR concept to calculate financial resilience.

In the primary resilience approach defined in the engineering sciences, this concept is calculated from any deviation from the normal functional level. The same definition is used in the standard model of financial resilience, and the amount of resilience is calculated based on the deviation from the performance level in the pre-crisis state. In this situation, the concept of resilience will be easily understood by senior managers. However, in financial risk literature, risk metrics are often used, and financial managers have a better understanding of these issues. For this purpose, the concepts of VaR and CoVaR have been used. For the managers of the organizations themselves, in order to investigate with one more factor (such as the type of risk affected), the use of VaR and CoVaR methods are more accurate and more useful. They can have better plans for improving their resilience in the future by examining various factors and their performance in the past. Of course, for investors and managers of financial institutions, this amount of review may not be valuable because of the need to collect much more data. Here we consider the strengths and weaknesses of each method, as shown in Table 4.

Please insert Table 4 about here

It is worth noting that all three groups of managers of financial institutions, micro-investors, and the organization's financial managers can use the approaches of calculating financial resilience. The first two groups, looking at companies' past and financial resilience, can use this criterion along with other criteria to buy stocks. In comparison, the organizations' financial managers should take measures to get out of the current situation by examining the risk factors and comparing the situation with the group shares during the risk, which is not within the scope of this study.

Our results about the performance of three methods revealed the good ability of the proposed methods.

Here we use the Altman Z-score model to compare the proposed model's capability to predict the understudied firms' bankruptcy. The results are shown in table 5. According to this table, for firms that bankruptcy has not been observed, the Z-Score is in a safe zone, and financial resilience is a significant distance from bankrupt companies' financial resilience. For firms in which bankruptcy is observed, the Z-score is in the distress zone, and the calculated financial resilience value is significantly different from non-bankrupt firms. Nevertheless, for firms within the Z-Score model's gray zone, one firm is bankrupt, and two firms have not gone bankrupt. Also, Z-score cannot decide these firms; the calculated financial resilience has a good ability to separate them. Therefore, we can see that our proposed method has a good performance in separating between bankrupt and non-bankrupt firms.

Please insert Table 5 about here

6. Conclusion

Financial fluctuations, changes in commodity prices, and economic crises have caused financial damage to firms. In this regard, the issue of financial resilience of firms, especially after the economic crisis of 2008, was considered. Most articles in this field were limited to qualitative recommendations for improving resilience, statistical models for developing hypotheses, and regression models to examine resiliency. The existing quantitative methods have usually divided the firms into good and bad groups by classifying financial resilience. In fact, the lack of a precise method that can show firms' financial resilience in small steps of time has been one of the problems. In this paper, the resilience status was investigated using the financial performance of firms. For this purpose, a function indicating financial performance was developed using stock prices, EBIT, total liabilities ratio to the total value of the company's assets, working capital on total assets, and EPS. Then, according to the financial performance chart, the shock periods were identified, and by developing a function indicating the lack of resilience, which was calculated through the amount of lost performance during the shock period, the financial resilience value was calculated. This paper developed three models to calculate the financial resilience in standard, VaR-based, and CoVaR-based models. In the first case, the total lost performance was considered. In the second case, the lost performance amount was considered for the area below the VaR amount. In the third case, the lost performance amount was determined for the area below the CoVaR amount.

It is notably, in the second and third approaches, the VaR of the financial performance should be calculated once without considering the risk causes and once with considering risk causes. In this case, the financial performance function must be calculated by identifying the risk cause and calculating it.

In order to evaluate the performance of the proposed approach, the information of eight firms listed on the Tehran Stock Exchange was used. Among these firms, four firms have gone bankrupt (considered in accordance with Article 141 of Commercial Code of Iran), and four firms have been in a good position. Due to the need to identify the causes of the crisis in the three proposed methods to calculate financial resilience, the eight selected firms are in two industrial groups: petrochemical and food staff.

Examining the financial performance of these firms reveals that there were several shocking periods for all of them. By identifying these periods, the resilience value was calculated in all three methods. The results show a significant difference in the financial resilience value of bankrupt and non-bankrupt firms. However, even with the use of the Altman Z-Score model, this separation was not well done.

