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Research paper

Evaluation of Systemic Risk and Spillover of Index Volatilities of Different Industry Groups in Tehran Stock Exchange

Mehdi Mohammad pour[1], Majid Zanjirdar[2], Peyman Ghafari Ashtiani[3]

[1] Department of Management, Ar.C., Islamic Azad University, Arak, Iran.
mehdi.mohammadpour8435@iau.ac.ir

[2] Department of Finance, Ar.C., Islamic Azad University, Arak, Iran.
majid.zanjirdar@iau.ac.ir

[3] Department of Management, Ar.C., Islamic Azad University, Arak, Iran.
pe.ghafari@iau.ac.ir

Abstract:
The expansion of communications between active industries and companies in different industry groups on the Tehran Stock Exchange has caused that, in the event of volatility in an industry index, this volatility can spread like a domino to other industry groups and also to other economic sectors, creating systemic risk. Therefore, it is necessary to identify the index of volatile industries, calculate and evaluate the contribution of each of them to the occurrence of systemic risk, the amount of spillover, and the amount of their influence and impact on each other. The purpose of this research is to prioritize the volatility of time series data of 30 industry indices of Tehran Stock Exchange, from 2008 to 2024 using 6 entropy methods, calculate the systemic risk of the growth of each industry index using the conditional value at risk measure ΔCoVaR, and also evaluate the amount of volatility spillover using the TVP-VAR auto-regressive model to predict and prevent the destructive effects of volatility. The research findings show: The highest volatility is related to 8 indices: other mines, communication equipment, agriculture, leather products, coal, petroleum products, chemicals and cement. Also, the highest contagion is to companies active in the coal industry. In addition, the chemical and cement industries can begin to be a systemic risk to the Iranian capital market. Also, a net examination of the spillover effect shows that the growth of the chemical, cement, and communication equipment industries is injecting spillovers into other industries.

Keywords: Systemic Risk, Entropy, Conditional Value at Risk, Spillover of Volatility.
Classification: MSC2010 Classifications: 91G70-62O05.

1 Introduction

The uncertainty of various economic and financial sectors in developing countries, including Iran, is greater than in other countries. In addition, over the past decade, as a result of Western sanctions, the emergence of targeted subsidies, the increasing

[2]Corresponding author
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growth of liquidity, and other obvious and hidden factors, the Iranian economy has been in a very special situation. Budget deficit, lack of exchange rate control, coin, housing, and automobile markets have also experienced severe volatility's. The volatility of the stock exchange index and its successive record-breaking have also been clearly visible in recent years. The recession in economic activities, the decline in the employment rate, and high inflation have caused numerous livelihood problems, instability in economic activities, and confusion among investors in the financial markets. Due to the increasing interactions and growing interconnection's between financial markets, the transmission of recessions and booms from one market to another is growing at a remarkable rate. Due to the occurrence of financial crises and the interconnectedness and interconnections of financial markets and various sectors of the economy, the issue of systemic risk has attracted the attention of researchers around the world for about a decade as one of the main mechanisms for transferring crises from individual financial institutions to other institutions or from one market to other markets, and ultimately the entire economy.

The risk arising from internal connections and dependencies in a system or a market that, due to a failure in one component of the system and it's spread throughout the entire system or market, leads to a crisis in the entire system or market is called systemic risk [36]. Systemic risk is rapidly transmitted to other sectors due to the high level of linkage between financial markets and sectors of the economy. With timely identification and rapid response, financial crises can be prevented [11]. Since 1997, the term contagion has been introduced in economic and financial literature due to the connection between markets, financial institutions, and various sectors of the economy. Examining the degree of influence of different markets and the degree of dependence of these markets on each other creates the opportunity to reduce the destructive effects of a crisis on different sectors or direct it in a desirable direction by using appropriate policies before and after it occurs [37].

Trade and economic relations between different countries mean that if a crisis occurs in one country, it will severely affect other countries and economies across the trade borders of one country. Financial and real markets within countries also have reciprocal effects on each other, and the weakening of each has side effects on the other market, which ultimately challenges economic stability. Government thinks tanks, think tanks, and researchers around the world have been using various methods and tools to prevent its recurrence or find a way to predict the time of crises, confront and prevent similar crises.

In examining financial markets, one of the most important markets is the stock market (capital). This market is one of the most prosperous financial markets in the world, and investors can achieve high profits by purchasing shares in the stock market. At the same time, there are also risks in this market that must be considered [43]. A country's capital market is closely related to its economic structure, and its strength and weakness can indicate the economic situation of that country [9]. The Iranian capital market consists of various industries, and an

industry index has been defined for each group of these industries. By examining the changes in these indices, managers of these industries can make investment decisions or decisions to control the status of the company and the industry in which they operate. On the other hand, due to the interconnectedness between different industries and the behavior of investors in choosing their investment portfolio, there is a possibility of shocks and volatility's being transmitted from one industry to another [28]. Therefore, identifying the degree of impact, influence, and spillover of shocks and volatility's from each industry to another, in a situation where there are many uncertainties in the Iranian business environment, will provide guidelines for more appropriate decision-making in different industries [30].

The propagation of shocks or volatilises in a financial system is from the macroeconomic perspective, depending on the type of systemic event and the mechanism that leads to default or collapse, and the result will be a reaction between real and financial variables, causing fluctuations in them. For example, an inflationary stagnation or exchange rate fluctuation causes a wave of fluctuation or failure in economic enterprises. Each economic enterprise operates in a specific industry, so this fluctuation or failure causes fluctuations in the industrial index in which the enterprise operates. This phenomenon also affects the indices of other different industries with different intensities and causes them to fluctuate. This is the core of the concept of systemic risk indicators for various industry groups in the capital market. Systemic risk assessment and contagion of volatility provide early warning signals for early detection of crises. They also indicate the degree of contagion of volatility [12].

One of the most important signs of uncertainty in an economic system is high and severe volatility in economic variables. Obviously, volatility's lead to uncertainty in investment, both in terms of profitability and investment costs. This unpleasant phenomenon in the economy has caused economic policy makers in every country to seek to reduce the uncertainty environment and increase the predictability of economic variables.A review of various studies shows that the selection of variables and indicators for systemic risk studies does not follow a scientific approach and merely focuses on a part of the market and economic variables to examine and evaluate them. While the selection of volatile variables and indicators creates the conditions for the emergence of systemic risk. Also, domestic research in the field of systemic risk and contagion of volatility has focused more on macroeconomic variables such as inflation rate, exchange rate, oil price, gold price, total stock exchange index, and gross domestic product. In this regard, Taleblou and Mohajeri's research in 2021 also shows that in the past decade, only 8 percent of published articles evaluated the stock exchange's selected industry indices [39]. Therefore, this research will address some of the research gaps, including how to select variables based on the highest level of volatility and also focusing on all indices of different industry groups in the Tehran Stock Exchange as a symbol of the country's economy.

In order to determine the degree of volatility of financial data, including the

volatility of price indices of different industry groups in the capital market, we use entropy, which is a concept from information theory and thermodynamics, as a criterion for measuring uncertainty in this system. In financial markets, this concept is used to measure the degree of volatility or uncertainty in prices and financial indices. In addition, based on the concepts of thermodynamics and its expansion and development in financial and economic studies, the use of various entropy methods is purely a matter of taste and no evaluation has been made regarding the comparison of the results of their simultaneous application, so this research will also answer this research gap [2].

In order to control uncertainty and predict the effects of volatilities, prioritizing the volatility of different indicators is not enough because the contribution of each indicator and the direction of contagion of volatile to other indicators cannot be assessed, so different systemic risk measures are used to solve this problem. Various measures have been used in this regard so far. However, there is no consensus on the selection of the best measure to assess systemic risk [21]. However, among all the methods that have been used so far and are discussed in the research background section, the delta value-at-risk method has a higher validity. First, unlike other models, it does not focus only on the extreme values of the sequence, so it uses all the information of the time series data. Second, it considers the possibility of contagion of the financial crisis caused by unbelievable factors resulting from internal connections between financial institutions. Third, it shows the direction (side) of contagion of a variable or indicator to other variables and indicators [13].

