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Original Research

Evaluation Systemic Risk and Volatility Contagion of Macroeconomic Variable with Entropy's and TVP-VAR

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ABSTRACT

The intertwining of different sectors of the economy has caused that in case of volatility in one sector spreads in a domino-like manner to other economic sectors and causes systemic risk. Therefore, it is necessary to identifying the variables that have the highest volatility, to evaluate the contribution of each variable to the occurrence of systemic risk and the amount of their influence. In this research, from the 2007 to 2023, the amount of volatility was calculated and prioritized using 6 Entropy methods. Then, the systemic risk of macroeconomic variables growth was calculated on ΔCoVaR, MES and SES measures, and the spillover determined using TVP-VAR. Findings show: the highest volatility is related to the total index of Tehran Stock Exchange, price of Imam coin and gold, dollar rate, liquidity & GDP. Also, the use of each Entropy methods has the same results in the ranking of the volatility. In all 3 methods of systemic risk, the growth of the exchange rate is the cause of systemic risk and the initiator of contagion. Also, the growth of the total index of the Tehran Stock Exchange and liquidity recipient the spillover and share of negative news higher than positive news.

1 Introduction

In the last few decades, due to the creation of economic bubbles in the housing sector, the payment of cheap loans after the September 11 incident, the lack of monitoring and control of capital and commercial risk by banks, the withdrawal of obligations by banks after the issuance of securities, etc., the world economy has weakened the foundations of the economy around the world and caused severe financial crises. Due to the commercial and economic relations, between different countries, the effects of crises have strongly affected the commercial borders of one country on another country and in a domino way on other countries and economies. In this situation, despite the efforts of statesmen, economists and local and international monetary and financial institutions, the scope of these crises has

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become wider and deeper day by day. In the commercial and economic borders within the countries, the financial markets and other sectors and other markets have mutual effects on each other, and the weakening of each has side effects on the other market, and this ultimately challenges economic stability. The occurrence of financial crises and the interrelationship of financial institutions and different sectors of the economy has caused the issue of systemic risk as one of the main mechanisms of crisis trans-mission from individual financial institutions to other institutions or from one market to other markets and finally the entire economy to be the focus of researchers around the world. Systemic risk means the risk caused by internal connections and dependencies in a system or a market, which, due to the occurrence of a failure in a part of the system and it's spread throughout the system or market, leads to a crisis in the entire system or market [43]. Systemic risk is quickly transferred to other sectors due to the very high connection of financial markets with parts of the economy, which can be prevented from the occurrence of a financial crisis with timely identification and quick response [13]. Investors in their investment's decisions will prefer smooth profit with low fluctuation [38] and Investment as a financial decision always comprises two elements, investment risk and rate of return. The interchange of these two provides different compound of investment [50]. The issue of the relationship between markets, financial institutions and different sectors of the economy has caused the word contagion to be raised in the economic and financial literature since 1997. Contagion in markets can be shown in two ways: co-movement or in other words correlation and causation. Studying contagion in financial markets and finding how positive and negative shocks move in different markets provides guidelines for policymakers to improve economic performance [20]. The occurrence of financial crises entails a lot of economic costs for countries. Therefore, governments should apply policies in order to reduce the imposed costs, prevent the spread of the crisis and deal with it, according to their economic conditions [39]. Formulation of these policies requires investigation, evaluation and analysis of systemic risk in financial markets and other economic sec-tors. Investigating the effectiveness of financial markets and other parallel markets from incoming shocks, the degree of dependence of these markets on each other creates the opportunity to reduce its destructive effects or direct it in a favorable direction by using appropriate policies, before and after the occurrence of the crisis on different sectors [45]. Systemic risk assessment needs to specify the variables that can be used as signals to enable timely diagnosis of crisis in the form of early warning signals. What is important is the selection of a wide range of variables that have been used in different studies. The indicators that should be able to provide warning signals should also be the most effective factors. These variables should have the ability to show the degree of contagion of volatilities and volatility between macroeconomic variables [35]. Uncertainty in the economy is a situation in which the possible events that will happen in the future are not clear and known, or if they are known, the probability of their occurrence or the probability distribution function is unclear. Based on this, uncertainty in macroeconomics can be interpreted as the inability of agents to accurately predict the results of their decisions. One of the most important signs of uncertainty in an economic system is high and severe volatilities in economic variable. In developing countries, including Iran, one of the reasons why the private sector is less willing to enter the economy is the volatilities of economic variables. Obviously, volatilities both in terms of profitability and investment costs lead to uncertainty in investment. This un-pleasant phenomenon in the economy has caused economic policy makers in every country to seek to reduce the atmosphere of uncertainty and increase the predictability of economic variable. To measure different dimensions of systemic risk, various metrics have been proposed so far. But identifying which measure shows the relationship between financial markets and macroeconomics is still an open issue in research in this field [25]. In the domestic research conducted in the area

