International Journal of Finance and Managerial Accounting, Vol.10, No.36, Winter 2024 IJFMA

Compilation of the financial stress index in the stock exchange using the DCC-GARCH approach

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Submit: 16/08/2022 **Accept:** 07/12/2022

ABSTRACT

Since incrementing stress in the financial markets is of major significance for the analysis and forecasting of economic activities and can be reflected in the multitude of variables of the financial market, knowing the main sources of financial stress and its effects on actions and different economic sectors the title is considered one of the important areas in financial discussions. Due to the importance of this issue, The purpose of this research is to design a financial stress index to predict the occurrence of a financial crisis. In this research, a composite index has been designed to measure the financial system of Iran and the effects of financial turbulence in the conditions of uncertainty in the financial markets and the Tehran Stock Exchange between 2008 and 2020. In this research, R software was used to perform the final analysis.The factors of currency volatility, stock market index volatility, banking industry volatility, coin price volatility, energy carrier volatility, and insurance industry volatility were used as variables in the final model. It was used, and three factors of currency volatility, stock market volatility, and banking industry volatility were used to design and construct the financial stress index. This research was conducted in five steps based on the DCC-GARCH approach. Finally, based on the variables of financial institutions and the stock market index, a prediction model based on neural networks for the financial stress index was presented. From the results, we find that all the independent variables of the research have a positive and significant effect on the financial stress index, except for the coin price volatility index, which has a negative and significant impact. The model's coefficient of determination is also 0.8736, which indicates that the quality of the fitted model is favorable.

Keywords: turbulence, financial stress, DCC-GARCH, neural networks, evaluation.

1. Introduction

Financial crises have been one of the common phenomena during the economic life of countries(Thalassinos & Thalassinos, 2018). How to deal with the crisis and reduce its negative consequences has been one of the most important concerns of the countries involved in the crisis(Hagelund, 2020; Pierrehumbert, 2019). Other countries have also based their efforts on preventive measures against the occurrence of crisis and preventing its spread to their economy(Sukharev, 2020; Wasserman et al., 2020). In general, financial crisis means extreme fluctuations that occur in indicators such as interest rates, stock indices and balance of payments(Huang et al., 2021).The quick integration of emerging financial markets with the global market has increased the risk of spreading financial crises across these markets (Nguyen et al., 2022). The macroeconomic fundamentals and herding behavior have witnessed a concurrent effect on the global economy. Particularly, after the global financial crisis, emerging markets experience greater impetus to the vulnerabilities of crises(Mai, 2022; Mundra & Bicchal, 2020). The severe consequences of this crisis are documented in the literature. The development of financial instruments in Iran promises a positive outlook for Iran's financial system, which of course will also bring concerns. Undoubtedly, the development of these tools will increase the entanglement and depth of the country's financial market and make its components more dependent on each other than before. If stress or instability spreads widely throughout the financial system, the damage done to the economy is more severe (Hollo et al., 2012). Thus, the interconnected structure of financial markets accounts for the real-time monitoring of financial stability and early warnings of crises. It is widely accepted that a financial crisis is a period of “systemic” stress, during which the stress is ultimately transmitted to the real economy and leads to recession (Duprey et al., 2017). Generally, when a systemic risk occurs, stock markets plummet, the monetary bank system and bond market fall under stress, and volatility in the stock market and the exchange market increases significantly (Dovern & van Roye, 2014). Due to the complex nature of financial markets, it is always challenging to capture stressed periods (Battiston & Martinez-Jaramillo, 2018; Gong et al., 2019). Hence it can be stated that Stress in the financial and economic structure of a country is very important for analyzing and predicting economic activities (Heydarian, 2018; Li et al., 2022). Adverse financial situations can potentially be transmitted to the whole economy through many channels (Su et al., 2022). Therefore, small financial turbulences can even lead to worsening economic conditions if they are strengthened; for this reason, after the financial crisis of 2008, many researchers at the global level have investigated the factors affecting financial stress(Ishrakieh et al., 2020). Financial stress analyses have since gained significant attention; Bianco et al. (2011) note that while no series representing financial stress in the US existed in 2008, 12 alternative series were available by 2010 (Bianco et al., 2011). Following the 2008 global financial crisis, we have seen a growing body of research investigating the effect of financial stress on the economy's health. Numerous researchers have explored the extent to which financial stress is related, in most cases, which precedes economic contractions (Basu & Bundick, 2017; Bonciani & Van Roye, 2016) .After the global financial crisis, policymakers started identifying indicators to predict financial stress(Bernanke, 2018). In this way, experts paid attention to the methods known as early warning indicators to measure financial instability(Borio & Drehmann, 2009; Illing & Liu, 2006; Wang, 2022). In this context, indicators such as banking crisis with low economic growth(Batuo et al., 2018; Dinçer et al., 2018), international reserves and real exchange rate(Aizenman & Riera-Crichton, 2008; Edwards, 1983; Tabata, 2022), volatility in the banking industry index, debt bond gap, exchange rate volatility(Bagella et al., 2006; Hussain et al., 2021) were noticed.

It should be noted that there is a great variety in the field of standard indicators for measuring the level of stress in the components of the financial system in a separate form, each of which indicates the signs of financial friction(Hollo et al., 2012). While all these indicators provide useful information, this issue is always It is discussed whether the stress observed in a specific part of a market is the specific nature of that market or whether this stress is very broad and is considered a systemic phenomenon. One of the methods of analyzing the information of individual indicators is to design a composite index of financial stress or "Financial stress index". Therefore, in the literature related to systemic risk, a group of

researchers in the post-crisis years has been dedicated to the development of financial stress indicators to measure systemic risk. In line with this research, the capital market and its indicators and effect on financial stress were considered. In one of the first researches, Van Roye (2011) also showed that financial stress is reflected in many financial market variables(Van Roye, 2011). Financial stress is an unobservable variable in the economy, and many efforts have been made to define and measure it. Some researchers have defined financial stress as directly related to the performance of financial markets(Carlson et al., 2011). Others have realized it indirectly to systematic risk(Louzis & Vouldis, 2012) or attributed it as a product of interactions between market vulnerability and turbulence(Grimaldi, 2010). Some researchers have also investigated the relationship between financial stress and macroeconomic variables (Apostolakis & Papadopoulos, 2019) or exchange rates (Adam et al., 2018). Although there is still no agreement on the definition of financial stress, most economists have common elements about this concept, so it can be said that financial stress is caused by disturbances in the normal functioning of financial markets(Barnichon et al., 2022). Stress in a country's financial and economic structure is very important for analyzing and predicting economic activities(Chatzis et al., 2018). Especially when the crisis spreads to the real economy, economic growth decreases, and the unemployment rate increases(Afonso & Blanco-Arana, 2022; Verick, 2009). Financial stress comes from turbulences and vulnerable financial structures; hence the greater the financial fragility (weakness in financial conditions and structure), not only itself but also with the effect of turbulences entering the market and multiplying and Strengthening it through increasing financial loss, risk (increase in expected possible loss) and uncertainty in the market has increased stress. Increasing the cost of credit and creating tension in financial institutions and investors has caused a downward trend in It becomes economy(Rahimi Baghi, 2018).