Regression models can be used to more accurately assess the extent of spillover of volatility's from one index to another (impact and influence) and which industries are receiving and which industries are injecting volatility's. In traditional time series regression models, it was assumed that a relationship with fixed coefficients could be applied at different times. This unrealistic assumption led to incorrect results, so the results of research led to the emergence of dynamic models that are better suited to the reality of the real world. Among these models is the dynamic time-varying model, the TVP-VAR model, which was presented by Koop and Korobilis in 2014 [23]. The above model has many advantages over other vector auto-regressive models such as DCC-GARCH. Given that financial time series, including the stock exchange industry price index, can experience structural failures and cyclical changes over time, the use of time-varying coefficients (TVP) leads to more accurate results.

Therefore, according to the above explanations, the main goal of this research is a precise and comprehensive assessment of the volatility, systemic risk, and spillover effect of the volatility of various industry indices of the Iranian capital market in order to predict and prevent the destructive effects of volatility. Therefore, to achieve this goal, volatility is evaluated and prioritized using the entropy method. The next innovation and goal of this research is to compare the results of using several entropy methods to show how different methods differ from each other and

which method or methods are more appropriate to use in the economic conditions of Iran. In addition, in order to determine the contribution of each indicator to the occurrence of systemic risk and its direction, it will also be evaluated in this research, which will be used in this research due to the advantages of the ΔCoVaR method.Also, the amount of spillover of each industry index's volatility onto other industry indices is evaluated based on the TVP-VAR method, and the degree of their influence and mutual influence is also calculated.

The results of this research will help politicians, investors, decision-makers, and economic activists to examine the status of the volatile industries of the Tehran Stock Exchange, the channels of contagion, the level of systemic risk of each industry, and the level of volatility spillover, and take the necessary preventive measures in times of crisis. In this study, after the introduction in the second section, the theoretical foundations and summary of the results of past research are presented, then the research methodology will be discussed in the third section. The findings based on the research questions are presented in the fourth section, and the final section presents conclusions and suggestions.

2 Theoretical foundations and research background

In developing countries, including Iran, the volatility of different sectors of financial markets is higher than in other advanced and industrialized economies [20]. The result of these volatility's, especially in the capital market, will cause uncertainty for economic actors, investors, and managers of various industries, and will cause uncertainty and hesitation in their decision-making. The theoretical basis of uncertainty has its roots in the book by Kenneth Arrow (1971) [22]. In his book, Comte first presented a conceptual framework for the subject of risk and uncertainty, long before many other scientific schools. The principles of risk and uncertainty presented by Comte were widely used in all areas of economic and financial knowledge in the following years, and became an integral part of the theoretical knowledge of decision-making in the fields of finance and economics. General systems theory was also proposed by Ludwig von Bertalanffy in her book General Systems Theory in 1968 [24]. According to Bertalanffy's general systems theory, scientific disciplines are not inherently separate from each other, just as different parts of a cell interact with different parts of an organism. (feminine) After presenting the general theory of systems, many researchers have used Ludwig's general theory of systems extensively in their research, using inter-root methods and models, and this continues to be the case. Shannon introduced the concept of entropy, which is rooted in the properties of physical and thermodynamic systems, in 1948 after introducing the second law of thermodynamics [35]. According to Shannon's initial definitions, entropy is a quantity that represents the amount of energy that cannot be converted into useful work. After the concept of entropy was introduced, efforts to understand and apply entropy continued, eventually leading to the development of a new

microscopic view. According to this new and developed view, entropy is a quantity that indicates the degree of disorder in the molecular structure of systems. On the other hand, increasing the amount of entropy leads to the decay and destruction of the system. The important point is that the entropy of a system is directly related to the amount of information available in it. A system with more order can be described with fewer bytes of information, while a system with less order requires more bytes of information to be described [16].

Based on the theoretical foundations mentioned, given that volatility is one of the main factors of uncertainty, in order to investigate and evaluate the systemic risk and contagion of volatility in the growth of the index of different industry groups in the Tehran Stock Exchange, we first prioritize the volatility of the indices using the concepts of entropy. The use of entropy in domestic research in the field of systemic risk has been limited, and recently, Nasrollahi et al. in 2025 used entropy to prioritize macroeconomic variables using a variety of entropy methods and prioritized macroeconomic variables in terms of their degree of volatility [31].

Regarding the spillover of volatility and turbulence, one group of theories focuses on fundamental factors (such as public shocks, trade relations, and financial relations) and another group focuses on the occurrence of contagion based on investor behavior (including issues arising from liquidity and motivation, information asymmetry, market coordination issues, and investor revaluation). Systemic risk research has attracted the attention of governments, policymakers, researchers, etc., since the financial crisis of 2007-2009, as a macro-level risk that causes instability in the entire financial system [1]. The result of increased systemic risk, in addition to increasing the probability of a crisis, is its negative economic effects on the real sectors of the economy [40]. Predicting volatility's and their destructive effects requires examining, evaluating, and analyzing the extent of volatility's and examining the extent and direction of systemic risk in financial markets.

In reviewing the background of research conducted on systemic risk and the spillover of volatility and uncertainty in financial markets, considering the multiplicity of metrics in measuring different dimensions of systemic risk, determining which metric best reflects the relationship between financial markets, including the stock market, is still an open issue in research in this field [21]. But most of the early statistical concepts for calculating systemic risk have emphasized the central limit theorem. However, the value theory of frein Fisher in 1912 focuses more on distribution sequences and can better estimate financial events [26]. Examples of the frein phenomenon are events such as the 2007-2009 US financial crisis and the 1999 financial crisis in East Asian countries, which have a low probability of occurrence but have large and destructive effects. However, given that the time series and distribution of financial returns cannot be described by Gaussian models and have negative skewness and high elongation. Therefore, researchers turned their attention to developing conditional quantiles called conditional risk measures [2], and the success of conditional risk measures can be seen in numerous studies.

Conditional Value at Risk ΔCoVaR was introduced by Adrian and Brunnermeier in 2011 and 2016 [2] [3]. This measure measures the contribution of an institution to systemic risk from the difference between the institutions conditional value at risk in a crisis situation and in normal conditions. Brownlees, and Engle also introduced the marginal expected loss measure MES in 2012 [8]. This measure shows how much an institution would contribute if the entire economic system were to go into crisis. The difference between MES and ΔCoVaR is thatΔCoVaR is a forward-looking measure and MES is a post-crisis (retrospective) measure [7].

In 2014, Oscar et al., using the ΔCoVaR approach, showed that in the Eur ozone between 2004 and 2014, other financial services sectors contributed the most to systemic risk during crises. Also, in the United States, during the same period, the insurance industry was the most systemically risky financial sector, and the banking sector contributed the least to systemic risk [33]. In 2016, Azari Gharehloo et al., examined the systemic risk of 20 large listed companies using the ΔCoVaR, MES, CES, SES, and lower-tail dependence (LTD) measures and divided them into two groups of low and high impact [4].

The results of Mansi et al.'s 2021 study using the VaR indicate a spillover effect between the oil market and the stock markets during the 2008-2009 financial crisis, which was exacerbated by the COVID-19 pandemic [27].

In 2019, Trung used the VAR approach to examine the contagion effect of US economic policy uncertainty on the global economy. The results of this study show that the movement of the US economic policy uncertainty shock on the volatility of other global economies [41]. In 2014, using the EGARCH method, Calmes and Theoret concluded that the banking system in the United States and Canada was severely affected by systemic risk during and after the financial crisis [10].

In 2024, Taleblou et al. used the TVP-VAR approach to estimate the systemic risk and spillover of stock market volatility in order to optimize the stock portfolio. The results of their research show that, first, systemic risk is significant in the Iranian capital market and the role of base metals in pairwise relationships is greater than that of other industries [38].

Mohammadi Nejad Pashaki et al., in 2023 used the BEEK-ARCH model to examine the existence of spillover effects in different sectors. The results show that exchange rate returns, gold, and base metals have spillovers to stock returns. Base metals return also have spillovers to stock returns. In addition, there is a one-way spillover from base metals returns to stock returns and a volatility spillover from stock returns to exchange rate returns during the years 1388 to 1399 [29].

In 2022, Hamidi et al. used the TVP-VAR approach to examine the contagion of uncertainty between sectors (finance, housing, and macroeconomics). Their research results show that the housing sector has been the recipient of uncertainty from other sectors in all periods, except for the beginning of 2008. The financial sector has also played a dual role at different points in time [19].

In 2021, Fallah Shams and Banisharif used the MGARCH approach to investigate

the contagion of financial risks in banks listed on the Tehran Stock Exchange. The results show that the two-way contagion reflects the market, liquidity, and credit risks of banks [14].The results of Mamipour and Feli's research in 2017 show that the spillover of oil price volatility on the returns of stock market industries using the Markov approach is caused by the market itself and causes low and high volatility in the oil and stock markets. In addition, the largest amount of spillover is from the oil market to the basic metals industry index [25].