of uncertainty in macroeconomics, the following variables have been considered: inflation rate, exchange rate, oil price, gold price, stock market index and gross domestic product. In the review of the research conducted inside the country, especially the results of Taleblo and Mohajeri's [47] research in 2019, it was found that in the past decade, domestic researchers have focused sporadically on situations in the field of systemic risk and their volatility modeling, the results of which include: 30% of the articles investigated the contagion of volatility in selected domestic markets, 22% of the articles dealt with the contagion of volatility from global markets, especially oil and stock market, 8% of the articles dealt with the modeling of volatility between the indices of selected industries on the stock exchange, and 40% of the articles dealt with the modeling of the volatility of stock prices and the total index of the stock market and assets. While in foreign research, the main articles are related to the modelling of the price index of basic goods, the volatility of financial markets and the volatility of macroeconomic variables. Also, the review of internal researches shows that the issue of systemic risk and contagion of uncertainty of macroeconomic variables and their impact on each other has been given less attention and there is a research gap. Therefore, in this realization, it has been tried to solve some of the research gaps. Also, the results of this research will help politicians, decision-makers and economic activists to take the necessary follow-up measures in times of crisis by identifying the turbulent macroeconomic variables, contagion channels, the level of systemic risk of each variable and the amount of spillover volatilities. In this research, after the introduction in the second part, the theoretical foundations and the summary of the past research results are stated, then the research methodology will be discussed in the third part. Next, in the fourth part, the findings based on the research questions are given, and the final part presents the conclusions and suggestions.

2 Theoretical Foundations and Research Background

Macroeconomic variables in developing countries, including Iran, fluctuate more than advanced and industrialized economies [24]. Therefore, these volatilities create uncertainty for economic operators and investors and cause uncertainty in their decision making. Therefore, economic activists pay special attention to the factors and causes of uncertainty in the macro economy. The theoretical basis of this problem is rooted in the book of Kenneth Arrow [28]. In his book, Kent discussed the concepts of risk and uncertainty for the first time. Before many scientific schools, he presented a conceptual framework of the subject of risk and assurance, which later became widely relevant and applied in all fields of economic and financial knowledge and became a part of the theoretical knowledge of decision making in the field of finance and economics. Also, based on the general theory of systems, which was emphasized by Ludwig von Bertalanffy in her book General Theory of Systems in 1368 [31], the fields of science are not separate in their essence, just as different parts of a cell interact with different parts of an organism. Therefore, the use of inter-root methods and patterns based on the general theory of the Ludwig system has been widely used in research and is still being used. Therefore, in the discussion of examining the degree of volatility and uncertainty in different sectors, including macroeconomic variables, it is possible to use the concepts of entropy in identifying and prioritizing the degree of volatility of variables. Entropy is basically a property that was discovered for physical and thermodynamic systems after reaching the second law of thermo-dynamics by Shannon in 1948 [42]. After some time, trying to understand entropy with a microscopic view led to a new definition of entropy. In this perspective, entropy is a quantity that shows the degree of disorder in the molecular structure of systems, and its increase leads to the deterioration and destruction of the system. The entropy of a system with

more order can be described with fewer bytes of information, while a system with less order needs more bytes of information to be described [19]. The use of the concept of entropy in systemic risk studies has recently taken a special place. From a systemic point of view, in every system there are factors that act against the order of the system and can cause the system to be weak [7]. In the discussion of volatility and volatility contagion, various theories have been proposed regarding shock transmission channels and contagion, which have been examined in the form of two general groups. A group of theories focuses on fundamental factors (such as public shocks, trade relations and financial relations) and another group explains the occurrence of contagion based on the behavior of investors [15]. After the financial crisis of 2007-2009, the research of systemic risk as a macro-level risk that is the cause of the instability of the entire financial system has received the attention of governments, policy makers, researchers, etc. [2]. An increase in systemic risk, in addition to increasing the probability of a crisis, has negative economic effects on the real sectors of the economy [48]. The occurrence of financial crises entails a lot of economic costs for countries. Therefore, it is necessary for governments to apply policies in order to reduce the imposed costs, prevent the spread of the crisis and deal with it [39]. To measure different dimensions of systemic risk, various metrics have been proposed so far. But identifying which measure shows the relationship between financial markets and macroeconomics is still an open issue in research in this field [25]. In the review of risk literature, in general, the volatility or standard deviation of returns can be introduced as the simplest measure of risk when financial returns have a normal distribution. This condition of normality makes the use of this method fragile in calculating the risk of financial time series [26]. Therefore, this measure alone cannot provide sufficient information. Also, the value at risk is one of the unfavorable risk measures that calculates the maximum amount of potential loss in a certain probability and a certain time horizon. Parametric and non-parametric methods are used to calculate value at risk. In parametric methods, it is assumed that the financial returns have a special distribution such as normal, T-Student, etc. But in non-parametric methods, no assumption is imposed on the distribution function of returns. Rather, the approach of these methods is based on the principle that the not-so-distant future is largely similar to the past, so past information can be used to predict expected risk due to the repetition of the way variance and correlation coefficient are formed. The most important non-parametric approaches of historical simulation are: basic historical simulation, bootstrap historical simulation, balanced historical simulation. Contrary to known statistical concepts that are often based on the central limit theorem, Ferin's value theory proposed by Fisher in 1912 focuses on distribution sequences and provides a better potential for estimating financial events [32]. Because the time series and distribution of returns cannot be described by Gaussian models and the returns of financial as-sets have negative skewness and high elongation, researchers have turned their attention to conditional quantiles. In general, the reason for choosing conditional measures of systemic risk compared to other approaches, including Ferin's value theory, is:

-Previous models focus on extreme values of the sequence and thus ignore the information that is present in all data samples.