An increase in financial stress has caused uncertainty about the value of financial assets, which can lead to a rise in the volatility of asset prices(Bekaert et al., 2009; Fu et al., 2022). While making most companies cautious, price fluctuations lead to delaying important decisions about investment or hiring labor until the uncertainty is resolved(Bloom, 2014; Dixit et al., 1994). Also, financial stress causes the adoption of credit standards by banks, and in this way, it causes a decrease in economic activities(Hakkio & Keeton, 2009; Su et al., 2022). One of the reasons why investors demand higher returns on bonds or stocks (during financial crises) is that banks are less willing to lend(Kordloui, 2015). An increase in financial stress can reduce economic activities in three ways. First, the increase in uncertainty regarding the price of financial assets can lead to a rise in the volatility of asset prices. Empirical studies show that price fluctuations while making more companies cautious, lead to delaying important decisions about investment or hiring labor until the uncertainty is resolved(Hakkio & Keeton, 2009). Another thing is that financial stress with an increase in the costs of companies may lead to a decrease in economic activities through the reduction of their expenses(Davig & Hakkio, 2010; Franks, 1998). Reluctance to keep risky assets and increasing information asymmetry can lead to an increase in the borrowing cost of companies(Kang et al., 2021). In addition, financial stress can impose more costs on companies through the issuance of new bonds(Guizani & Abdalkrim, 2022; Wruck, 1990).

Also, the sudden change in investors' expectations causes a decrease in the net worth of companies. As a result, an unexpected reduction in their wealth leads to a sharper increase in companies' financing costs (Davig & Hakkio, 2010). Therefore, the increase in financing costs causes companies to reduce their expenses, and this causes more stagnation in economic activities(Akram, 2019). Finally, financial stress causes the adoption of strict credit standards by the banks and thus reduces economic activities(Hakkio & Keeton, 2009; Houngbédji & Bassongui, 2022). Investors demand higher bonds or stock returns (during financial crises) because banks are less willing to lend(Cevik et al., 2013). In such a situation, banks reduce lending in two ways; first, by increasing the interest rate of new loans, they reduce their attractiveness to borrowers(Davig & Hakkio, 2010). Another thing is that by increasing the minimum credit standards, borrowers are made more difficult to qualify for loans. Therefore, the policies adopted by the banks can increase the financing costs of the companies, by affecting their expenses, they can cause a decrease in economic activities and intensify the destructive effects of financial stress.

Considering the alarming effects of the crisis, there was a fear that Iran would also be exposed to the damages caused by it. Although due to the lack of connection between Iran's financial market and its little integration with world markets, the direct and immediate effects of this crisis in the monetary and financial sector of the country were not significant as in European and East Asian countries, the indirect and long-term effects of the crisis in the financial markets as well as The real part of the economy, especially considering the dependence of Iran's economy on export earnings, can affect macroeconomic variables. There was also this concern that the consequences of the crisis would affect the business environment, limit the available financial resources and the profit margin of the companies accepted in the capital market, and affect the development of the market by harming the shareholders. Capital and the implementation of the general policies of Article 44 have an effect(Matofi, 2016). This study contributes to the growing literature by preparing a financial stress index to measure financial stress in the financial market of Iran. Therefore, this research seeks to determine what factors lead to financial stress on Tehran Stock Exchange. And how can you reach a financial stress index by combining them in the Tehran Stock Exchange?

The paper is organized as follows: Section 2 reviews the literature review. The methodology is illustrated in Section 3. Then, the Analyze in Section 4. Finally, Section 5 Results and Suggestions.

2. Literature review

Indeed, the crisis highlighted the significance ance of having an early index of the crisis, i.e., an index that could at minimum measure the overall stress level in the financial market. therefore, an assortment of financial stress indices (FSI), in the latest times, have been proposed to denominate the level of stress in the financial market. These indexes target the measurement of a build-up of stress before a full-blown crisis, thus providing intuition into fluctuating stress levels. likewise, financial stress measures are beneficial for assessing financial inconsistency and can feed into policy decisions to flux out the stress before it blows out on the full scale. So far, a multitude of researchists have tried to predict the financial stress index model to predict interior and external shocks, however, there has not been a single consensus among them. In their investigation, Duprey (2020) uses Canada's FSI to estimate the relationship between fiscal stress and GDP and states that recession and fiscal stress have the greatest negative impact on GDP (Duprey, 2020). Hollo et al. (2012) rely on this notion of systematic stress and use the portfolio theoretic aggregation approach, which considers the time-varying crosscorrelation between sub-indices. They propose a composite indicator of systemic stress (CISS) for the Euro area using data from different market segments: equity, bond, money, forex markets, and financial intermediaries(Hollo et al., 2012). Guru (2016) constructed a financial sector stress index (FSSI) utilizing the PCA method by synthesizing three segment-specific indexes: currency, banking, and stock markets. as regards, none of the perusal accounted time-varying nature of stress prevalent across different financial markets(Guru, 2016). In their research, Yao et al. (2020) measured the dynamics of China's financial stress from the perspective of interconnectedness and stated that financial stress has become more important since the boom crisis and stated that interbank and bond markets play the main role in stress transmission. Finally, the asymmetric and non-linear economic effects of financial stress are investigated and thresholds are determined to distinguish between periods of financial stress and normal periods. The financial stress index developed in their research effectively shows the real-time situation and identifies periods under stress (Yao et al., 2020). Mezghani & Boujelbène-Abses (2021) Their research investigated the effects of financial stress on financial markets: dynamic correlation and portfolio hedging. Their results showed that the correlation between oil and equity bond markets is stable during non-shock periods, but evolves at lower frequencies during oil and financial shocks. In addition, they have found that the main transmitter of risks are the oil market and financial stress. This relationship is mainly long-term driven, indicating that markets quickly process the spillover effect of financial stress and the shock is transmitted in the long run, and the case of negative (positive) financial stress, investors should hold more oil (stocks) than stocks (oil) in Have their own portfolio to minimize the risk.(Mezghani & Boujelbène-Abbes, 2021).In the Indian context, Shankar (2014) estimates the financial condition index using the principal component method on 13 financial market variables encompassing four money market