In 2018, Babajani et al. attempted to design a model to predict systemic risk in the Iranian capital market using the expected final drop approach, the ARMA-GJR-GARCH-DCC framework, and a sequential non parametric estimator [5]. Fallahi and Jahangiri also conducted a study in 2015 with the aim of testing the existence of financial contagion between the foreign exchange, stock and gold coin markets. In this study, using the dynamic conditional correlation method (DCC-GARCH), the correlation structure for daily data of exchange rate returns, stock market index and gold coin prices was examined. The results confirm the contagion phenomenon only between the foreign exchange and coin markets [15].

In 2015, Nikoomaram et al., using a VAR and MGARCH model, confirmed the relationship between the impact of capital market contagion from parallel foreign exchange, gold, and oil markets and showed that the best representative for measuring the contagion of the Iranian capital market is data related to the total index of the Stock Exchange [32].

3 Methodology

This research is based on an applied purpose and is based on fundamental research conducted by previous researchers and is based on retrospective data. Also, a desk research method was used to collect theoretical sources. After identifying the research variables, seasonal time series data for the 30 industry indices from the 2008 to 2024 were extracted from the Aghah brokerage website. (https://oldonline.agah.com). Next, using various entropy methods, the volatility of the priority industry index is calculated, and then the systemic risk of 8 selected industry indices is calculated using CoVaR systemic risk measures, and finally, using the TVP-VAR model, the growth spillover of each industry index and its impact on other industries are evaluated. The analysis steps are carried out using Excel, Eviews 10, and Payton software.

volatility's and shocks in indexes of various industry groups in Tehran Stock Exchange cause volatility to spread domino-like to other industry groups and finally to other economic sectors and cause systemic risk. Therefore, it is necessary to identify the industrial groups that have the highest level of turbulence, to calculate and evaluate the contribution of each of the industries of Tehran Stock Exchange in the occurrence of systemic risk, the amount of spillover and the amount of influence and their impact on each other This issue will help investors, industry managers,

policy makers, etc. in predicting and preventing the harmful effects of industry index volatility's. Therefore, the questions of this research are:

(i) What is the priority of the volatility index of different industry groups in Tehran Stock Exchange based on various entropy methods?

(ii) Is there a difference in prioritizing the volatility rate of the index of different industry groups in the use of these methods?

(iii) What is the value of the systemic risk index of different industry groups based on the ΔCoVaR measure?

(iv) What is the contagion of volatility and fluctuating series of index of different industry groups based on vector auto-regression model with variable parameter in time (TVP-VAR)?

In addition, The statistical population of this research includes the index of 50 active industries in the Tehran Stock Exchange, and the statistical sample of the research includes 30 industry groups out of 50 industries. These industries have been selected according to the following.

(i) In terms of simultaneity, they are industries whose index has been defined since 2008.

(ii) They all have continuous information.

The variables used in this research and their measurement methods are given in table (1).

In Tables (1), the index of each industry is calculated using Equation (3.1) and the growth of the index of each industry is calculated using Equation (3.2).

$$\mathcal{I}ndustrial\ Index_t = \sum_{i=1}^{n} p_i q_i / D_i \tag{1}$$

Where p(i) is equal to Price of the i-th firm in the industry at t, q(i) is equal to Number of issued shares of i-th firm in the industrial at t and D(i) is Base price of industry i at time t.

$$G.\ Industrial\ Index_t = ((Industrial\ Index_t - Industrial\ Index_(t-1))/ \\ Industrial\ Index_(t-1)) * 100 \tag{2}$$

Other variables and their measurement methods are explained below.

3.1 Entropy methods

In this research, various entropy methods have been used to determine and prioritize the level of volatility of the index of different industry groups in the Tehran Stock Exchange, and each of the methods used will be explained below.

Table 1: Research Variables and Symbol

Variable Symbol	Index Title	Variable Symbol	Index Title
Anboohsazi(t)	Accumulation	Entesharat(t)	Publications
Bank(t)	Bank	Haml(t)	Transport
Khodro(t)	Automotive	Barghi(t)	Electrical Applications
Radio(t)	Radio	Rayaneh(t)	Computer
Zeraat(t)	Agriculture	Zoghalsang(t)	Coal
Sayeremaaden(t)	other Mines	Siman(t)	Cement
Kashi(t)	Ceramic tiles	Shimi(t)	Chemistry
Ghazaee(t)	Foods	Foil(t)	Petroleum Products
Felezzat(t)	Metals	Fanni(t)	Technical Engendering
Ghand(t)	Sugar	KaneF(t)	Metal Mineral
KaneNF(t)	Metal non-Mineral	Lastik(t)	Robber
Machin(t)	Machines	Charm(t)	Leather
Choobi(t)	Wood	Felezzi(t)	Metals
Kaghaz(t)	Paper	Mansoojat(t)	Textiles
Darooye(t)	Medicinal	Ertebati(t)	Communication Tools
Tepix(t)	Tehran Stock Exchange	G.Tepix(t)	Growth of Tehran Stock Exchange
G.Zeraat(t)	Growth of Index of Agriculture	G.Zoghalsang(t)	Growth of Index of Coal
G.Sayeremaaden(t)	Growth of Index of other Mines	G.Siman(t)	Growth of Index of Cement
G.Shimi(t)	Growth of Index of Chemistry	G.Foil(t)	Growth of Index of Petroleum Products
G.Charm(t)	Growth of Index of Machines	G.Ertebati(t)	Growth of Index of Communication Tools

Shannon Entropy

In 1948, Shannon's definition of entropy of a random variable X with H(X) as the probability of occurrence was in accordance with formula Equation (3.3) [35].

$$\mathcal{H}(X) = -\sum P(x)\log p(x) = E[\log 1/(p(x))] \tag{3}$$

When the base of logarithm is 2. Ha(x) specifies the entropy of the random variable X based on the base of the logarithm of a. In order to calculate the entropy, first the data are linearized using Equation (3.4) and instead of q(i), D(i) values are calculated. Then, in order for the values to be between zero and one, the K factor is calculated from Equation (3.5) and multiplied by the H value. According to the obtained value (H), for the final prioritization, the degree of deviation is first calculated based on Equation (3.6) and then normalized using Equation (3.7).

$$\mathcal{D}_i = q_i/(\sum_{i=1}^{n} q_i) \tag{4}$$

$$\mathcal{K}_i = 1/(LNn) \tag{5}$$

$$(d_i) = 1 - H \tag{6}$$

$$\mathcal{W}_i = d_i/(\sum_{i=1}^{n} d_i) \tag{7}$$

In Equation (3.4), p(x)i is equal to the value of each variable at each period of time and D(i) is linearized value of each variable. In Equation (3.5), n equal to number of periods. In Equation (3.6), d(i) is deviation degree parameter and finally in Equation (3.7), W(i) is the normalized weighting value of entropy's for variable i.

Renyi Entropy

In 1961, The first generalization of entropy was presented by Renyi, where the entropy of order alpha for the discrete random variable X was presented in the form of Equation (3.8) [34]. Then other calculations are calculated according to Equations (3.4-3.7).

$$\mathcal{H}(X) = 1/(1-\alpha)\log\sum p(x)^{\alpha} \tag{8}$$

In addition, the value of alpha is equal to 2.

Tsallis and Modified Tsallis Entropy

In 1988, Tsallis expressed the entropy of order ailpha for a discrete random variable in the form of Equation (3.9) [42]. Then, after introducing the basic Tsallis model for entropy, the generalized Thesalis entropy was introduced in the form of Equation (3.10) . Other calculations are calculated according to Equations (3.4-3.7).

$$\mathcal{H}(X) = 1/(\alpha-1)[1-\sum p(x)_i^{\alpha}] \tag{9}$$

Then, after introducing the basic Tsallis model for entropy, the generalized Tsallis entropy was introduced in the form of Equation (3.10). Other calculations are calculated according to Equations (3.4-3.7).

$$\mathcal{H}(X) = 1-\sum p(x)^{\alpha} \tag{10}$$

In addition, the value of alpha is equal to 2 and other variable is such as Shannon entropy.