- Limit value theory is inefficient in estimating and examining the difference and how to connect and connect institutions in critical and normal periods.

- These models measure how the effect of the default risk of a financial institution change when other institutions face negative shocks.

- It measures the spread of volatilities.

- They consider the contagion of the financial crisis caused by invisible factors that are caused by internal communication between financial institutions.

- In addition to determining the individual risk of institutions, it is possible to determine the level of excess risk acceptance at the system level through the delta value at risk.
- It is also possible to determine the direction of the spread of entity i and j [5].

The review of the conducted research indicates the success of conditional risk measures, Adrian and Branermir introduced the Conditional Value at Risk measure (ΔCoVaR) in 2011 and 2016 [5-6] to measure systemic risk. This measure calculates the risk of the financial system under the condition that another institution is in a critical situation. Therefore, the contribution of an institution in creating systemic risk is obtained from the difference between the value exposed to the conditional risk of the institution in the crisis situation and normal conditions. Among other indicators of systemic risk is the MES marginal expected loss indicator, which shows the share of an institution if the entire economic system suffers a crisis. Like ΔCoVaR, this measure shows the final contribution of an institution to systemic risk and also its importance in the occurrence of systemic risk, with the difference that ΔCoVaR can be called a pre-crisis (prospective) measure and MES measure can be called a post-crisis (retrospective) measure [10]. In 2012, [4] introduced the SES Systemic Expected Loss Model. This model depends on the value at risk considering the worst-case scenarios. This measure is the average α or A percentage of the worst losses. Below is a summary of the history of domestic and foreign re-searches. Acharya et al., in 2009 [3], as one of the first studies, evaluated the ability of the expected systemic collapse measure in predicting emerging risks during the 2009-2007 financial crisis. Using the net return of an institution, they showed that the expected loss of the system increases with the leverage of the institution and the expected loss of the system. In 2014, using the ΔCoVaR approach, Oskar et al. [25] showed that in the Eurozone, for the period between 2004 and 2012, other financial services sectors contributed the most to systemic risk in times of cri-sis. Also, the banking sector is more involved in systemic risk than the insurance sector. In contrast, the insurance industry is the most systemically risky financial sector in the United States for the same period, while the banking sector contributes the least to systemic risk in this area. In 2014, based on an EGARCH method, [12] showed that the banking industry has a homogeneous behavior towards uncertainties caused by the macroeconomics, therefore, the banking system in the United States and Canada during the financial crisis was greatly affected by the systemic risk caused by it and after. In 2016 [44], compared the performance of three systemic risk measures at the institution level. His results show that the conditional value-at-risk criterion predicts the performance of institutions during the crisis and provides a useful forecast for the occurrence of systemic risk in the future, but the criterion of expected systemic collapse and Granger causality did not provide a reliable prediction of the performance of financial institutions during the crisis. In 2017, using the data of American financial institutions for the period of 2005-2014 [29], compared and examined different and common criteria of systemic risk and concluded that the use of different criteria of systemic risk leads to different assessments of the risk of different financial institutions. In 2021[34], investigated the dynamics of volatility spillovers between Brent crude oil and stock markets in the United States (S&P500 index), Europe (STOXX600 index), Asia (Dow Jones Asia index) and the stock markets of five vulnerable European Union (EU) countries using the AR (1)-FIGARCH and VaR model. The results show that there is a spillover effect between oil and stock markets. In researches inside Iran, in 2013, using a VAR and MGARCH model, they confirmed the relationship of capital market contagion effect from the parallel markets of currency, gold, and oil and showed that the best representative for measuring the contagion of Iran's capital market is the data related to the total index of the stock exchange. The result of [18] research in 2014 using the dynamic conditional correlation method (DCC-

GARCH) confirms the existence of contagion phenomenon only between currency and coin market. Also, in 2017, [9] tried to design a model for predicting systemic risk by using the final expected drop approach, the GJR-GARCH-DCC framework and a sequential non-parametric estimator. The results show that the influence of leverage in MES is positive and significant and the values are correlated. In 2018 [40] used a GARCH model to show the similarities and differences in the volatility of Tehran Stock Exchange industries. In 2020, [46] measured the risk of the levy process by using the combined method of VaR and Monte Carlo. In 2009, [15] investigated the difference in the efficiency of the models estimated by parametric and non-parametric methods and came to the conclusion that there is a significant difference between CVaR model portfolios and MV model portfolios in terms of the ratio of return to CVaR of the portfolio and return to standard deviation of the portfolio. Also, choosing the most appropriate measure of risk depends on the goals and needs of investors in risk management and control. In 2015, [8] investigated the systemic risk of 20 large companies in the Tehran Stock Exchange from the beginning of 2010 to the end of September 2014 with measures of Delta at Conditional Risk (ΔCoVaR), Marginal Expected Loss (MES), Component Expected Loss (CES), Systemic Expected Loss (SES) and Low Tail Dependency (LTD) and finally divided these companies into two influential groups. They divided more and less. In 2016 [18] evaluated the systemic risk in these banks by using the CoVaR criterion. "The estimation results show that the changes in the conditional risk value for Middle Eastern Bank have the highest value (15.61) and the lowest value (0.32) for Capital Bank. In 1402, 32 used Entropy to prioritize macroeconomic variables using various entropy methods and prioritized macroeconomic variables in terms of volatility.