variables and three variables each from the bond market, forex market, and stock market(Index, 2014). In their research, Touhidi et al. (2022) examined the financial stress and the growth of Iran's economic sectors. They stated that for this purpose, they used the quarterly data from 1991 to June 26, 2017, of the banking, stock, and currency markets. And by using the method of principal component analysis, credit weighting, and the generalized exponential self-explanatory heterogeneity variance approach (EGARCH) to estimate price indices and a multidimensional amount of financial stress "within" and "between" » Various parts of the financial system (banking, stock market, and currency market) have been discussed. Then, the effect of financial stress on sector growth was investigated using the Markov-switching model. The results indicate that despite severe financial stress in Iran in the considered period, its effect on the growth of the agricultural, industrial, and service sectors is insignificant or meaningless in most cases. It seems that these results are an example of the failure of the nominal sector to function properly and its imperceptible effect on the real sector of the economy, which is rooted in the bank-centeredness of the financing system, the inefficiency of the capital market, and various government interventions in the money and capital market(Touhidi, 2022). Rezagholizadeh et al. (2020) investigated the effect of financial stress on the stock returns of industries listed on the Tehran Stock Exchange. The results of their research show that in all four estimated models, the effect of the financial stress index on the stock returns of industries is negative and statistically significant. In other words, the financial stress in the studied markets, including the capital market, money market, and currency market, has a negative effect on the stock returns of industries and leads to a decrease in the stock returns of these industries. Also, the research findings show that in all the estimated models, the world price of oil, exchange rate, and interest rate positively affect the stock returns of the studied industries in Iran. In addition, the findings show that the estimated coefficients for the inflation rate variable in all models are negative and statistically significant(Rezagholizadeh, 2020).

3. Methodology

This research aims to design and construct an index to predict the occurrence of financial stress in the financial markets of Iran. Since shock variables were used in previous research, in this research, the factors of currency volatility, stock market index volatility, banking industry volatility, coin price volatility, energy carrier volatility, and insurance industry volatility are used as variables in The final model was used and three factors of currency volatility, stock market volatility and banking industry volatility were used to design and construct the financial stress index. Considering the importance and application of the results, this research helps managers to make better decisions in the field of policy in the complex environment of the Tehran Stock Exchange Organization, so the present research is practical in terms of its purpose. Therefore, in the present study, the research hypotheses are designed as follows:

Hypothesis 1: The currency volatility factor affects the financial stress index in the stock exchange.

Hypothesis 2: The factor of stock market index volatility (index drop) affects the financial stress index.

Hypothesis 3: The factor of banking industry turbulence affects the financial stress index.

Hypothesis 4: The factor of gold coin price volatility affects the financial stress index.

Hypothesis 5: The turbulence factor of energy carriers affects the financial stress index.

Hypothesis 6: The turbulence factor of the insurance industry affects the financial stress index.

In this research, the statistical population is the data of the total index and other stock exchange indices. Our sampling method, according to the nature of the data, i.e., the time series of the total index and sub-indices, is cross-sectional. The statistical sample includes the financial markets and the capital market of Iran. The collected data is also a time series archived between 2009 and the end of 2021. It should be noted that for the model's design, data from October 12, 2009, to December 19, 2019, was used. Data from January 21, 2019, to February 17, 2021, was used for the model test. In this research, to test the desired hypotheses, the time is from 2009 to 2021. Excel spreadsheet software was used to prepare the necessary variables related to the hypotheses for the model. First, the collected information was entered into the work pages created in the environment of this software. Then the necessary calculations were made to obtain the variables of this research. After calculating all the essential variables to be used in the models of this research, these variables

were combined in single worksheets to be transferred to the software used in the final analysis. R 3.6.1 software was used in this research to perform the final analysis.

3.1. The model used to test hypotheses

According to the contents stated in the previous section and the hypotheses examined in this study, the final model used to test the hypotheses is as follows.

model (1)

$FSI= \alpha_0 + \alpha_1 TEPIX_{i,t} + \alpha_2 Dollar_{i,t} + \alpha_3 Bank_{i,t} + \alpha_4 Coin_{i,t} + \alpha_5 Oil_{i,t} + \alpha_6 Bime_{i,t} + U_t$

3.2. The dependent variable

Financial stress (FSI):

The variables involved in the design and construction of the financial stress index include the volatility of the currency market, the volatility of the stock market index, and the volatility of the banking industry. To aggregate the three sub-indices of Iran's financial system to provide the financial stress index, the methodology of Hollo et al. (2012) and Iachini & Nobili (2016) is carried out by combining GARCH models (Hollo et al., 2012; Iachini & Nobili, 2016; Rezazadeh, 2020). According to the portfolio theory, the overall risk of the portfolio of financial stress indicators depends not only on the volatility of these sub-indices but also on the dependence (mutual dependence) of these sub-indices; Therefore, the stress index proposed for Iran's financial system in this research gives relatively more weight to situations in which stress increases in several market components at the same time. The FSI index is made according to the methodology of Hollo et al. (2012) as follows:

relationship (1)

$$FSI = (W^0 S_t) \times C_t \times (W^0 S_t)'$$

Where in:

FSI financial stress index

W: the vector of weights of the variables that make up the financial stress index

S_t:: the vector of the constituent variables of the financial stress index at time t

C_t:conditional correlation matrix between the variables that make up the financial stress index at time t

And $(W^0 S_t)$is the product of the weights such as indices and the vector of sub-indices at time t, and $(W^0 S_t)'$ is also the inverse of this matrix(Rezazadeh, 2020).

relationship (2)

$$C_t = \begin{bmatrix} 1 & \rho_{12.t} & \rho_{13.t} \\ \rho_{21.t} & 1 & \rho_{23.t} \\ \rho_{31.t} & \rho_{32.t} & 1 \end{bmatrix}$$

The constituent variables of the financial stress index have already been obtained (volatility of the total stock market index, currency volatility, and banking index volatility). On the other hand, the dynamic conditional correlation of these variables has also been calculated from the previous section and with the DCC-GARCH approach. Only one unknown part remains, which is the constant vector of the weights of each variable. In the next section, we calculate each variable's optimal weights with a scientific approach based on the opinion of experts.

3.3. Independent variables:

The independent variables in this research are stock market index volatility, currency volatility, banking industry index volatility, gold coin price volatility, energy carrier index volatility, and insurance industry index volatility. The research variables' details and how they were obtained are given in Table (1).

As stated in the above table, the main dependent variable of the research, which is the financial stress index, is itself formed through three other side variables by using the appropriate generalized variance heteroscedasticity model (GARCH) for each of the returns of the total index of the Tehran Stock Exchange, Free currency price return (dollar) and banking industry index return, we extract the resulting conditional variance values under the title of turbulence of these markets and consider them as input variables to construct the financial stress index. The variance and the conditional standard deviation can be regarded as volatility in examining the relationship between volatility and return.