Simpson and Modified Simpson Entropy

The basic formula of Simpson's entropy was introduced as Equation (3.11) and after the introduction of Simpson's basic model for entropy, the generalized Simpson's entropy was introduced as Equation (3.12). Other calculations are calculated according to Equations (3.4-3.7).

$$\phi_s = \sum p_s(1-p_s)^r \tag{11}$$

$$\phi_s = 1-\sum(1-p_s)^{\alpha} \tag{12}$$

In Equations (3.11-3.12), phi(s) is the entropy value and p(s) is value of each variable at each period of time. In additional the value of alpha and r is equal to 2.

3.2 Conditional value at risk delta

In 2011 and 2016, based on the concept of value at risk (VaR), Adrian and Brunnermeier calculated conditional value at risk (CoVaR) by first calculating CoVaR of financial markets in two normal and critical states and then calculating their difference, which is called ΔCoVaR [2] [3]. According to the studies done, ΔCoVaR has become one of the common metrics for measuring systemic risk [6]. In the following, the method of its calculation according to Equations (3.13-3.16) is given.

$$(pr) = R_i \leq VaR_q^i = q \tag{13}$$

$$\mathcal{C}oVaR_q^m|i = VaR_q^m|R_i = q \tag{14}$$

$$(pr)(R_m \leq CoVaR_q^m|i|R_i = VaR_q^i) = q \tag{15}$$

$$\delta CoVaR_q^m|i = CoVaR_q^m|R_i = VaR_q^i - (CoVaR_q^m|R_i = median_q^i) \tag{16}$$

where VaR(q) is equal to the value at risk of the market (i) at the confidence level (1-q)percent and R(i) is the return of each market or variable.

3.3 TVP-VAR method

The incorrect assumption in traditional time series regression models was that a relationship with constant coefficients can be used in varying times. Therefore, this false and unrealistic assumption leads to incorrect results. The efforts made in this regard led to the emergence of dynamic models that are better suited to the reality of the real world. One of the new time-varying dynamic methods is the TVP-VAR model, which was presented in 2014 by Koop and Korobilis [23], and has not been used much in domestic research so far. One of the advantages of this method is to determine the influence and effectiveness of each variable on other variables and to determine the overflows caused by volatility's. Also, the above model has many advantages over other vector auto regressive models Because considering that the index time series of different industry groups can undergo structural failures and periodic changes over time, the use of time-varying coefficients (TVP) leads to more accurate results [13].Suppose that X(t), for T, t=1,..., T is an n*1 vector of variables to estimate unobserved variables and Y(t) is a s*1 vector of the studied indicators, in this case the model will be in the form of formulas (3.17) and (3.18).

$$\mathcal{Y}_t = C_t + \beta_t, 1Y_(t-1)+,,,+B_(t,p)Y_(t-p) + \beta\epsilon_t \tag{17}$$

$$\beta_t = \beta_(t-1) + \eta_t \tag{18}$$

In the above relation, B(t),1,,B(t,p)) are the VAR coefficients and epsilon(t) are the error components with a normal distribution of zero mean and time variable covariance Y(t) and N(0, R(t)) (for eta). According to this method, the regression coefficients of the VAR model are obtained based on a random process over time, and all errors are uncorrelated with each other and over time.

4 Findings

4.1 Descriptive Statistics of Seasonal Data

Table (2) shows the descriptive statistics of the price index of variables in the macroeconomic sector of Iran between 2008 and 2024. The presented descriptive statistics include mean, median, maximum and minimum.

Table 2: Descriptive Statistics of variable from 2008 to 2024

Variable	Min.	Med.	Avg.	Max.
Anboohsazi(t)	240	744	3333	17490
Bank(t)	95	647	2309	9656
Entesharat(t)	4806	78337	495174	3269200
Haml(t)	513	4104	13017	71689
Khodro(t)	2626	15783	77817	359270
Barghi(t)	23557	435572	1649591	7879840
Radio(t)	101	770	2101	10807
Rayaneh(t)	239	7342	22095	89807
Zoghalsang(t)	129	1148	13000	63906
Zeraat(t)	241	6987	76333	385963
Sayeremaaden(t)	792	6048	85645	651804
Siman(t)	141	704	4037	25210
Kashi(t)	231	2031	15628	75246
Shimi(t)	255	4946	33562	174775
Ghazaee(t)	269	3391	16952	81161
Foil(t)	16742	270721	1839526	10466022
Felezzat(t)	3248	33930	338691	1773300
Fanni(t)	45	692	2327	9270
Ghand(t)	276	5544	46884	218618
KaneF(t)	1206	15517	131776	582946
KaneNF(t)	137	2170	15261	79689
Lastik(t)	1736	17744	94219	507929
Machin(t)	2008	12841	84004	393587
Charm(t)	72	1020	9585	87331
Choobi(t)	4581	39227	292708	1674756
Felezzi(t)	1239	23784	77434	419246
Mansoojat(t)	153	1298	4490	27946
Kaghaz(t)	1216	9462	35522	258610
Darooye(t)	461	7939	40182	207426
Ertebati(t)	195	2536	19188	210955
Tepix(t)	7966	77983	465509	2211856
G.Tepix(t)	-12.9	5.02	7.19	50.57
G.Zoghalsang(t)	-40	8	13	113
G.Zeraat(t)	-45	6	17	157
G.Sayeremaaden(t)	-52	2	19	234
G.Siman(t)	-26	1	11	130
G.Shimi(t)	-15	8	12	123
G.Foil(t)	-46	6	14	171
G.Charm(t)	-52	2	19	257
G.Ertebati(t)	-62	0	18	248

According to the results of table (2), the highest amount of positive growth is related to the growth of the transportation industry index, the growth of the automobile industry index, the growth of the leather products industry index, the growth of the other mining industry index, and the growth of the banking industry index by the amount of 327, 269, 257, 234, and 207 percent, and the lowest amount of positive growth is related to the growth of the textile industry index and the

growth of the pharmaceutical industry index by the amount of 66 and 94 percent. In addition, the largest negative growth was related to the growth of the transportation industry index and the growth of the communication equipment industry index at a rate of minus 62 percent.

4.2 Evaluation of the first and second questions of the research

In order to answer questions one and two by using the various entropy methods mentioned in section (3), the calculations are done and the results can be seen in table (3) (In table (3) V equal to value of entropy and R is a ranking of each variables. According to the results of table (3), the ranking of the volatility index of

Table 3: Entropy's Normalized Value and Ranking

	Shannon		Renyi		Tsallis		M.Tsallis		Simpson		M. Simpson	
Variable	V	R	V	R	V	R	V	R	V	R	V	R
Anboohsazi(t)	0.030	24	0.077	19	0.03327	19	0.03332	17	0.032	19	0.032	19
Anboohsazi(t)	0.030	24	0.077	19	0.03327	19	0.03332	17	0.032	19	0.032	19
Entesharat(t)	0.033	19	0.077	22	0.03324	22	0.03329	22	0.032	22	0.032	22
Bank(t)	0.027	27	0.076	27	0.03299	27	0.03325	26	0.029	27	0.029	27
Haml(t)	0.029	25	0.077	23	0.03324	23	0.03331	21	0.032	23	0.032	23
Khodro(t)	0.033	18	0.077	18	0.03328	18	0.3331	19	0.032	18	0.032	18
Barghi(t)	0.031	21	0.076	25	0.03310	25	0.03327	25	0.030	25	0.030	25
Radio(t)	0.024	30	0.074	30	0.03276	30	0.03319	30	0.026	30	0.026	30
Rayaneh(t)	0.026	29	0.075	29	0.03279	29	0.03321	29	0.026	29	0.027	29
Zeraat(t)	0.038	3	0.078	8	0.03349	8	0.03338	7	0.035	8	0.035	8
Zoghalsang (t)	0.038	5	0.078	7	0.03349	7	0.03336	9	0.035	7	0.035	7
Sayeremaaden (t)	0.042	1	0.080	2	0.03389	2	0.03351	1	0.43	2	0.042	2
Siman(t)	0.035	12	0.079	4	0.03361	4	0.03343	3	0.037	4	0.037	5
Kashi(t)	0.036	11	0.078	10	0.03340	10	0.03335	10	0.034	10	0.034	10
Shimi(t)	0.036	8	0.078	6	0.03351	6	0.03339	6	0.036	6	0.036	6
Ghazaee(t)	0.032	20	0.076	24	0.03315	24	0.03328	24	0.031	24	0.031	24
Foil(t)	0.037	6	0.079	5	0.03360	5	0.03334	4	0.037	5	0.037	4
Felezzat(t)	0.037	7	0.078	9	0.03347	9	0.03337	8	0.035	9	0.035	9
Fanni(t)	0.027	28	0.075	28	0.03287	28	0.03322	28	0.027	28	0.027	28
Ghand(t)	0.035	13	0.077	16	0.03331	16	0.03333	16	0.033	16	0.033	16
KaneF(t)	0.036	10	0.077	12	0.03339	12	0.03334	15	0.034	12	0.034	12
KaneNF(t)	0.036	9	0.077	13	0.03338	13	0.03334	14	0.034	13	0.034	13
Lastik(t)	0.034	16	0.078	11	0.03340	11	0.03335	11	0.034	11	0.034	11
Machin(t)	0.034	17	0.077	17	0.03328	17	0.03332	18	0.032	17	0.033	17
Charm(t)	0.038	4	0.079	3	0.03380	3	0.03342	5	0.040	3	0.040	3
Choobi(t)	0.034	14	0.077	14	0.0334	14	0.03331	20	0.033	14	0.033	14
Felezzi(t)	0.028	26	0.076	26	0.03302	26	0.03325	27	0.029	26	0.029	26
Kaghaz(t)	0.030	22	0.077	20	0.03327	20	0.03329	23	0.032	20	0.032	20
Mansoojat(t)	0.030	23	0.077	21	0.03325	21	0.0334	13	0.032	21	0.032	21
Darooye(t)	0.034	15	0.077	15	0.03334	15	0.03335	12	0.033	15	0.033	15
Ertebati(t)	0.040	2	0.081	1	0.03402	1	0.03349	2	0.044	1	0.043	1