3 Methodology

The purpose of this research is to develop the knowledge of systemic risk. This research is based on the practical purpose and is based on the fundamental research done by previous re-searchers, and this issue is achieved by using different methods and comparing the results and evaluating them, and it has a confirmatory approach with regard to the development of systemic risk knowledge. Therefore, it is considered comparative research. Also, considering that we investigate and collect information using available books, researches, and software, it is of a library type and is based on post-event data. The data includes seasonal time series data of price and growth of macroeconomic indicators from the beginning of 2017 to the end of 2012, which are selected based on a systematic review method. In the following, the research implementation method is described. Due to the intertwining of different sectors of the economy, if there is volatility in one sector, this volatility spreads to other economic sectors in a domino way and causes systemic risk. Therefore, identifying the variables that have the highest amount of volatility, as well as the contribution of each variable in the occurrence of systemic risk and the amount of their influence and influence in predicting and preventing the destructive effects of volatilities in macroeconomic variables will help economic activists through answering the questions of this research. Therefore, the questions of this research are:

1-What is the priority of the volatility of macroeconomic variables based on various entropies?

2-Which of the entropy methods better shows the amount and priority of fluctuation in macroeconomic variables and is there any difference in the use of these methods?

3-What is the systemic risk value of macroeconomic variables based on ΔCoVaR, MES, SES?

4-What is the contagion of volatility and the amounts of series of macroeconomic variables based on vector autoregression models with time-varying parameters (TVP-VAR)?

Table 1: Research Variables and Their Measurement Methods

Row	Variable Symbol	Index Title	Method of Measurement	Description
1	Tepix_t	*Total index Of Tehran Stock Exchange*	$Tepix_t = \frac{\sum_{i=1}^{n} p_{it} q_{it}}{D_t} * 100$	p_{it}*Price of Company I in t* q_{it}*Number of Shares Issued* D_t *Base Price in t*
2	Oil_t	*Oil price($/Barrel)*	$Oil_t = P_t$	p_t*Price in t*
3	GoldPrice_t	*Gold Price Per Gram (Rial)*	$GoldPrice_t = \frac{750}{705} * \frac{P_t}{4.6083}$	p_t*Price of 1 Shekel (17 Carats) in t*
4	CoinPrice_t	*Coin Price (Rial)*	$CoinPrice_t = P_t$	p_t*Price in t*
5	Gold_t	*Gold ones Price ($)*	$Gold_t = P_t$	p_t*Price in t*
6	Dollar_t	*Dollar Price (Rial)*	$Dollar_t = P_t$	p_t*Price in t*
7	GDP_t	*Gross Domestic Product at Current Price*	$GDP_t = C_t + I_t + G_t + NX_t$	*Consumption (C), Investment (I) + Government Expenditure(G)& (Exports-Imports) (NX))*
8	DP90_t	*Gross Domestic Product at Base of 1390 Price*	$GDP90_t = C_t + I_t + G_t + NX_t$	*The Price of goods in the base year/ the price of goods in the 1390 year*
9	Liquidity_t	*Liquidity (H.M. Rial)*	$Liquidity_t = B_t + M_t + \sum_{i=1}^{n} A_i$	B_t *Sum of Banknote in t* M_t*Value of Mosques in the Hand of The People in t* A_i *Sum of Visual and non-Visual Deposits in t*
10	$\text{Interest Rate SH}_t$	*Interest Rate of Short Time (%)*	$Interest\ Rate\ SH_t = P_t$	p_t *Rate in t*
11	Interest Rate Y_t	*Interest Raye Per Year (%)*	$Interest\ Rate\ Y_t = P_t$	p_t *Rate in t*
12	Inf_t	*Inflation Rate (%)*	$Inf_t = \frac{CPI_t - CPI_{t-1}}{CPI_{t-1}} * 100$	*The Price of Goods in the Base year/ the price of goods in the current year*
13	Oil Income_t	*Oil Income (M$)*	$Oil\ Income_t = P_t$	p_t *Some of income in t*
14	G. Tepix_t	*Growth of Total index Of Tehran Stock Exchange*	$\text{G. Tepix}_t = \left(\frac{\text{Tepix}_t - \text{Tepix}_{t-1}}{\text{Tepix}_{t-1}}\right) * 100$	
15	G. GoldPrice_t	*Growth of Gold Price Per Gram (Rial)*	$G.\text{GoldPrice}_t = \left(\frac{\text{GoldPrice}_t - \text{GoldPrice}_{t-1}}{\text{GoldPrice}_{t-1}}\right) * 100$	
16	G. CoinPrice_t	*Growth of Coin Price (Rial)*	$G.\text{CoinPrice}_t = \left(\frac{\text{CoinPrice}_t - \text{CoinPrice}_{t-1}}{\text{CoinPrice}_{t-1}}\right) * 100$	
17	G. Dolar_t	*Growth of Dollar Price (Rial)*	$G.\text{Dolar}_t = \left(\frac{\text{Dolar}_t - \text{Dolar}_{t-1}}{\text{Dolar}_{t-1}}\right) * 100$	
18	G. GDP_t	*Growth of Gross Domestic Product at Current Price*	$\text{G. GDP}_t = \left(\frac{\text{GDP}_t - \text{GDP}_{t-1}}{\text{GDP}_{t-1}}\right) * 100$	
19	G. Liquidity_t	*Growth of Liquidity (H.M. Rial)*	$G.\text{Liquidity}_t = \left(\frac{\text{Liquidity}_t - \text{Liquidity}_{t-1}}{\text{Liquidity}_{t-1}}\right) * 100$	