Table (1) research variables

Independent variable name	Symbol	Discussion
The volatility of the total stock index	TEPIX	It is obtained from the yield fluctuation model of the total stock market index, and it is one of the constituent variables of the financial stress index, which is also present as one of the independent variables in the final model. This variable considers and calculates the fluctuation in the fundamental value of assets as uncertainty in the .behavior of financial investors (Falahpour, 2019)
Exchange rate volatility (dollars)	Dollar	Due to the high dependence of Iran's economy on oil revenues and imports, exchange rate fluctuation in Iran is one of the important indicators in measuring the stress of financial markets. In this research, we use the commonly used currency, the dollar, for analysis (Falahpour, 2019). This variable is obtained from the free exchange price yield fluctuation model. It is one of the constituent variables of the financial stress index, which is also present as one of the independent variables in the final model.
The turbulence of the banking industry index	Bank	The volatility of bank stocks reflects the uncertainty in their stock returns, which cannot be explained by the general movement of the market (Falahpour, 2019). This variable is obtained from the yield fluctuation model of the banking industry index and is one of the constituent variables of the financial stress index
Turbulence in the price of gold coins	Coin	This variable is obtained from the fluctuation model of coin price and is present as one .of the independent variables in the final model
Turbulence index of energy carriers	Oil	It is obtained from the Brent oil price volatility model and is present as one of the independent variables in the final model.
The turbulence of the insurance industry index	Bime	It is obtained from the volatility of the insurance industry index and is present as one of the independent variables in the final model.

Source: Researcher's findings

4. Analyze

The general approach of this research can be divided into three general parts; Thus, in the first part, we examine the variables of the problem along with its descriptive statistics, then we describe the process of making the financial stress index, and finally, using the linear regression model, we evaluate the designed financial stress index and the variables influencing it.

4.1 The process of building a financial stress index

4.1.1 Dynamic conditional correlation approach

As mentioned before, to build a financial stress index, we need to obtain the Volatility of the entire stock market index and the exchange rate price Volatility along with the Volatility of the banking industry index. To obtain volatility, we can use the heterogeneity models of variance on the daily performance of these variables. Thus, the variance of the extracted conditions can be considered as Volatility by choosing an optimal ARMA-GARCH model for the daily return of the total stock index, currency price, and banking industry index. Figure (1) shows the time series diagram of the daily return of the total index of the Tehran Stock Exchange along with the daily return of the exchange rate and the banking industry index.

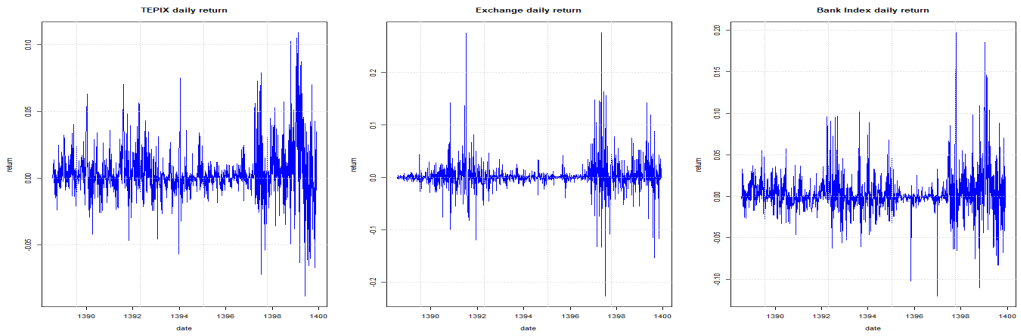

Figure (1). Time series diagram of daily returns of the total stock market index, currency prices, and the banking industry index.Source: Researcher's findings

From table (2), we have descriptive statistics related to the daily return of the total stock market index, currency price, and banking industry index.

Variables	Mean	SD	Median	Minimum	Maximum	Range	Skewness	Kurtosis
Total stock index	0.002981	0.01673	0.00095	- 0.08839	0.1088	0.1972	0.9455	8.2764
Currency	0.0020	0.02547	0.00051	- 0.2257	0.2766	0.5032	1.2919	32.6163
Banking industry index	0.0025	0.02217	0.0000	- 0.1202	0.1968	0.31706	1.5028	13.5875

Source: Researcher's findings

By examining the concentration criteria (mean and median), we find that the average yield of the total index of the Tehran Stock Exchange is slightly higher than the yield of the currency and the banking industry index (about 0.05 to 0.1 percent) on the other hand, looking at the range and standard deviation values, open view We note that the total index of the stock market has lower values than the other two variables, which can somehow be concluded that the risk of the stock market is lower compared to the currency market. The skewness values for all three variables are in the range (-2 and 2), so the distribution of these three variables can be considered symmetrical. On the other hand, due to the positive and larger elongation value of 3, we find that the peak of the distribution is sharper and more elongated than the normal state. Is. With the results obtained from Table (2), it seems that the t-Student statistical distribution for these three variables is more suitable than the normal distribution. Table (3) shows the generalized Dickey-Fuller unit root test results, which indicate the research variables' meanness. From Table (4), we have the results of the Arch effect test, which confirms the assumption of variance heterogeneity due to the significant value obtained.

After studies based on information criteria such as AIC and BIC, the optimal intervals are determined; The results can be seen in Table (5).

After modeling the deviation of the conditional criteria of Volatility models, we extract the three variables of the total stock index, free exchange rate (Dollar), and banking industry index and use them as input variables to construct the stress index. This study used the multivariate GARCH-conditional dynamic correlation (DCC-GARCH) model approach to construct the financial stress index. Before modeling, we repeat the variance heterogeneity effects (ARCH) test again along with the dynamic conditional correlation test to ensure the correctness of this approach. Figure (2) shows the diagram of the input variables for the DCC-GARCH model.

Table (3) Results of Augmented Dickey-Fuller Test

Variables	Statistic	Sig
Stock market index Efficiency	- 8.9869	0.000
Currency price Efficiency	- 10.2898	0.000
Banking industry index Efficiency	- 10.0047	0.000
Coin market Efficiency	- 10.0419	0.000
Insurance industry index Efficiency	- 10.314	0.000
The efficiency of energy carriers	- 9.6355	0.000

Source: Researcher's findings

Table (4) Results of variance heterogeneity (ARCH) Test

Variables	Statistic	Sig
Stock market index Efficiency	53.153	0.000
Currency price Efficiency	115.777	0.000
Banking industry index Efficiency	8.775	0.0124
Coin market Efficiency	104.5334	0.000
Insurance industry index Efficiency	6.1704	0.0457
The efficiency of energy carriers	185.7735	0.000

Source: Researcher's findings

Table (5) Optimal models selected

Variables	Volatility Choice Model
Stock market index Efficiency	ARMA(4,2)-GARCH(1,1)
Currency price Efficiency	ARMA(1,2)-GARCH(1,1)
Banking industry index Efficiency	ARMA(2,2)-GARCH(1,1)
Coin market Efficiency	ARMA(0,1)-GARCH(1,1)
Insurance industry index Efficiency	ARMA(3,0)-GARCH(1,1)
The efficiency of energy carriers	ARMA(1,3)-GARCH(1,1)