There is an opportunity for future studies to provide a suitable mechanism for evaluating each of the qualitative approaches proposed in previous studies, using the proposed financial resilience approaches. In general, due to this paper's different nature, it was impossible to compare the three proposed approaches of the paper with previous studies. We emphasize that the purpose here is to provide a method for calculating resilience based on the company's past record as a measure of the organization's financial performance from investors' perspective to invest in that firms. Moreover, future studies can also focus on developing a different mechanism for integrating measures to define financial performance. They can also use other different approaches to calculate VaR and CoVaR (parametric and non-parametric approaches) and examine the differences in different methods. Moreover, the studies can

identify each firm's financial resilience status using the balance sheet information forecasting approaches and use it as one criterion for investing in the firms.

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List of Table captions:

List of Figure captions:

Table 1. The summary of the related literature.

References	Risk assessment aspects					Calculation aspects		Developing mechanism	Main outputs
	Disruptive risks	Market risks	Credit risks	Systemic risks	Liquidity risks	Quantitative	Qualitative		
Baur and parker [20]							✓		Defining financial resilience with regard to government debt markets and making suggestions to improve.
Guettafi, & Laib [21]						✓		SH	Evaluating the stability of a financial system with regard to two factors of financial resilience and transparency and the use of accounting variables in the qualitative evaluation of stability.
Papenfub, Saliterer, and Albrecht [22]	✓		✓	✓			✓	EA	Evaluation of financial resilience in Germany and the role of government in economic crisis. Evaluation through empirical study with regard to cash availability and questionnaire development.
Barbara [23]	✓			✓			✓	EA	Evaluation of financial resilience in Italy by theoretical sampling of Italian municipalities and study of their financial performance before and after the economic crisis. Investigation of shock absorption, vulnerability, predictive capacity and coping capacity as four aspects of resilience.
Korak, Saliterer, and Scorsone [24]	✓		✓		✓		✓	SA	Evaluating government financial resilience in the state of Michigan by sampling and studying their financial performance with respect to the shock absorption, forecasting, and coping capacity aspects.
Pal, Torestensson, and Mattila [25]	✓		✓		✓		✓	EA	Assessing government financial resilience in Sweden by sampling the four largest municipalities and studying the reasons for financial performance stability in the aftermath of the economic crisis.
De Aquino & Cardoso [26]	✓		✓		✓		✓	EA	Evaluating the financial resilience of municipalities in Brazil By examining the four major municipalities in the country, studying economic resilience indicators to evaluate and assess shock absorption, vulnerability, predictive capacity, and coping capacity as four aspects of resilience.
Jansson [27]	✓		✓		✓		✓	EA	Evaluation of financial resilience as one of the organizational resilience sectors in six Swedish companies and analysis of factors affecting financial resilience through an empirical study of companies with good, bad and medium financial status.
BCBS-Basel III [28]	✓	✓	✓		✓		✓		Development the resilience with focusing on two aspects of macroeconomic and intra-firm aspects and providing qualitative strategies to promote.
Hallegatte [29]	✓					✓			Focusing on the concept of economic resilience, considering the system's performance in the wake of a disruptive crisis. Proposing functions defined in organizational resilience literature as a function of calculating the resilience of an economy.
Pilguri [30]	✓	✓					✓	EA	Studying the impact of the global financial crisis on the Ukrainian banking system's financial resilience and suggest the basilar criteria to enhance the financial stability and resistance against crisis for banking systems.
Du Boys, Padovani, and		✓					✓		Considering the vulnerability of local governments influenced by the global financial crisis.