different industry groups in Tehran Stock Exchange shows that 4 entropy methods Rennie, Tsallis, Simpson and Generalized Simpson have completely similar results in terms of entropy, and the two entropy methods of Shannon and Generalized Tsallis have different results compared to each other and other methods. The important point in the obtained results is that out of 8 groups of different industries, based on various entropy methods, 7 groups have been ranked 1 to 7, and only the

index of the cement industry has been ranked 12th in the Shannon entropy method, but it has been ranked 3rd and 4th in other methods. Also, the basic metals industry index has been ranked 9 in 4 methods. Considering that one of the goals of this research was to use entropy to prioritize the amount of volatility and the use of a large number of variables causes complexity in calculations. According to the results obtained in this research, the first eight priorities include: The index of industries, other mines, communication devices, agriculture, leather products, coal, petroleum, chemical and cement products, which have more volatility than other industry groups and contribute more to creating systemic risk, were selected as target variables to calculate systemic risk. Next, in order to calculate the systemic risk, after calculating the seasonal growth of the six selected variables, we will examine the third question using the different methods given in section (3). The results are given in the next section.

4.3 Evaluation of the third research question

Considering that the data of this research is seasonal, in order to avoid false regression and to check the meanness of the variables, seasonal and annual Heggy unit root tests were used. Ghysels and Perron in 1993 and Ghysels in 1994 showed that the Heggy test is very useful and efficient in determining the unit root that leads to false regression. Heggy's test is obtained as a polynomial seasonal differentiation in the form of equation (4.1) [17] [18].

$$\delta_4 X_t = (1 - L^4)X_t = (1 - L)(1 + L)(1 + L^2)X_t \tag{19}$$

where L is the interrupt operator. Considering that both the price index data and the growth of macroeconomic variables have been used in this research, and the price index numbers are significantly different, the Manai test was performed only for the data series of the growth of the variables. The results indicate the absence of a unit root (in Heggy's test, the assumption of zero indicates the presence of a unit root).

(i) Assumption H0: the existence of a single root among the variables

(ii) Assumption H1: There is no single root among the variables

Next, the test result is shown in table (4).

After examining the existence of a single root, using the ΔCoVaR systemic risk method in this research, the systemic risk index of different industry groups was evaluated. The average of each of the systemic risk measures for the growth of these industries is presented in table (5). Based on this, the growth of the chemical and cement industry index is the most important factor for the occurrence of systemic risk in the Tehran Stock Exchange.

Value at risk is a measure of the maximum potential loss of value of an industry index over a specific time horizon with a given probability of 95 percent. In this case,

Table 4: Heggy's Test for Examining the Significance of Variables

Variable	Annual Unit Root	Seasonal Unit Root	Result
G.Zeraat(t)	0	0	Not Accepting the Null Hypothesis
G.Zoghalsang(t)	0	0	Not Accepting the Null Hypothesis
G.Sayeremaaden(t)	0	0	Not Accepting the Null Hypothesis
G.Siman(t)	0	0	Not Accepting the Null Hypothesis
G.Shimi(t)	0	0	Not Accepting the Null Hypothesis
G.Foil(t)	0	0	Not Accepting the Null Hypothesis
G.Charm(t)	0	0	Not Accepting the Null Hypothesis
G.Ertebati(t)	0	0	Not Accepting the Null Hypothesis
G.Tepix(t)	0	0	Not Accepting the Null Hypothesis

the value at risk of agriculture industry index growth is 32.39 percents, which has a 95 percent probability that the agriculture industry index growth value will not decrease by more than 32.39 units in a three-month (seasonal) time horizon. This value has been obtained for the growth of the coal industry index 42.4 units, for the growth of the other mining industry index 45.4 units, for the growth of the cement industry index 23.4 units, for the growth of the chemical industry index 21.2 units, for the growth of the oil products industry index 31 units, for the growth of the leather products industry index 51.7 units and for the growth of the communication equipment industry index 41.5 units. Conditional value at risk is a measure of the expected loss in the value of an industry index over a specific time horizon that is calculated given the occurrence of a specific event. In this case, the conditional risk value of the agriculture industry index growth is equal to 18.8 units, which means that in the event of a specific event, the expected loss in the agriculture industry index growth value will be 18.8 units during a season. This amount is 19.2 units for the growth of the coal industry index, 20.1 units for the growth of the other mining industry index, and 25.9 units for the growth of the cement industry index. For the growth of the chemical industry index, 20.8 units, for the growth of the oil products industry index, 19.5 units, for the growth of the leather products industry index, 19.7 units and 21.1 has been obtained for the growth of the communication equipment industry index. Value-at-risk delta is the difference between the conditional value-at-risk of an industry index in a normal and critical state. In this case, the delta of the conditional risk of the growth of the agriculture industry index is 0.258 units during a season. This amount has been obtained for the growth of the coal industry index of 0.62 units, for the growth of the other mining industry index of 2.28 units, for the growth of the cement industry index of 8.8 units, for the growth of the chemical industry index of 9.5 units, for the growth of the oil products industry index of 5.75 units, for the growth of the leather products industry index of 1.65 units and for the growth of the communication equipment industry index 3.87 units. Next, in figure (1), the systemic risk Volatility's of the growth index of each industry from 2008 to 2024 are shown.

Table 5: Average of Systemic Risk Measures

Variable	VaR	CoVaR	ΔCoVaR
G.Zeraat(t)	32.39	18.8	0.258
G.Zoghalsang(t)	42.4	19.2	0.62
G.Sayeremaaden(t)	45.4	20.1	2.28
G.Siman(t)	23.4	25.9	8.8
G.Shimi(t)	21.2	20.8	9.5
G.Foil(t)	31	19.5	5.75
G. Charm(t)	51.7	19.7	1.66
G.Ertebati(t)	41.5	21.1	3.87

4.4 Evaluation of the fourth research question

Due to the fact that the growth index of the industries is at the level of stationary and does not have annual unit root and seasonal unit root. Therefore, the relationship between the growth of industry indicators can be investigated using regression methods and correlation coefficient. In order to calculate their uncertainty, the ARCH auto regressive conditional variance model and the generalized GARCH auto regressive conditional variance model have been used as a substitute for the uncertainty of the industry index growth. For this purpose, the ARCH effect test was first investigated using the ARCH-LM statistic, the results of which can be seen in Table (6).

Table 6: Results of the ARCH Effect Test

Variable	Coefficient	Std. Error	z-statistic	Prob.
G.Zeraat(t)	0.16	0.068	2.4	0.016
G.Zoghalsang(t)	-0.46	0.285	-1.6	0.01
G.Sayeremaaden(t)	-0.047	0.0077	-6.05	0
G.Siman(t)	0.48	0.04	11.87	0
G.Shimi(t)	-0.15	0.056	-2.78	0.005
G.Foil(t)	0.257	0	6.22	0
G. Charm(t)	0.163	0.0049	32.97	0
G.Ertebati(t)	0.255	0.0006	387	0

The results of Table (6) show that the null hypothesis of the absence of ARCH effect is rejected, so the opposite hypothesis, the presence of ARCH effect, is confirmed. After confirming the effect of ARCH, based on AIC and BSC statistics, the GARCH(p,q) model was selected to calculate the uncertainties of the index of industry groups, and the results of the models can be seen in Table (7).