Source: Researcher's findings

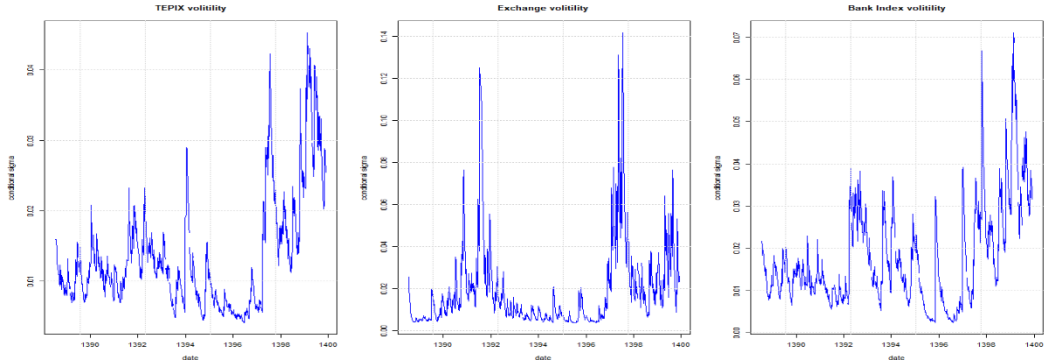

Figure (2). Daily Volatility time series chart of the banking industry's total stock index, currency price, and Volatility index.Source: Researcher's findings

From table (6), we also have the results of the ARCH effects test:

Table (6) Analysis of the effect of variance heterogeneity (ARCH) for the constituent variables of the financial stress index

Variables	Statistic	Sig
Total stock index	1498.137	0.000
Currency	1298.091	0.000
Banking industry index	1440.256	0.000

Source: Researcher's findings

According to the values obtained in Table (6), the assumption of arch effects is significant. On the other hand, Engle & Sheppard (2001) designed a test to examine the existence of dynamic correlation, the results of which are available in Table (7).

Table (7). Results of Engle & Sheppard Dynamic Correlation Test (2001)

Statistic	Sig
1379.356	0.000

As can be seen, the significant value is less than 0.05, which indicates the rejection of the null hypothesis that the correlation is constant. Thus, the opposite assumption of correlation dynamics is accepted, which somehow validates the DCC-GARCH approach we will follow. The Dynamic Conditional Correlation Model (DCC) is a generalized version of the fixed conditional correlation model performed by Engle III & Sheppard (2001). This model is as follows(Engle III & Sheppard, 2001):

model (2)

$$r_t = \mu_t + a_t$$
$$a_t = H_t^{1/2} z_t$$
$$H_t = D_t R_t D_t$$
$$R_t = diag(Q_t)^{-1/2} Q_t diag(Q_t)^{-1/2}$$
$$\varepsilon_t = D_t^{-1} a_t \sim N(0; R_t)$$
$$\bar{Q} = \frac{1}{T}\sum_{t=1}^{T} \varepsilon_t \varepsilon_t^T$$
$$Q_t = (1 - a - b)\bar{Q} + a\varepsilon_{t-1}\varepsilon_{t-1}^T + bQ_{t-1}$$

Where:

r_t is an n-unit vector of the time series at time t (usually, the logarithmic returns of stocks are considered, in this study, the subject under study is the constructive variables of the financial stress index).

A_t: vector n of a perturbation sentence at time t

H_t: matrix n × n conditional variance a_t time t

H_t ^ (1/2): The matrix n × n, which is usually obtained by the Cholesky decomposition of the Ht matrix.

Dt: The matrix n × n is the diameter of the conditional standard deviation at a_t time t.

Rt: Matrix n × n Conditional correlation at a_t time t.

zt: A n-vector of standard normal random variables.

$\bar{Q}$: Unconditional covariance matrix ε_t

εt: standardized wastes but correlated.

a; b are DCC parameters that must be true of the following two conditions.

1) $a \geq 0;\ b \geq 0$

2) $a + b < 1$

From Table (8), we have the fulfilled coefficients related to the dynamic correlation and each significance test.

The above table shows the estimated coefficients related to the multivariate GARCH model - dynamic conditional correlation. As it can be seen, both the obtained DCC parameters are greater than zero, and their sum is less than one, which indicates that the DCC conditions are established; on the other hand, considering the significant value obtained, the significance assumption of the coefficient a is only confirmed and the significance of b is not confirmed; With the positive DCC-a parameter, following a shock in the series of variables, an increase in the conditional correlation for the next period can be expected, on the other hand, the DCC-b parameter indicates the effect of the conditional correlation of the previous period on the current period. The larger this parameter is and the closer it is to one, it is expected that for each pair of calculated correlations, the correlation of the current period will be close to the conditional correlation of the previous period.

But since the estimated coefficient of this parameter is not significant, it can be concluded that the conditional correlation of the previous period does not have much effect on the current period. From figures (3), (4), and (5), we have two-by-two dynamic conditional correlation diagrams for financial stress index variables. Each of these graphs shows the conditional correlation over time for one variable against another variable. From how these graphs move, we can judge the amount of conditional correlation changes between variables; Or, in other words, observe how the effects and shocks of one variable spread to other variables.

Table (8) Table of Conditional Dynamic Correlation Estimation Coefficients (DCC)

Parameters	Estimation coefficient	SD	T	Sig
[Stock market index Efficiency].mu	0.00968390	0.000542127	17.86	0.00
[Stock market index Efficiency].omega	4.18889E-07	3.55777E-07	1.18	0.24
[Stock market index Efficiency].alpha	0.76071784	0.178823305	4.25	0.00
[Stock market index Efficiency].beta	0.23828164	0.16657882	1.43	0.15
[Currency price Efficiency].mu	0.00596821	0.000260885	22.88	0.00
[Currency price Efficiency].omega	1.60493E-06	4.44714E-07	3.61	0.00
[Currency price Efficiency].alpha	0.57199933	0.135186967	4.23	0.00
[Currency price Efficiency].beta	0.42699515	0.144524279	2.95	0.00
[Banking industry index Efficiency].mu	0.01319269	0.000732422	18.01	0.00
[Banking industry index Efficiency].omega	2.12481E-06	1.14546E-09	1854.99	0.00
[Banking industry index Efficiency].alpha	0.99899961	0.055562904	17.98	0.00
[Banking industry index Efficiency].beta	2.38253E-07	0.009094974	0.00	1.00
DCC-a	0.74529700	0.034616113	21.53	0.00
DCC-b	0.035455035	0.055225539	0.64	0.52

Source: Researcher's findings

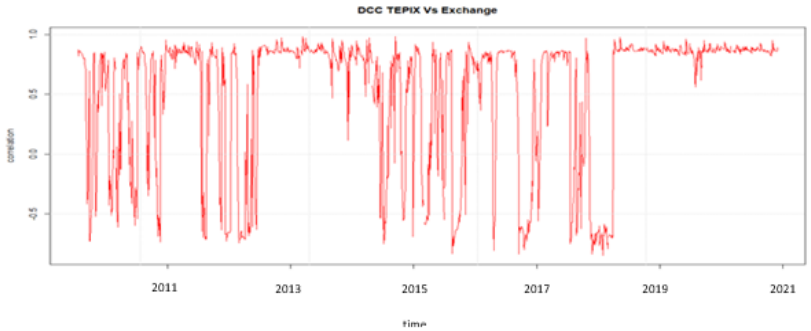

Figure (3) conditional dynamic correlation diagram between the two variables of total stock market index volatility and currency volatility (source: researcher's findings)

With a brief look at Figure (3), we find that the range of correlation changes between the two variables is approximately in the range of -0.8 to 0.9. Another noteworthy point is that the correlation behavior from 2019 onwards is quite positive and very strong between the volatility of the overall stock index and the currency volatility. In other words, it can be concluded that the contagious effects of the stock market and currency market turbulence on each other are very fast and with high intensity in different directions.