References	Risk assessment aspects					Calculation aspects		Developing mechanism	Main outputs
	Disruptive risks	Market risks	Credit risks	Systemic risks	Liquidity risks	Quantitative	Qualitative		
Monti [31]									Finding that the local policies stem from macro-national policies and implementing resilience promotion policies in long-term and short-term programs can reduce the country's vulnerability to global crises. Not identifying the resilience promotion policies in detail.
Mirzaei and Al-Khouri [32]		✓				✓		SA	Analyzing Kuwait as an oil-supplier economies' resilience in the global crisis and consider the banks and industrial growth situation. Finding that industries depending more on external finance have lower resilience during the global crisis.
Tabibian and Rezapour [33]	✓					✓		SA	Assessing the urban resilience and analyzing indicators in the assessment of urban resilience. Identifying 22 sub-criteria in 6 classes include: Social, economic, environmental, physical, infrastructural, and institutional for urban resilience.
Triggs, Kacaribu, and Wang [34]		✓		✓	✓	✓		EA	A survey of the crisis management experience of Indonesia in the crisis of Taper Tantrum 2013, which, despite the existence of risk, has a good performance in maintaining the unemployment rate, the positive trend of the capital market and fixing the inflation.
Behl, Dutta, and Chavan [35]	✓					✓		SH	Studying the effect of natural disasters on financial sectors in India And finding that e-governance can improve the financial resilience
Nkundabanyanga et al. [36]	✓	✓				✓		SH	Examining the relationship between firm characteristics, innovation, financial resilience, and survival of financial institutions in Uganda Finding that firm characteristics like: size, age, innovation and financial resilience have a predictive force on the survival of public interest firms such as financial institutions.
Salignac et al. [37]			✓				✓	EA	Defining financial resilience and developing a framework to measure financial resilience in Australia. Identifying economic resources, financial resources, financial knowledge and behavior, and social capital as financial resilience components.
Klapper and Lusardi [38]		✓	✓		✓		✓	EA	Investigating the effect of financial awareness on the individual or organizational levels in promoting financial resilience and statistical analysis of the situation of people with different levels of financial knowledge in four areas of interest, credit instruments, asset distribution, and inflation in financial resilience viewpoint.

* Note: In developing mechanism column SA is statistical analysis, EA is empirical analysis, and SH is statistical hypothesis.

Table 2. The list of firms and relevant information

Firm	Period of disruption	Industry group	Bankrupt	Description
Marun petrochemical company (MPC)	9.2018-3.2019	Petrochemical		The company has not accumulated losses in any year.
Zagros petrochemical company (ZPC)	1.2014-6.2014 9.2018-2.2019	Petrochemical		The company has not accumulated losses in any year.
Glucosan Company (GC)	10.2016-6.2017	Foodstuffs		The company has not accumulated losses in any year.
Lorestan Sugar Factory (LSF)	1.2014-9.2014	Foodstuffs		The company has not accumulated losses in any year.
Farabi Petrochemical company (FPC)	5.2018-9.2018	Petrochemical	✓	The company had accumulated losses in the three years 2015-2017, and its accumulated loss ratio to the amount of capital was more than eight times.
Shirin Sugar Factory (SSF)	3.2014-1.2015	Foodstuffs	✓	The company had accumulated losses from 2016 to 2019, and its ratio of accumulated losses to the amount of capital has been more than four times.
Naghshe Jahan Sugar Factory (NJSF)	9.2015-6.2016 12.2017-6.2018	Foodstuffs	✓	The company had accumulated losses from 2016 to 2019. Its ratio of accumulated losses to the amount of capital has more than two times.
Shirvan- Ghoocahn-Bojnourd Sugar Factory (SGBSF)	9.2014-9.2015	Foodstuffs	✓	The company had accumulated losses in the five years 2014-2018 and its accumulated loss ratio to the amount of capital was more than 1.5 times.

Table 3. The results of different models of financial resilience calculation

Firm	Standard method	VaR-based method		CoVaR-based method		
	Average of LOFR	VaR (95% confidence level)	Average of LOFR	The cause of risk	CoVaR (95% confidence level)	Average of LOFR
Marun petrochemical company (MPC)	0.2648	0.443	0.1962	Change in the price of oil and methanol	0.418	0.1886
Zagros petrochemical company (ZPC)	0.3266	0.122 (period 1) 0.446 (period 2)	0.2707	Change in the price of oil and methanol	0.098 (period 1) 0.411 (period 2)	0.2685
Glucosan Company (GC)	0.2963	0.264	0.2243	Change in raw material price	0.231	0.2049
Lorestan Sugar Factory (LSF)	0.1743	0.065	0.1591	Change in raw material price	0.053	0.1433
Farabi Petrochemical company (FPC)	0.5342	0.193	0.3984	Change in the price of oil and methanol	0.144	0.3612
Shirin Sugar Factory (SSF)	0.6914	0.187	0.5712	Change in raw material price	0.129	0.5563
Naghshe Jahan Sugar Factory (NJSF)	0.6104	0.133 (period 1) 0.073 (period 2)	0.5246	Change in raw material price	0.098 (period 1) 0.046 (period 2)	0.4958
Shirvan- Ghoocahn-Bojnourd Sugar Factory (SGBSF)	0.7431	0.046	0.6311	Change in raw material price	0.018	0.6038