The conditional variance calculated according to table (7) is selected as a sur-

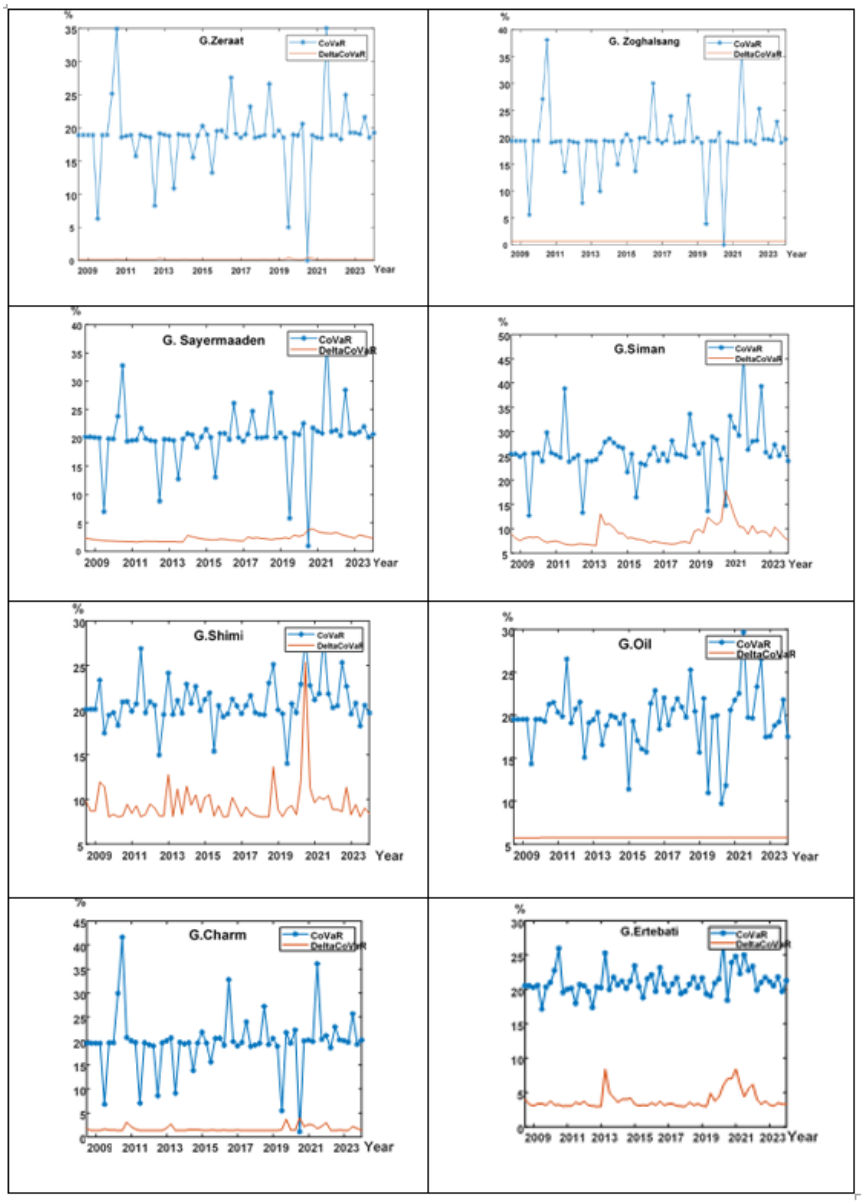

Figure 1: Systemic Risk Volatility in Type of CoVaR and ΔCoVaR

rogate for the uncertainty of the index growth of different industry groups. After estimating the models, to check the contagion between parts of the vector auto regression model with time-varying parameters, TVP-VAR has been used. For this purpose, firstly, in this section, the unconditional correlation coefficient between the growth of each industry index is calculated. The results can be seen in Table

Table 7: Estimation Results of GARCH(p,q) Models

Variable	GARCH(p,q) Models
G.Zeraat(t)	$c = 291.5$ $RESID(-1)^2 = -0.0009$ $REDSID(-1)^2 * (REDSID(-1) < REDSID(-2)^2$ $GARCH(-1) = 1.08, GARCH(-2) = -0.468$ $AIC = 10, SC = 10.23, HQ = 10.09$
G.Zoghalsang(t)	$RESID(-1)^2 = -0.4286$ $GARCH(-1) = 1.4286$ $AIC = 12.68, SC = 12.75, HQ = 12.7$
G.Sayeremaaden(t)	$C = 22.08$ $RESID(-1)^2 = 1.188$ $AIC = 10.03, SC = 10.16, HQ = 10.08$
G.Siman(t)	$RESID(-1)^2 = -0.045$ $GARCH(-1) = 0.95$ $AIC = 10.05, SC = 10.12, HQ = 10.079$
G.Shimi(t)	$RESID(-1)^2 = -0.463$ $GARCH(-1) = 0.536$ $AIC = 9.5, SC = 9.6, HQ = 9.55$
G.Foil(t)	$C = 483.66 RESID(-1)^2 = -0.04$ $GARCH(-1) = 0.58$ $AIC = 9.67, SC = 9.8, HQ = 9.72$
G. Charm(t)	$C = 787 RESID(-1)^2 = -0.055$ $RESID(-2)^2 = 0.153$ $GARCH(-1) = 1.02$ $GARCH(-2) = -0.36$ $AIC = 10.8, SC = 11.01, HQ = 10.89$
G.Ertebati(t)	$C = 9.66$ $RESID(-1)^2 = -0.037$ $RESID(-2)^2 = -0.2$ $GARCH(-1) = 1.18$ $GARCH(-2) = 0.05$ $AIC = 10.27, SC = 10.47, HQ = 10.35$

(8).

In table (8), V.1 to V.8 equlal to G.Zeraat(t) variable to G.Ertebati(t) variable. Based on the values in table (8), all the correlations of the growth of industries are positive, which is important. The highest correlation between the growth of the oil products industry index and the growth of the chemical industry index is 0.81. Also,

Table 8: Average of unconditional correlation between variables

Variable	V.1	V.2	V.3	V.4	V.5	V.6	V.7	V.8
G.Zeraat(t)	1							
G.Zoghalsang(t)	0.25	1						
G.Sayeremaaden(t)	0.46	0.34	1					
G.Siman(t)	0.58	0.48	0.64	1				
G.Shimi(t)	0.45	0.44	0.609	0.72	1			
G.Foil(t)	0.42	0.37	0.5	0.62	0.81	1		
G. Charm(t)	0.37	0.24	0.5	0.43	0.57	0.44	1	
G.Ertebati(t)	0.29	0.33	0.33	0.35	0.53	0.57	0.33	1

the correlation between the growth of the chemical industry index and the growth of the cement industry index is equal to 0.72. Also, the lowest correlation between the growth of the leather products industry index and the growth of the coal industry index is 0.24. The next rank is the lowest correlation rate of 0.25, related to the correlation between the growth of the coal industry index and the growth of the agriculture industry index. The result of the evaluation of the effectiveness and impact and the spillover effect of macroeconomic variables using the TVP-VAR model can be seen in the table (9).