From Figure (4), we can see that the conditional correlation between the volatility of the total stock index and the volatility of the banking industry index is approximately in the range of -0.9 to 0.9, which indicates a strong oscillation of correlation in different periods. From this diagram, it can be seen how the effects of the turbulence of the total stock index and the beta of the banking index on each other are almost rapid but in different directions. Finally, from Figure (5), we see the conditional dynamic correlation between the two variables of foreign exchange market turmoil and the turmoil of the banking industry index, which is similar to the above range of correlation changes over time in the range of 0.8 to 0.9, which is interpreted as above. This means we are witnessing a rapid and immediate spread in the turmoil of the foreign exchange market and the banking industry index. According to the three dynamic correlation diagrams obtained and also the significance of the parameter coefficient a of the DCC model, which indicates the effect of shocks on the conditional correlation of the future period of variables; We can confirm the constructive and effective role of these three variables in constructing the financial stress index.

It should be noted that the main purpose of this study is not only to investigate the contagion but also to use this dynamic conditional correlation to construct a financial stress index. Meanwhile, with a brief look at how the correlation behavior of variables can, we can have an insight into the effects of the stock market and foreign exchange market turmoil, as well as the banking industry index. In the following, by explaining the formula, we will construct the financial stress index and its components.

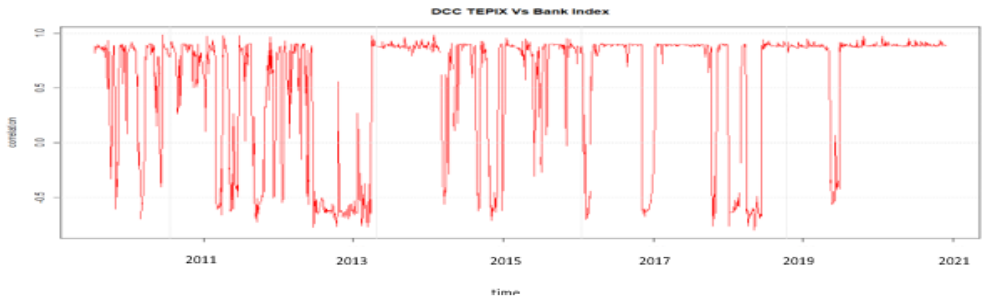

Figure (4). Conditional dynamic correlation diagram between two variables of total stock market volatility and banking index volatility (source: researcher's findings)

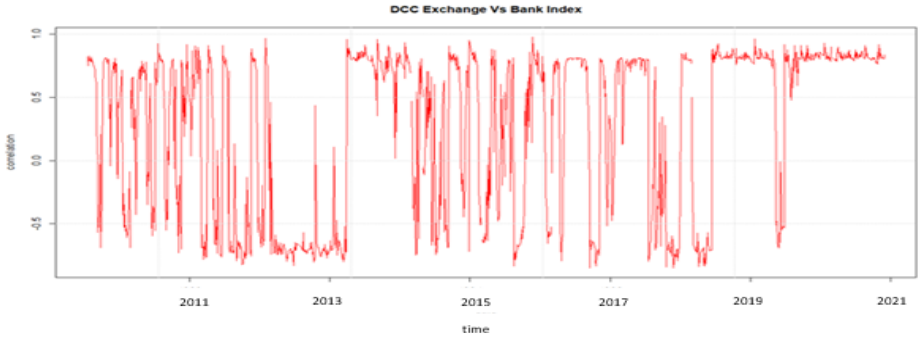

Figure (5). Conditional dynamic correlation diagram between two variables of foreign exchange market volatility and banking index volatility (source: researcher's findings)

4.1.2 Calculating optimal weights of financial stress index variables with the Analytical Hierarchy (AHP) approach:

We should consider one point in the verbal comments used for quality indicators. If the importance of element i over j is equal to n, then the importance of j over i is equal to 1/n. And according to this point, it is enough to fill only the values above the main diameter in the matrix of pairwise comparisons. The values below the main diameter will be the inverse of the values above the diameter. For example, the matrix of paired comparisons obtained by an expert is as follows:

Finally, having the matrix of pairwise comparisons in hand, we can calculate the corresponding weights, whose results can be seen in table (10).

After extracting the obtained weights using the Hollo formula that was stated at the beginning, we will construct the financial stress index. After constructing the financial stress index, we are trying first to measure the effect of the previously mentioned independent variables on the financial stress index using the linear regression model. On the other hand, evaluate and test this index at different time points. It should be mentioned that we used artificial neural networks (ANN) in this research to test the financial stress index. The tested time horizons are 50, 100, 150, and 300 days respectively. Figure (6) shows the designed financial stress index diagram.

As can be seen from the diagram in Figure (6), we see significant stress three times before 2019. The first considerable stress is observed between 2012 and 2013; from then until 2018, financial stress is almost in the form of microwaves. It moves with low intensity, and we see the lowest amount of stress in 2017, until in 2018, we suddenly see significant jumps in the stress index, so the most severe stress occurred this year. On the other hand, from 2018 until the end of 2020, we are witnessing strong waves of stress compared to recent years.