According to the systematic review of the research conducted in the field of systemic risk and macroeconomic variables, the number of 13 macroeconomic variables that had the highest frequency, especially in domestic researches, have been selected to determine the prioritization of the level of volatility. Then, in order to answer other research questions, the growth variables of each macroeconomic variable have been used. The variables used in the research and their measurement methods are given in table (1).

Other variables and their measurement methods are explained below.

3.1 Entropy's Method

In this research, a variety of entropy methods have been used to determine and prioritize the degree of volatility of macroeconomic variables, and each of the methods used will be explained below.

3.1.1 ShannonEntropy

Shannon's [41] definition of entropy of a random variable X with P(X) as the probability of occurrence was in accordance with formula (1).

$$\boldsymbol{H(X) = H(p) = -\sum_{x} p(x) log p(x) = E\left[log\left\{\frac{1}{p(x)}\right\}\right]} \quad (1)$$

which is the base of logarithm 2.

Ha(x) is the entropy of X when the logarithm to the given base specifies a.

To calculate the entropy, it is necessary to linearize the data using formula (2) and calculate the D_i values instead of q_i, and for the values to be in the range of zero to one, the K factor is calculated from formula (3) 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 formula (4) and then normalized using formula (5).

$$\boldsymbol{D_i = \frac{q_i}{\sum_{i=1}^{n} q_i}} \quad (2)$$

$$\boldsymbol{K_i = \frac{1}{LN\ n}} \quad (3)$$

$$\boldsymbol{d_i = 1 - H} \quad (4)$$

$$\boldsymbol{W_i = \frac{d_i}{\sum_{i=1}^{n} d_i}} \quad (5)$$

3.1.2 Reny Entropy

The first generalization of entropy was presented by René in 1961[40], where the entropy of order α for the discrete random variable X was presented in the form of formula (6). Then other calculations are calculated according to formulas (2-5).

$$\boldsymbol{H(X) = H(p) = -\sum_{x} p(x) log p(x) = E\left[log\left\{\frac{1}{p(x)}\right\}\right]} \quad (6)$$

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

3.1.3 Tessalis & Modified Tessalis Entropy

In 1988 [50], Thesalis expressed the entropy of order α for a discrete random variable in the form of formula (7). Then, after introducing the basic Thesalis model for entropy, the generalized Thesalis entropy was introduced in the form of formula (8). Other calculations are calculated according to formulas (2-5).

$$H_{T\alpha}(X) = \frac{1}{\alpha - 1}\left[1 - \sum_{i=1}^{n} p_i^{\alpha}\right] \tag{7}$$

$$H_{T\alpha}(X) = 1 - \sum x^{\alpha} \tag{8}$$

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

3.1.4 Simpson& Modified Simpson Entropy

The basic formula of Simpson's entropy was introduced as formula (9) and after the introduction of Simpson's basic model for entropy, the generalized Thesalis entropy was introduced as formula (10).

$$\varphi_r = \sum_{s=1}^{S} p_s(1 - p_s)^r \tag{9}$$

$$\varphi_r = 1 - \sum(1 - \rho_s)^{\alpha} \tag{10}$$

And the value of α and r is equal to 2.

3.2 Systemic Risk Methods

3.2.1 ΔCoVaR Method

In 2011 and 2016, Adrian and Brunmeer [5-6] introduced conditional value at risk (CoVaR) based on the concept of value at risk (VaR) in order to calculate systemic risk. CoVaR of financial markets is calculated in two normal and critical states and their difference is called ΔCoVaR. According to the conducted investigations, ΔCoVaR has become one of the common metrics for measuring systemic risk [9]. In the following, the method of its calculation according to formula (11) is given.

$$\begin{aligned} &pr(R_i \le VaR_q^i) = q \\ &CoVaR_q^{m|i} = VaR_q^m | R_i = q \\ &pr(R_m \le CoVaR_q^{m|i} | R_i = VaR_q^i) = q \\ &\Delta CoVaR_q^{m|i} = (CoVaR_q^{m|R_i = VaR_q^i} - CoVaR_q^{m|R_i = median_q^i}) \end{aligned} \tag{11}$$

where VaR_q^i is equal to the value at risk of the market (i) at the confidence level (q-1) % and R_i is the return of each market or variable.