Table 9: The Relationship between Aggregate Dynamics and Variables

Variable	V.1	V.2	V.3	V.4	V.5	V.6	V.7	V.8	From
G.Zeraat(t)	51.48	3.49	4.37	17.87	6.95	5.74	6.13	3.96	48.52
G.Zoghalsang(t)	1.72	58.76	3.39	15.01	9.18	5.53	0.59	5.82	41.24
G.Sayeremaaden(t)	4.46	4.01	40.05	14	12.97	11.52	5.24	7.76	59.95
G.Siman(t)	5.58	6.85	9.17	28.26	13.61	10.10	4.69	18.74	71.74
G.Shimi(t)	7.01	4.35	10.12	16.28	29.59	16.69	3.55	12.41	70.41
G.Foil(t)	6.6	2.82	8.28	13.47	22.24	32.4	3.1	11.1	67.6
G. Charm(t)	11.6	3.31	6.76	13.43	7.02	3.29	42.79	11.8	57.21
G.Ertebati(t)	6.61	2.13	6.83	12.45	13.92	11.39	0.9	45.78	54.22
To	45.56	26.97	48.92	102.51	85.9	64.25	24.2	71.59	470.89
Inc. Own	98.05	85.73	88.97	130.77	115.49	96.65	66.99	117.36	
Net	-1.95	-14.27	-11.03	30.77	15.49	-3.35	-33.01	17.36	34

In table (8), V.1 to V.8 equlal to G.Zeraat(t) variable to G.Ertebati(t) variable. Based on the results of table (9), about 51.8 percent of the volatility's in the growth of the agriculture industry index are caused by this variable and 48.2 percent are caused by other variables. So that 3.49 percent of its volatility's are caused by the growth of the coal industry index and 4.37 percent of the volatility's are caused by the growth of the other mining industry index, 17.87 percent are caused by the growth of the cement industry index, 6.95 percent are caused by the growth of the chemical industry index, 5.74 percent are caused by the growth of the oil products industry index, 6.13 percent are caused by the growth of the leather products industry index and 3.96 percent are caused by the growth of the communication equipment industry index. Also, the impact of the growth of the agriculture indus-

try index on the growth of the coal industry index, the growth of the other mining industry index, the growth of the cement industry index, the growth of the chemical industry index, the growth of the oil products industry index, the growth of the leather products industry index and the growth of the communication equipment industry index is 1.72, 4.46, 8.58, 7.01, 6.60, 11.6 and 6.61 percent respectively.

According to the results of table (9), about 58.76 percent of the growth volatility's of the coal industry index are caused by this variable and 41.24 percent are caused by other variables. So that 1.72 percent of its volatility's are caused by the growth of the agriculture industry index and 3.39 percent of the volatility's are caused by the growth of the other mining industry index, 15.01 percent are caused by the growth of the cement industry index, 9.18 percent are caused by the growth of the chemical industry index, 5.53 percent are caused by the growth of the oil products industry index, 0.59 percent are caused by the growth of the leather products industry index, and 5.82 percent are caused by the growth of the communication equipment industry index. Also, the influence of coal industry growth index on agriculture industry growth, other mines growth index, cement industry growth index, chemical industry growth index, oil products industry growth index, leather products industry growth index, and communication equipment industry growth index are 3.49, 4.01, 6.85, 4.35, 2.82, 3.31 and 2.13 percent respectively.

Based on the results of table (9), about 40.05 percent of the growth volatility's of the other mining industry index are caused by this variable and 59.95 percent are caused by other variables. So that 4.46 percent of its volatility's are caused by the growth of the agriculture industry index, 4.01 percent of the volatility's are caused by the growth of the coal industry index, 14 percent are caused by the growth of the cement industry index, 12.97 percent are caused by the growth of the chemical industry index, 11.52 percent are caused by the growth of the oil products industry index, 5.24 percent are caused by the growth of the leather products industry index, and 7.76 percent are caused by the growth of the communication equipment industry index. Also, the effect of the growth of the other mining industry index on the growth of the agriculture industry index, the growth of the coal industry index, the growth of the cement and chemical industry index, the growth of the oil products industry index, the growth of the leather products industry index and the growth of the communication equipment industry index has 4.37, 3.39, 9.17, 10.12, 8.28, 6.76 and 6.83 percent, respectively.

Based on the results of table (9), about 28.26 percent of the growth volatility's of the cement industry index are caused by this variable and 71.74 percent are caused by other variables. 8.58 percent of its volatility's are caused by the growth of the agriculture industry index, 6.85 percent of the volatility's are caused by the growth of the coal industry index, 9.1 percent are caused by the growth of the other mining industry index, 13.61 percent are caused by the growth of the chemical industry index, 10.10 percent are caused by the growth of the oil products industry index, 4.69 percent are caused by the growth of the leather products industry index, and

18.74 percent are caused by the growth of the communication equipment industry index. Also, the effect of the growth of the cement industry index on the growth of the agriculture industry index, the growth of the coal industry index, the growth of the other mining industry index, the growth of the chemical industry index, the growth of the oil products industry index, the growth of the leather products industry index and the growth of the communication equipment industry index has 17.87, 15.01, 14, 16.28, 13.47, 13.43 and 12.45 percent, respectively.

Based on the results of table (9), about 29.59 percent of the growth volatility's of the chemical industry index are caused by this variable and 70.41 percent are caused by other variables. So that 7.01 percent of its volatility's are caused by the growth of the agriculture industry index, 4.35 percent of the volatility's are caused by the growth of the coal industry index, 10.12 percent are caused by the growth of the other mining industry index, 16.28 percent are caused by the growth of the cement industry index, 16.69 percent are caused by the growth of the oil products industry index, 3.55 percent are caused by the growth of the leather products industry index, and 12.41 percent are caused by the growth of the communication equipment industry index. Also, the effect of the growth of the chemical industry index on the growth of the agriculture industry index, the growth of the coal industry index, the growth of the other mining industry index, the growth of the cement industry index, the growth of the oil products industry index, the growth of the leather products industry index and the growth of the communication equipment industry index has 6.95, 9.18, 12.97, 13.61, 22.24, 7.02 and 13.92 percent, respectively.

Based on the results of table (9), about 32.40 percent of the growth volatility's of the oil products industry index is due to this variable and 67.6 percent is due to other variables. So that 6.60 percent of its volatility's are caused by the growth of the agricultural industry index, 42.82 percent of the volatility's are caused by the growth of the coal industry index, 8.28 percent are caused by the growth of the other mining industry index, 13.47 percent are caused by the growth of the cement industry index, 22.24 percent are caused by the growth of the chemical industry index, 3.10 percent are caused by the growth of the leather products industry index, and 11.10 percent are caused by the growth of the communication equipment industry index. Also, the influence of the growth index of the oil products industry on the growth of the agriculture industry index, the growth of the coal industry index, the growth of the other mining industry index, the growth of the cement industry index, the growth of the chemical industry index, the growth of the leather products industry index and the growth of the communication equipment industry index has 5.74, 5.53, 11.52, 10.10, 16.69, 3.29 and 11.39 percent respectively.

According to the results of table (9), about 42.79 percent of the growth volatility's of the leather products industry index is due to this variable and 57.21 percent is caused by other variables. 11.60 percent of its volatility's are caused by the growth of the agriculture industry index, 3.31 percent of the volatility's are caused by the growth of the coal industry index, 6.76 percent are caused by the

growth of the other mining industry index, 13.43 percent are caused by the growth of the cement industry index, 7.02 percent are caused by the growth of the chemical industry index, 3.29 percent are caused by the growth of the petroleum products industry index, and 11.80 percent are caused by the growth of the communication equipment industry index. Also, the influence of the growth of the leather products industry index on the growth of the agriculture industry index, the growth of the coal industry index, the growth of the other mining industry index, the growth of the cement industry index, the growth of the chemical industry index, the growth of the oil products industry index and the growth of the communication equipment industry index is 6.13, 0.59, 5.24, 4.69, 3.55, 3.10 and 0.90 percent, respectively.

According to the results of table (9), about 45.78 percent of the growth volatility's of the communication equipment industry index is due to this variable and 54.22 percent is caused by other variables. So that 6.61 percent of its volatility's are caused by the growth of the agriculture industry index, 2.13 percent of the volatility's are caused by the growth of the coal industry index, 6.83 percent are caused by the growth of the other mining industry index, 12.45 percent are caused by the growth of the cement industry index, 13.92 percent are caused by the growth of the chemical industry index, 11.39 percent are caused by the growth of the oil products industry index, and 0.09 percent are caused by the growth of the leather products industry index. Also, the influence of the growth of the communication equipment industry index on the growth of the agriculture industry index, the growth of the coal industry index, the growth of the other mining industry index, the growth of the cement industry index, the growth of the chemical industry index, the growth of the oil products industry index and the growth of the leather products industry index has 3.96, 5.82, 7.76, 18.74, 12.41, 11.10 and 11.80 percent, respectively.

According to the results of table (9), the growth of the agriculture industry index, the growth of the coal industry index, the growth of the other mining industry index, the growth of the oil products industry index, and the growth of the leather industry index are the receivers of the overflow from other variables because their net flow is negative, that is, the received overflow of this variable from other variables is more than the transfer overflow of this variable to other variables. In addition, the growth of the total index of the Tehran Stock Exchange and the growth of cash receipt are overflows from other variables because their net flow is negative, that is, the received overflow of this variable from other variables is more than the transfer overflow of this variable to other variables.