Table 4. The strength and weaknesses of different models for financial resiliency calculation

Method	Strength	Weakness
Standard model	Very simple and understandable Close to the traditional concept of resilience	Relatively low accuracy Disregarding the cause of the crisis
Modified VaR based model	Relatively simple and understandable High accuracy	Need relatively large data Disregarding the cause of the crisis
Modified CoVaR based model	High accuracy Regarding the cause of the crisis	Needs lots of data Complex and time-consuming Far from the traditional concept of financial resilience

Table 5. The comparison between different methods

Firm	Z-score	1st FR model	2nd FR model	3rd FR model	Bankrupt
MPC	3.23(*)	0.7352	0.8038	0.8114	
ZPC	2.25 (**)	0.6734	0.7293	0.7315	
GC	2.74 (**)	0.7037	0.7757	0.7951	
LSF	3.59(*)	0.8257	0.8409	0.8567	
FPC	1.97 (**)	0.4658	0.6016	0.6388	✓
SSF	1.67 (***)	0.3086	0.4288	0.4437	✓
NJSF	1.52 (***)	0.3896	0.4754	0.5042	✓
SGBSF	1.04 (***)	0.2569	0.3689	0.3962	✓

Note. * shows that the Z-score is in the safe zone, ** shows that the Z-Score is in the Grey Zone, and *** shows the Z-Score is in distress zone.