3.2.2 MES Method

The expected final deficit MES calculates the return of financial institutions when the entire market is in crisis. By measuring the share of a financial institution in systemic risk, Brownlees and Engel 2012

[11] concluded that systemic risk for a financial institution occurs when the market return falls below the selected threshold, and in this case, the return of the financial institution is considered as systemic risk and can be calculated according to formula (12-13).

$$R_{m.t} = \mu_{m.t} + \sigma_{m.t}\epsilon_{m.t} \tag{12}$$

$$R_{i.t} = \mu_{i.t} + \sigma_{i.t}\rho_{i.t}\epsilon_{m.t} + \sigma_{i.t}\sqrt{1-\rho_{i.t}^2\eta_{i.t}} \tag{13}$$

where $\epsilon_{m.t}$ and $\mu_{i.t}$ are the perturbation components that are assumed to be independent. Note that the perturbation components are simply obtained from the Cholsky decomposition. Equation (13) shows the pricing model of conditional capital assets with variable beta coefficients over time. Therefore, the conditional average of yield or growth of a macroeconomic variable can be rewritten as formulas (14) and (15).

$$R_{i.t} = \mu_{i.t} + \frac{cov_{t-1}(R_{m.t}\cdot R_{i.t})}{\sigma_{m.t}^2}(R_{m.t} - R_{i.t}) + \sigma_{i.t}\sqrt{1-\rho_{i.t}^2\eta_{i.t}} \tag{14}$$

$$R_{i.t} = \mu_{i.t} + \beta_{i.t}(R_{m.t} - \mu_{m.t}) + \sigma_{i.t}\sqrt{1-\rho_{i.t}^2\eta_{i.t}} \tag{15}$$

where $\beta_{i.t}$ is the variable beta coefficient over time. Considering the above relationships and conditional volatility modeling using conditional correlations by DCC model and multivariate GARCH model, MES is displayed as formula (16).

$$MES_{i,t}(C) = \mu_{i,t} + \delta_{i,t}\rho_{i,t}E_{t-1}\left[\varepsilon_{m,t}/\varepsilon_{m,t} < \frac{C-\mu_{m,t}}{\delta_{m,t}}\right] \tag{16}$$

In this regard: C is the threshold value (proportionate to different conditions), $\mu_{i,t}$ is the conditional average of variable growth, $\delta_{i,t}$ is the conditional standard deviation of GJR and $\rho_{i,t}$ is the conditional correlation of the total market and the i-th variable. Therefore, according to formula (17), we will have:

$$Var_{t-1}\begin{pmatrix}R_{i,t}\\R_{m,t}\end{pmatrix} = D_{i,t}P_{i,t}D_{i,t} = \begin{vmatrix}\sigma_{i,t} & 0\\0 & \sigma_{m,t}\end{vmatrix}\begin{vmatrix}1 & \rho_{i,t}\\\rho_{i,t} & 1\end{vmatrix}\begin{vmatrix}\sigma_{i,t} & 0\\0 & \sigma_{i,t}\end{vmatrix} \tag{17}$$

Due to the high impact of negative news in the economy, Garch GJR(p,q) model is used. In this model, whenever negative volatilities have a greater impact, the model is well able to determine conditional variance and conditional dynamic correlation between variables. Whenever the coefficient of leverage effect (ε<0) in this model is zero, the model is converted to the GARCH model according to formula (18).

$$\sigma_t^2 = k + \sum_{i=t}^{P}\gamma\sigma_{t-1}^2 + \sum_{j=1}^{Q}\alpha_j\epsilon_{t-j}^2 + \sum_{j=1}^{Q}\xi_j I[\varepsilon_{t-j} < 0]\,\varepsilon_{t-j}^2 \tag{18}$$

The two methods MES and ΔCoVaR work in the opposite way. That is, MES considers the market crisis as a systemic risk and considers the return of the financial institution as a systemic risk event, but ΔCoVaR considers the crisis in a financial institution as a systemic risk and extracts the market return as a crisis.

3.2.3 SES Method

This measure is the average α or A percentage of the worst losses, which is usually considered the VaR value as the boundary that determines the worst losses or returns. Suppose that $\boldsymbol{R_{it}}$ is the growth of macroeconomic variable i with time horizon t with average α or A percent so that:

$$\boldsymbol{\alpha = A\%\epsilon\ (0,1)}$$
$$\boldsymbol{\alpha = 1 - P} \tag{19}$$

In formula (19), α represents the percentage of probability of the worst returns (growth), so it is expected that A percentage will be realized. So according to formulas (20) and (21) we will have:

$$\boldsymbol{SES_{\alpha,t-1}(L) = \frac{1}{1-\alpha}(E_t(R_{it}|R_{it} < F^{-1}(L))} \tag{20}$$

$$\boldsymbol{SES_{\alpha,m,t-1}(L) = inf_{Q\in Q_\alpha}E^Q(R_{it})} \tag{21}$$

In these formulas: $\boldsymbol{Q_\alpha}$ is a set of the size of the probability of the occurrence of completely continuous systematic risk in the measurable space, R is the variable return or growth, $\boldsymbol{F^{-1}(L)}$) is the inverse of the density function of the probability of loss compared to the violation of the value at risk and L is equal to the density function of the i variable.