In figure (2), the overall trend of communication between the growth of different industries index, the impact of positive news and negative news can be seen with the method of frequency communication. Based on the results of this chart, firstly, in the time period under investigation, negative news has a dominant effect on the formation of communication between indicators, and the impact of this news has been on the rise since 2017. Of course, the interesting thing to note is the significant impact of positive news in shaping communication.

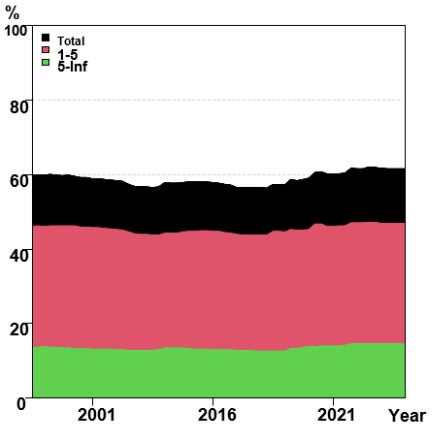

Figure 2: The Overall trend of Relationships between Variables

5 Discussion and conclusion

The results of the quarterly data analysis from the 2008 to 2024 for 30 indices of Iran's capital market industry using six entropy methods, regardless of the amount of volatility calculated from each method, show that 4 methods, Renyi, Tsallis, Simpson and Generalized Simpson have completely similar results in terms of entropy, and the two generalized Shannon and Tsallis methods have different results compared to each other and other methods. The important point in the obtained results is that 8 groups of different industries are ranked 1 to 7 based on various entropy methods, and only the index of the cement industry is ranked 12th in the Shannon entropy method, but it is ranked 3rd and 4th in other methods. Also, the basic metals industry index has been ranked 9 in 4 methods. The result of using different entropy methods in the industry index section of Tehran Stock Exchange, the results show that the use of each of the entropy methods has the same results in the ranking and amount of entropy (volatility or fluctuation) that the first eight priorities include: Other mining industry index, communication equipment industry index, agriculture industry index, leather products industry index, coal industry index, petroleum products industry index, chemical industry index and cement industry index, which have more volatility than other industry groups, were selected as target variables to calculate systemic risk. Based on the results of table (3), in terms of the entropy value (volatility), the highest volatility value has been calculated using Shannon's entropy method. And the volatility range calculated in this method is higher than other methods.

The results of the conditional value at Risk delta (ΔCoVaR) measure in the growth of the Tehran Stock Exchange industry index show that the largest contribution to creating systemic risk is related to the growth of the chemical industry index, the

growth of the cement industry index, and the growth of the oil products industry index. Therefore, it is necessary to pay special attention to the volatility's of these three industries in order to prevent inflammation and extreme volatility's in the Tehran Stock Exchange, and investors should be more sensitive to the volatility's of these indices. Based on the findings of this section, it can be concluded that if there is a systemic risk in the capital market, the most volatility's (contagion) will occur in the companies that operate in the coal industry, and on the other hand, this industry will have the least impact of volatility's on the capital market. Also, chemical and cement industries can start to influence the capital market of Iran. Although similar research has not been done in the field of systemic risk in stock market industries, However, the findings of the current research are in line with the results of Mohammadi Aghdam et al.'s research in 2016 [28], who stated that the impact of Iran's economy on exogenous variables is very low due to the lack of connection between the capital market and global stock exchanges, limited banking transactions and the receipt of small foreign facilities compared to other countries, so the effect of internal communication between different industries is not separate from the changes and volatility's of each industry.

Also, the results of this study are different from the results of Taleblou 's study in 2024. They showed that the role of the base metals industry in pairwise relationships and creating systemic risk is greater than other industries [38]. While in this study, base metals are ranked 7th, 8th, and 9th in terms of quantity based on various entropy methods. While in this study, base metals are ranked 7th, 8th, and 9th in terms of quantity based on various entropy methods. The reason for this issue could be, firstly, due to the research period and secondly, due to the use of a systematic method in selecting research variables (industry index), which was not used in the study by Taleblou et al. to select stock exchange industries on this basis.

In addition, considering the theoretical foundations mentioned in Section 2, the application of the entropy method, which has its roots in thermodynamics, and its connection with Ludwig's general theory of systems as well as Kant's theoretical foundations on the subject of uncertainty, led to the creation of a systematic method in the present study, and in this respect, it is one of the new researches in the field of systemic risk and the contagion of volatility of various industry indices in the Tehran Stock Exchange.

The results of evaluation of volatility contagion of Tehran Stock Exchange industry index based on vector autoregression models with time-varying parameters (TVP-VAR) to evaluate the influence of the growth of each industry index on the growth of other industries show: 51.8 percent of the volatility's in the growth of the agriculture industry index are caused by this variable, and the growth of the cement industry index has the greatest effect on the agriculture industry index. Therefore, it can be concluded that other factors and variables affect the growth volatilities of the agriculture industry index. This issue also applies to the growth of the coal

industry index, with the difference that the biggest impact on this industry is due to the growth of the cement industry index. 59.95 percent of the volatilities in the growth index of the other minerals industry are caused by other variables, especially the growth of the cement industry index, the growth of the chemical industry index, and the growth of the oil products industry index. 71.74 percent of the volatilities in the growth of the cement industry index are caused by other variables, especially the growth of the communication equipment industry index, the growth of the chemical industry index, and the growth of the oil products industry index. 70.41 percent of chemical industry index growth volatilities are caused by other variables, especially 16.69 percent are caused by oil products industry index growth, cement industry index growth. 67.6 percent of the volatilities in the growth index of the oil products industry are caused by other variables, especially the growth of the coal industry index, the growth of the chemical industry index, and the growth of the cement industry index. 57.5 percent of the volatilities in the growth of the leather products industry index are caused by other variables, especially the growth of the cement industry index and the growth of the communication equipment industry index. 54.22 percent of the volatilities in the growth of the communication equipment industry index are caused by other variables, especially the growth of the chemical industry index and the growth of the cement industry index.

The results of the net analysis of the spillover effect of the growth index of each industry (pure dynamic integration of system variables) show that the growth of the agricultural industry index, the growth of the coal industry index, the growth of the other mining industry index, the growth of the oil products industry index and the growth of the leather industry index are receivers of the spillover from other industry indices and other variables are injecting the spillover effect. In addition, the greatest impact on Iran's capital market industries is related to the growth of the cement industry index, the growth of the chemical industry index, and the growth of the communication equipment industry index, and the least impact is the growth of the coal industry index and the growth of the leather products industry. Also, based on the results obtained, firstly, in the time frame under investigation, negative news has a dominant effect on the formation of relationships between industry indicators, and the effect of this news has been on the rise since 2017. Of course, the interesting thing to note is the significant impact of positive news in shaping communication. Also, the net contagion criterion shows that the intra-system dependence between the growth of different industries in the capital market is 34.8 percent on average, and this criterion is the contagion of shocks from other variables to the studied variables without considering the effect of the variables themselves, the lower this value is, the better. According to the average net contagion, the obtained results are acceptable.

Considering the innovation of this research in using entropy to select variables to calculate systemic risk and contagion of volatility, the lack of resources to use entropy methods to compare research results has been one of the limitations of the

research. In addition, due to the non-simultaneity of the creation of indices of different industries in the Tehran Stock Exchange during the period of research (2008 to 2024), the number of 20 currently active industry indices whose information had not been established since the beginning of the period were removed.
The scientific findings of the research are: The approach used in the research to investigate the impact and effectiveness of the growth index of different industry groups has had stronger results than other domestic researches. The approach used in the systematic research and investigation of systemic risk has evaluated all aspects of the problem, and none of the internal research has been done with this approach and comprehensively. Therefore, the obtained results are highly reliable. The results of the use of research approaches, in addition to specifying the amount of volatility, the amount of systemic risk and the contagion of volatility of the variables used in the research, have also determined the time of occurrence of volatility's, which will make it possible to investigate political and economic events at that time, and it will be possible to predict and take preventive measures for similar conditions in the future. In addition to the quantitative results obtained in different parts of the research, the impact of positive and negative news in different years on the Tehran Stock Exchange is one of the results of this research, with the explanation that the role of negative news in different periods on the amount of volatility, systemic risk, and the contagion of volatility of variables is clearly visible.

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