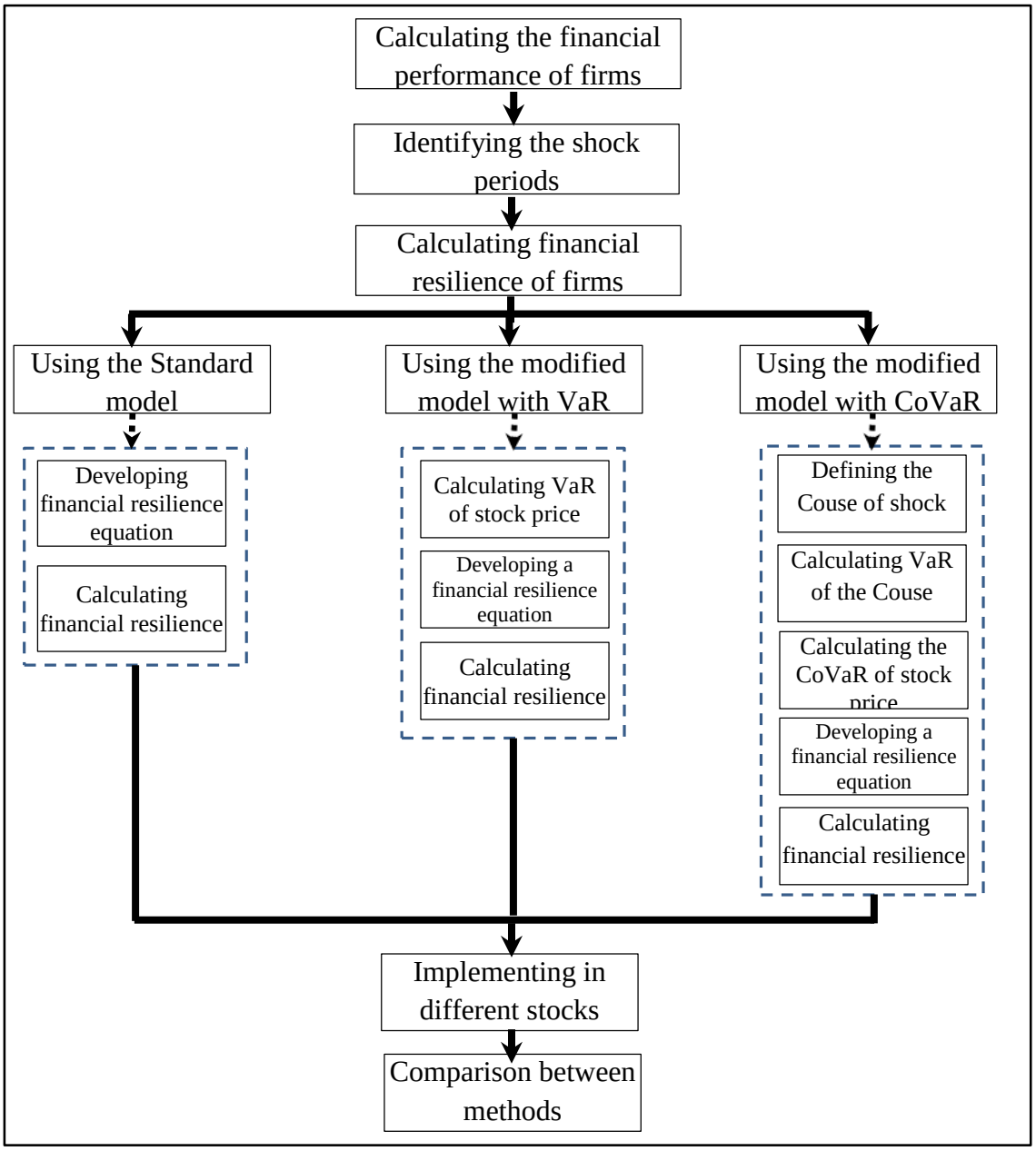


Figure 1. The flowchart of the proposed approach

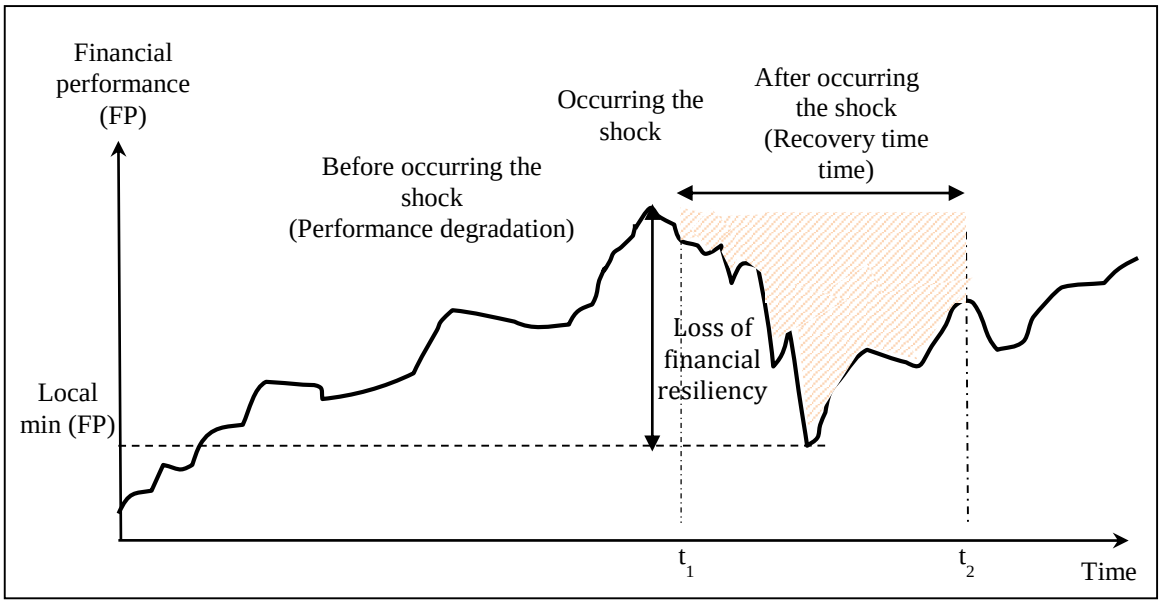


Figure 2. The main model of calculating financial resilience

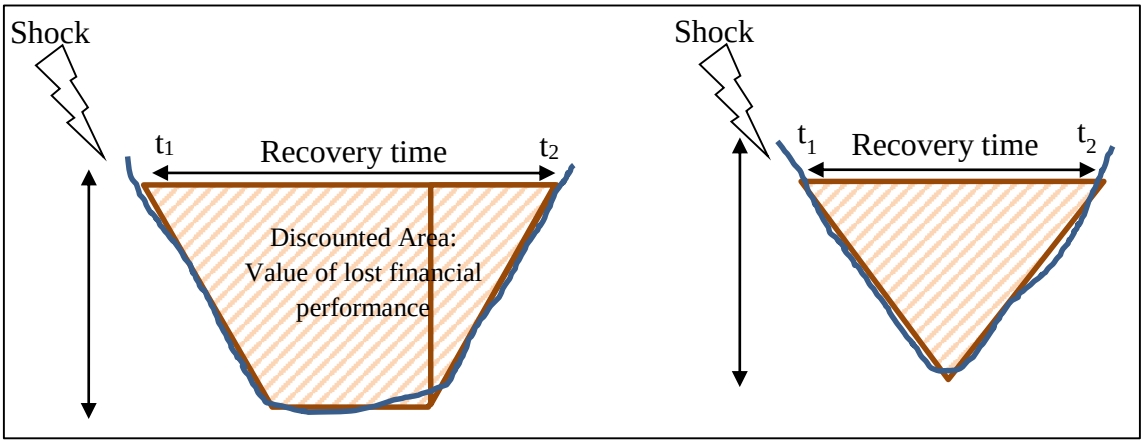