3.3 TVP-VAR Method

In traditional time series regression models, it was assumed that a relationship with constant coefficient can be used in different times. This false and unrealistic assumption leads to incorrect results, so the results of the research 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 [30], and has not been used much in domestic research so far. One of the advantages of this method is to determine the im-pact and effectiveness of each variable on other variables. Also, the above model has many ad-vantages over other vector autoregressive models, because due to the fact that the time series of variables and macroeconomic indicators can undergo structural failures and cyclical changes over time, the use of time-varying coefficients (TVP) leads to more accurate results [16].

Suppose that Xt, for T, t=1,..., T is an n*1 vector of variables to estimate unobservable variables and Yt is a s*1 vector of the studied indicators, in this case the model will be in the form of formulas (22) and (23).

$$\boldsymbol{Y_t = C_t + B_{t,}1Y_{t-1} + \cdots + B_{t,p}Y_{t-p} + B\epsilon_t} \tag{22}$$

$$\boldsymbol{\beta_t = \beta_{t-1} + \eta_t} \tag{23}$$

In the above relation, $(B_t, 1, \dots, B_{t,p})$ are the VAR coefficients and ϵ_t are the error components with a normal distribution of zero mean and time variable covariance Y_t and N (0, R_t)~η. 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 Systematic Review of Texts to Select Research Variables

Considering the wide range of macroeconomic indicators and variables, in order to determine the research variables based on a systematic method, research in the field of systemic risk and variables of the macroeconomic sector were examined, and according to the frequency of the variables used in this research, based on the highest frequency, especially in internal research, the research variables were selected according to the stages of Table (2).

Table 2: Systematic Review of Texts and Selecting Variables

Step	Title	Description
1	*Choose of Key Words.*	*Systemic risk, Uncertainty, Contagion, Entropy, Value at Risk (VaR), Conditional Value at Risk (CoVaR), Marginal Expected Shortfall (MES), Systemic Expected Shortfall (SES)*
2	*Persian Data Bases*	*SID* *Civilica* *Noormags* *Magiran*
3	*Foreign Data Bases*	*Science direct Elsevier* *Springer Emerald* *Scopus* *Google scholar*
4	*Study community*	*all kinds of articles, theses, Books, Online Sources*
5	*Study and Vector summary*	*A Summary of the Research, Variables and Methods used, and the Results of the Research Conducted.*
6	*Forming a Frequency Table*	*The Research Frequency table is Drawn Based on the Macroeconomic Variables used in the Research.*
7	*Selecting Variables*	*The Macroeconomic Variables that had the Highest Frequency in the Research were Selected.*

4.2 Descriptive Statistics of Seasonal Data

Table (3) shows the descriptive statistics of the price index of variables in the macroeconomic sector of Iran between 1387 and 1402.

Based on the results of table (3) and emphasizing the growth variables, the average growth of the total stock market index in the study period was 7.19%, in this period the total stock market index had a maximum growth of 60.58%. Also, the average growth of the price of each gram of gold during the period under review was 6.62%, and the price of gold had a maximum growth of 46.61%. The average price growth of Imam coin was 6.62 percent and its maximum growth was 43.66 percent. The exchange rate has an average growth of 5.37%. GDP has an average growth of 4.48% and its maximum growth was 32.78%. Liquidity has an average growth of 5.85% and its maximum growth was 22.91%.

Table 3: Descriptive Statistics of Seasonal Data Yield from 1387 to 1402

Row	Variable	Minimum	Median	Average	Maximum
1	Tepix_t	7966	77983	465509	2211856
2	Oil_t	27.31	67.59	71.60	115.97
3	GoldPrice_t	180900	1143135	5158198	32536000
4	CoinPrice_t	2070000	11379000	56726734	388060000
5	Gold_t	837.15	1326.94	1434.43	2159.99
6	Dollar_t	9260	34835	119052	603510
7	GDP_t	714716	2745245	4412431	19444890
8	DP90_t	1364175	1542784.29	1544028.48	1903915
9	Liquidity_t	1622.93	10383.9	19253.24914	78808
10	Interest Rate SH_t	6	10	11.11	16.1
11	Interest Rate Y_t	14	16	17.33	23
12	Inf_t	9	27.95	27.39	47.1
13	Oil Income_t	3.9	14.3	15.75	33.3
14	G. Tepix_t	-12.9	5.02	7.19	50.57
15	G. GoldPrice_t	-39.01	4.56	6.62	43.66
16	G. CoinPrice_t	-37	4.93	6.62	43.66
17	G. Dolar_t	-49.79	2.02	5.37	49.84
18	G. GDP_t	-21.84	5.46	4.48	32.78
19	G. Liquidity_t	-15.51	5.6	5.85	22.91

According to the results of table (3), the highest amount of positive growth related to the growth of the inflation rate and the growth of the total index of the Tehran Stock Exchange was 69.23% and 60.57%, respectively, which indicates significant changes during one season. Also, the lowest positive growth was related to liquidity growth with 22.91 percent. The largest amount of negative growth was related to the growth of the dollar rate by -49.79 percent during one season.