In the following, from the table (11), we have the results of the significant test of the coefficients of the independent variables on the stress index, which are as follows:

Table (9) matrix table of pairwise comparisons by an expert

Importance in the financial system	stock market turbulence	Currency turbulence	Turbulence in the banking industry
stock market turbulence	1	5	0.25
Currency turbulence	0.2	1	7
Turbulence in the banking industry	4	0.143	1

source: researcher's findings

Table (10) of weights obtained from the process of hierarchical analysis

Indicator	Total stock index	Currency rate	Banking industry index
Weight	0.349	0.410	0.241

source: researcher's findings

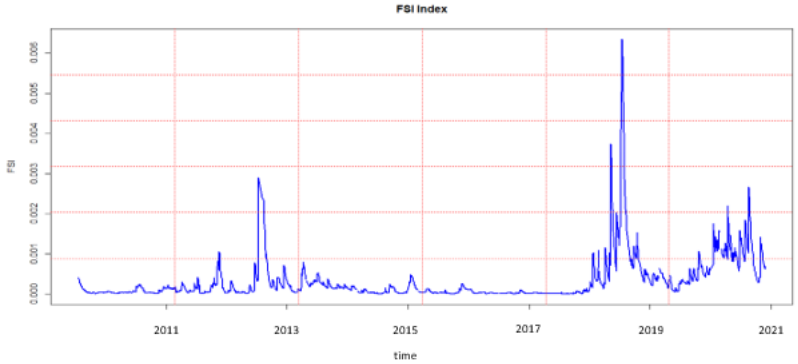

Figure (6). Financial stress index chart designed for the years 2009 to 2020(source: researcher's findings)

Table (11). Significance test of independent variables on the financial stress index

Coefficients	Estimation	SD	T	Sig
y-intercept	-0.0003963	0.00001353	-29.295	0.00
Stock market index Efficiency	0.01835	0.001193	15.38	0.00
Currency price Efficiency	0.02553	0.0005105	50.015	0.00
Banking industry index Efficiency	0.005216	0.000721	7.234	0.00
Coin market Efficiency	-0.007047	0.0005805	-12.139	0.00
Insurance industry index Efficiency	0.003047	0.0007633	3.992	0.00
The efficiency of energy carriers	0.0006226	0.0002726	2.284	0.02

source: researcher's findings

Considering the significant values, we find that all the independent variables of the research have a significant effect on the financial stress index, except for the coin market turmoil, which has a negative impact, and the other independent variables have a positive effect on the financial stress index. The value of the model determination coefficient is 0.8736, which indicates that the quality of the fitted model is desirable.

4.1.3 Evaluation of financial stress index using an artificial neural networks approach

In the final part of this research, we evaluate the financial stress index designed in different time horizons using artificial neural networks. For this purpose, 4-time horizons of 300, 150, 100, and 50 days have been considered, which can be seen from table (12) of the evaluation results of their financial stress index. This work aims to build a prediction model for the financial stress index and, accordingly, to issue a warning to the economic system.

• Artificial Neural Networks (ANN)

In this research, neural network architecture is used in the form of an input layer with six features, which are the same independent variables that were used in the previous section of the regression model; A hidden layer with ten neurons, which combines these features at a higher level, and an output layer, which is the target variable, which is the financial stress index. After training the network, the results are given in table (12).

As can be seen from the above table, the forecasting of the financial stress index based on the input variables performs better in shorter time horizons, so it can be concluded that the stress index forecasting model designed based on the inputs is as follows: It should be considered a quick warning system. Therefore, based on the changes in the input variables, the amount of financial stress can be predicted, and appropriate management measures can be taken accordingly.

Table (12) descriptive statistics of input variables along with financial stress index

Variables	Average	Standard deviation	Middle	minima	Maximum	skewness	Kurtosis
Financial stress index	0.0003	0.0005	0.0001	0.0000	0.0063	4.4152	30.4883
The volatility of the total stock market index	0.0138	0.0083	0.0115	0.0041	0.0453	1.459	1.7388
Exchange rate volatility	0.018	0.0184	0.0115	0.0038	0.1417	2.6739	9.6725
The turbulence of the banking industry index	0.0179	0.0121	0.0143	0.0024	0.071	1.367	2.2321
Turbulent coin market	0.0240	0.0164	0.0184	0.0074	0.1074	1.9033	4.3956
The turbulence of the insurance industry index	0.0202	0.0101	0.0181	0.0064	0.0696	1.088	1.4268
The turbulence of energy carriers	0.0306	0.0212	0.0264	0.0165	0.2687	6.3544	50.6988

source: researcher's findings

Table (13) settings of the models used in the research

ANN model	
Network type	MLP
Number of hidden layers	1
Number of neurons	10
Activation function	Linear
Learning algorithm	BFGS

source: researcher's findings

Table (14) shows the results of the prediction accuracy of the financial stress index during different time horizons

MAE	RMSE	MAE	RMSE	time horizon (working day)
0.000017	0.000026	0.000021	0.000032	50
0.000050	0.000063	0.000020	0.000030	100
0.000141	0.000202	0.000029	0.000032	150
0.000149	0.000326	0.000023	0.000032	300

source: researcher's findings

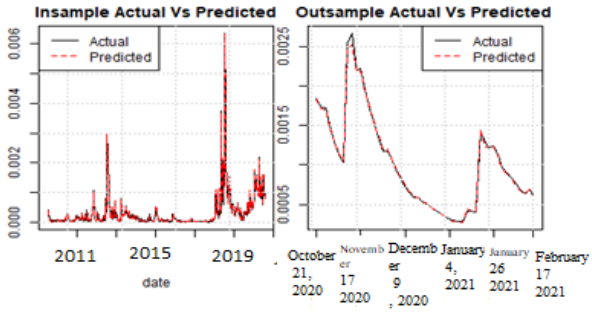

Figure (7) financial stress index prediction chart for a time horizon of 50 working days (source: researcher's findings)

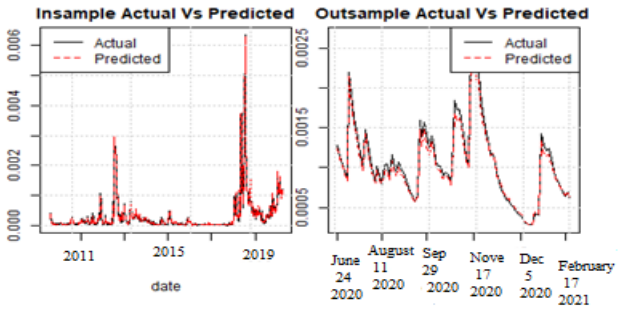

Figure (8) financial stress index prediction chart for the time horizon of 100 working days (source: researcher's findings)

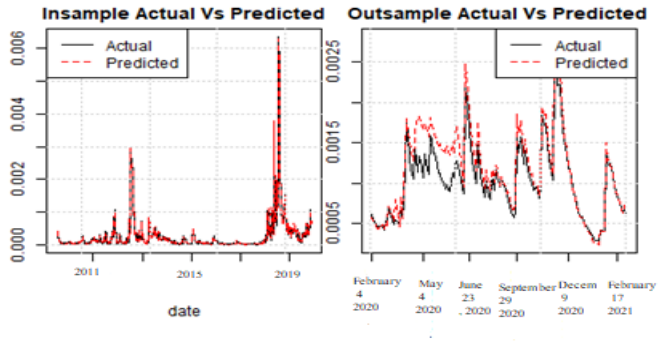

Figure (9) financial stress index prediction chart for a time horizon of 150 working days(source: researcher's findings)