Figure 3. A schematic view of modified LOFR (loss of financial resilience)

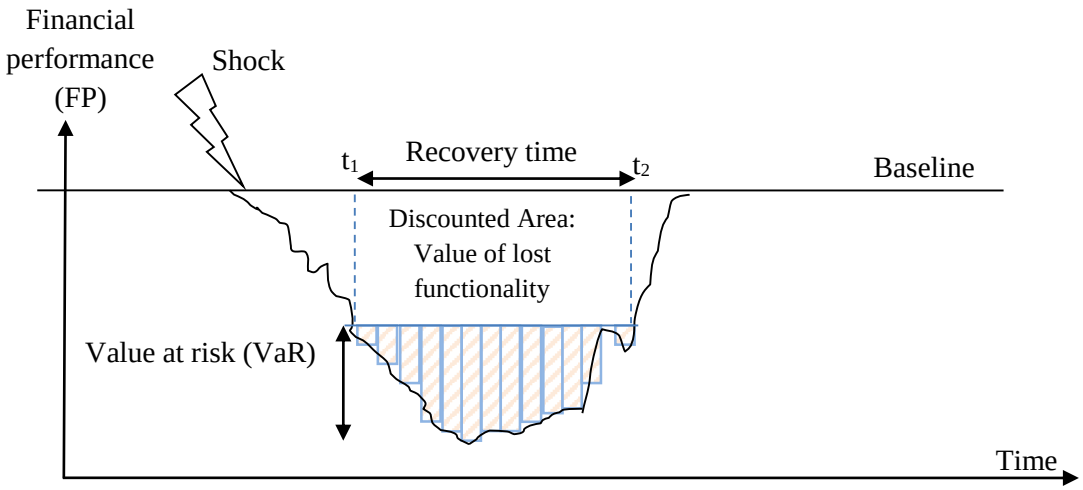


Figure 4. A schematic view of LOFR (loss of financial resilience) function for different risks

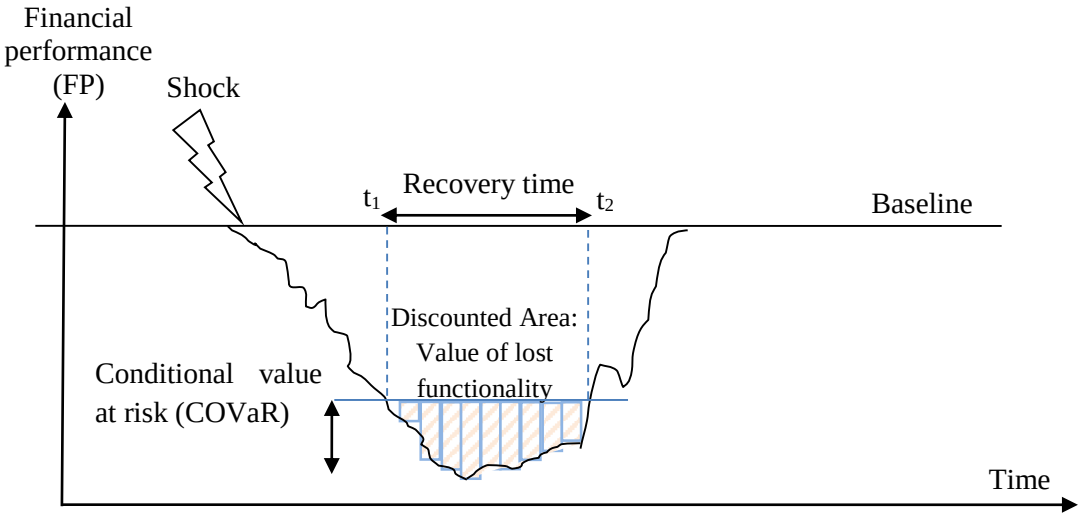
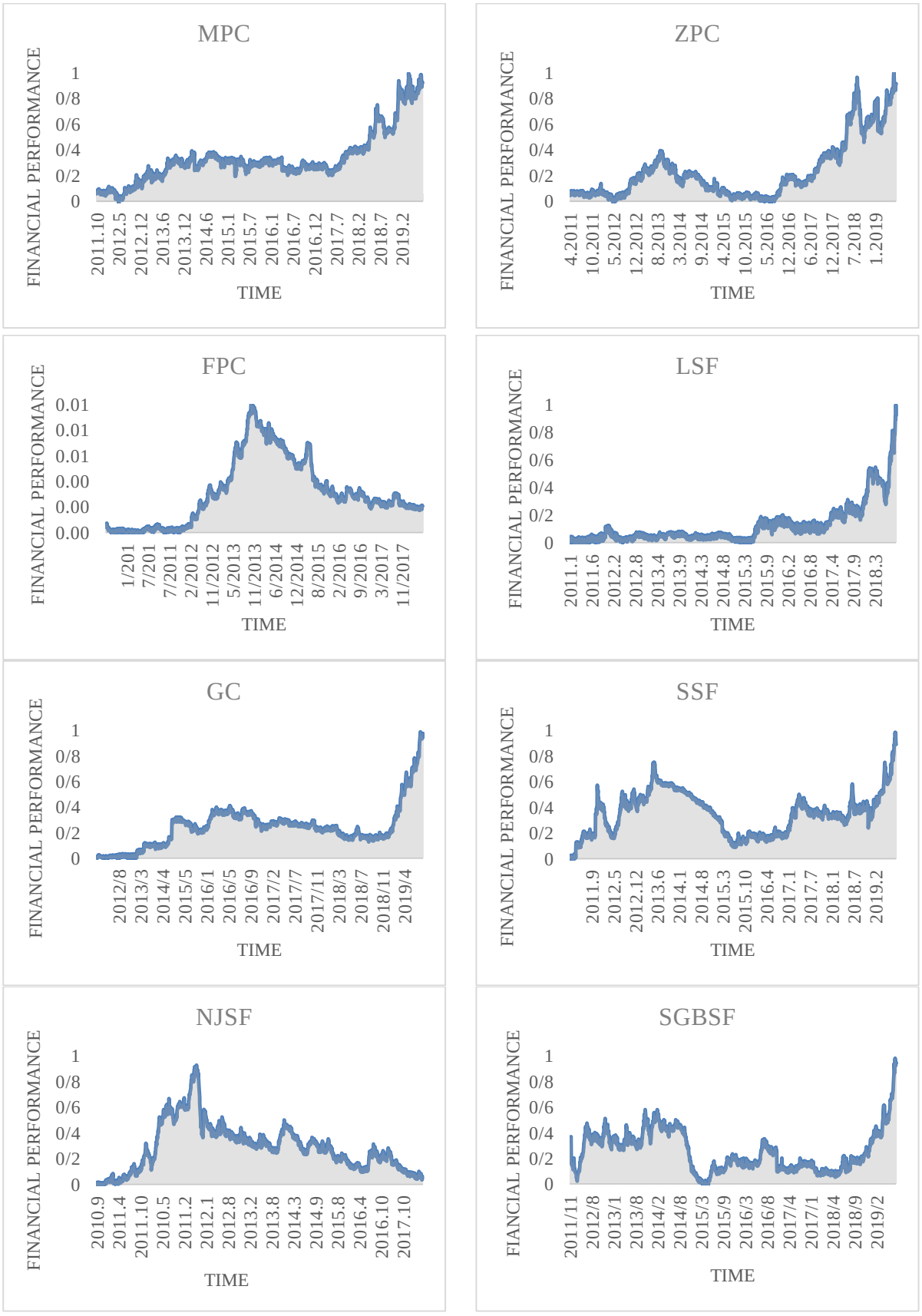


Figure 5. A schematic view of LOFR (loss of financial resilience) function for systemic risks



Figures 6. The financial performance of different firms