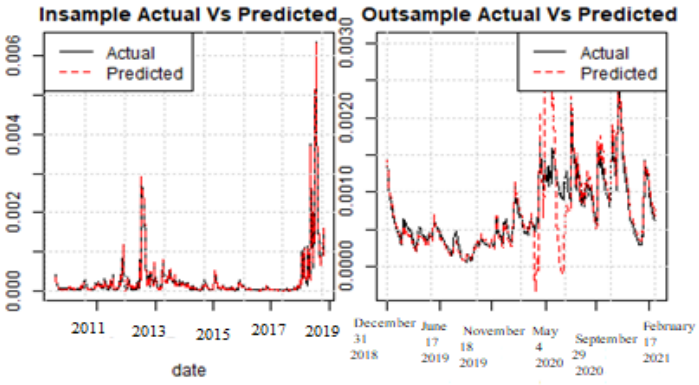

Figure (10) financial stress index prediction chart for a time horizon of 300 working days(source: researcher's findings)

5. Results

The global financial crisis was a bitter reminder of the spillover effects of financial turmoil on emerging market economies. The event's aftermath shows the adverse repercussion effect of the crisis on the real economy. It is, therefore, imperative for policymakers to monitor the prevailing level of financial stress across the market .The recent global financial crises indicate the many weaknesses of financial systems. One of the most important lessons of these crises is that financial system supervisors and decision-makers do not have the necessary tools to identify the process of increasing stress and measure it on time.

Another problem is that even when they are aware of the process of its formation, they do not have the tools that allow them to intervene quickly (Hollo et al., 2012). Therefore, the main concern about financial stress is how economic activities are affected by them and how policymakers can reduce the economic consequences caused by it and prevent the occurrence of similar incidents in the future (Cardarelli et al., 2009). Based on this, hypotheses were proposed in the present study according to the research literature6. In this research, the general goal is to design and construct an index to predict the occurrence of financial stress in the financial markets of Iran. All the variables used in this research are on a quantitative scale. Observations in the form of daily time series from October 12, 2009, to February 17, 2021, which are from October 12, 2009, to January 20, 2019, as training data for modeling and Construction of financial stress index and from January 21, 2019, to February 17, 2021, is considered as experimental data for testing and evaluating the designed stress index.

After explaining the variables and how they are obtained, and their effect on the financial stress model, the researcher concludes that: the main dependent variable of the research, which is the financial stress index, is itself formed through three other side variables in such a way that by using the heterogeneity model Generalized variance (GARCH) suitable for each of the returns of the total index of the Tehran Stock Exchange, the return of the free currency price (dollar) and the return of the banking industry index, extracts the values of the resulting conditional variances under the title of turbulence of these markets and as an input variable. It is considered for the construction of the financial stress index. In examining the relationship between volatility and efficiency, both variance and conditional standard deviation have been considered as volatility. By examining the average and median criteria, we find that the average yield of the total index of the Tehran Stock Exchange is slightly higher than the yield of the currency and the banking industry index. On the other hand, looking at the values of range and standard deviation, we can see that the total index of the stock market has lower values than the other two variables, which in a way can be concluded that the risk of the stock market is lower compared to the currency market. The obtained skewness values for all three variables are in the range (2 and -2), so the distribution of these three variables can be considered symmetrical. It is more stretched. The unit root test and the arch effect test were used to check the meanness and the existence of heterogeneity of variance in the research variables to select the

optimal model and, finally, modeling. The results show that the results of the generalized Dickey-Fuller unit root test are given, which indicates the significance of the research variables. In other words, because the significance of the test is less than 0.01, the research variables are significant at the 0.99 confidence level. Also, the ARCH effects test results at the 0.99 confidence level show that the assumption of heterogeneity of variance is also confirmed. In other words, the significance level of the test is less than 0.01. Also, the result shows that the banking industry index (sig=0.0124) and insurance (sig=0.0457) have a significance greater than 0.01. Therefore the statistical hypothesis is rejected, and the hypothesis of heterogeneity of variance is not confirmed in their case. The results of modeling the effects of heterogeneity Variance (arch) were repeated along with the dynamic conditional correlation test to ensure the validity of this approach.

The analysis showed that at the confidence level of 0.95, the significance is less than 0.05. Therefore, the statistical hypothesis of the existence of correlation dynamics is accepted, which in a way gives credibility to the DCC-GARCH approach. The results of the estimated coefficients related to the multivariate Garch model - dynamic conditional correlation show that both the obtained DCC parameters are greater than zero and their sum is less than one, which indicates that the DCC condition is established; on the other hand, considering With the significant value obtained, the assumption of the significance of coefficient a is only confirmed, and the importance of b is not confirmed, with the positiveness of the DCC-a parameter, following the occurrence of a disturbance in the series of variables, an increase in the conditional correlation for the period The next can be expected, on the other hand, the DCC-b parameter expresses the conditional correlation effect of the previous period on the current period. The larger this parameter is and the closer it is to one, it is expected that for each pair of calculated correlations, the correlation of the current period will be close to the conditional correlation of the previous period. But since the estimated coefficient of this parameter is not significant, it can be concluded that the conditional correlation of the previous period does not have much effect on the current period.

The suggestions provided are in line with the obtained results and also the strengthening of the existing model is presented. For this reason, the researcher believes that:

- Strengthening non-oil inputs will reduce the country's dependence over time and reduce the impact of oil price fluctuations and their destructive effects on the country's economy.
- Establishing policies to control unpredictable fluctuations and turbulences, to reduce the destructive effects on the country's economy.
- Trying to strengthen the value of the national currency by implementing important policies to improve the macroeconomic performance of the country.
- Considering that one of the duties of the stock exchange officials is to determine the stock price of the companies admitted to the stock exchange, and this price should reflect all the factors affecting the stock market, therefore, all economic factors, including currency and price fluctuations, should be taken into account. Stock prices should be considered.
- Active investors as well as new investors should pay enough attention to the short and long-term effects of price and currency changes on indices and not use sudden changes in indices as a criterion for evaluation.
- Fundamental attention through new methods of market management, insuring investors, guaranteeing profitability, and long-term support can be very important in the turbulent conditions of the capital market.
- Considering that the turbulence in the currency market, energy carriers, and banks is effective in the long term, it is suggested that the financial managers of the companies, if they seek to invest the company's assets in the capital market in the form of shares are, to reduce the investment in this market and to invest in resources that have a higher yield.
- It should be noted that the turbulence in the currency market and prices are exogenous from the point of view of CEOs and they do not have the power to influence it and considering that these turbulences have positive effects in the short term and negative effects in the long term on the index. have a price, managers are suggested to pay more attention to the real performance of the

company and profitability in their evaluations and to consider the long-term view in their analyzes and decisions so as not to be misled and make wrong decisions.

Availability of data and material: There is no conflict of interest between colleagues in this article.

Competing interests: This article comparatively analyzes stock exchange companies.

Funding: No funding has been received from any organization.

Authors' contributions: All authors have an equal share in this article.

Acknowledgments: We have our thanks and appreciation from the Iran Stock Exchange Organization.

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