4.2 Analysis of the First& Second Question

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 (4).

Table 4: Entropy's Normalized Value and Ranking

V Equal to Normalized Value R Equal to Ranking		Shannon		Reny		Tessalis		M.Tessalis		Simpson		M. Simpson	
Row	Variable	V	R	V	R	V	R	V	R	V	R	V	R
1	Tepix_t	0.206	1	0.085	2	0.081	2	0.774	2	0.133	2	0.125	2
2	Oil_t	0.011	9	0.072	9	0.075	9	0.0766	9	0.045	9	0.051	9
3	GoldPrice_t	0.180	3	0.085	3	0.081	3	0.0774	3	0.013	3	0.119	3
4	CoinPrice_t	0.193	2	0.086	1	0.081	1	0.0775	1	0.141	1	0.125	1
5	Gold_t	0.006	10	0.071	10	0.074	10	0.0766	10	0.043	10	0.049	10
6	Dollar_t	0.146	4	0.083	4	0.080	4	0.0772	4	0.108	4	0.104	4
7	GDP_t	0.088	6	0.079	6	0.078	6	0.0770	6	0.083	6	0.083	6
8	DP90_t	0.001	13	0.070	13	0.074	13	0.0766	13	0.041	13	0.047	13
9	$Liquidity_t$	*0.144*	*5*	*0.081*	*5*	*0.079*	*5*	*0.0771*	*5*	*0.092*	*5*	*0.091*	*5*
10	$Interest\ Rate\ SH_t$	*0.004*	*11*	*0.071*	*11*	*0.074*	*11*	*0.0766*	*11*	*0.043*	*11*	*0.048*	*11*
11	$Interest\ Rate\ Y_t$	*0.003*	*12*	*0.071*	*12*	*0.074*	*12*	*0.0766*	*12*	*0.042*	*12*	*0.048*	*12*
12	Inf_t	*0.029*	*7*	*0.073*	*7*	*0.075*	*7*	*0.0767*	*7*	*0.051*	*7*	*0.057*	*7*
13	$Oil\ Income_t$	*0.020*	*8*	*0.073*	*8*	*0.075*	*8*	*0.0767*	*8*	*0.049*	*8*	*0.054*	*8*

According to the results of table (4), except for the total index of Tehran Stock Exchange and the price of Imam coin, the ranking of other macroeconomic variables is the same in 6 entropy methods. In connection with the total index of Tehran Stock Exchange, this index ranks first in Shannon entropy and second in other entropies. Regarding the Imam coin price variable, its rank in Shannon entropy is 2, but in other entropy methods it is 1. Overall, the results in the macroeconomics section show that the use of each of the entropy methods has the same results in determining the amount and rank of entropy (volatility or fluctuation). Considering that one of the purposes of using entropy is prioritizing the amount of volatility in this research and the use of a large number of variables causes complexity in calculations. According to the results obtained in the prioritization of the variables, the first six priorities, which have a higher and significant amount of volatility than other macroeconomic variables and have a greater contribution to creating systemic risk, were selected as the target variables for calculating 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 different methods given in section (3.2.2) and the results are given in the next section.

4.3 Analysis of the Third 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 Hegi unit root tests were used. Research in 1993 and 1994[22-23] showed that the Heggy test is very useful and efficient in determining the unit root that leads to false regression. Heggy test is obtained as a polynomial seasonal differentiation in the form of formula (24).

$$\Delta_4 X_t = (1 - L^4)X_t = (1 - L)(1 + L)(1 + L^2)X_t \tag{24}$$

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, this 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).

Assumption H0: the existence of a single root among the variables

Assumption H1: There is no single root among the variables

Next, the test result is shown in table (5).

Table 5: Heggy's Test for Examining the Significance of Variables

Row	Variable	Annual Unit Root	Seasonal Unit Root	Result
1	$G.\,Tepix_t$	0.01	0	Not Accepting the Null Hypothesis
2	$G.\,GoldPrice_t$	0	0	Not Accepting the Null Hypothesis
3	$G.\,CoinPrice_t$	0	0	Not Accepting the Null Hypothesis
4	$G.\,Dolar_t$	0	0	Not Accepting the Null Hypothesis
5	$G.\,GDP_t$	0	0	Not Accepting the Null Hypothesis
6	$G.\,Liquidity_t$	0	0	Not Accepting the Null Hypothesis

After examining the existence of a single root, using different methods of measuring systemic risk in this research, the systemic risk of Iran's macroeconomic variables was evaluated. The average of each of the system risk measures for these variables is presented in table (6). According to most criteria, the growth of the exchange rate, the growth of the Imam coin price, and the growth of the gold price per gram are the most important factors for the occurrence of systemic risk in the Iranian economy.

Table 6: Average of Systemic Risk Measures in the Iranian Economy from 2008 to 2023

Row	Variable	VaR	CoVaR	ΔCoVaR	MES	SES
1	$G.\,Tepix_t$	22.02	15.45	3.25	1	9.4
2	$G.\,GoldPrice_t$	20.7	15.7	7.9	1.2	9
3	$G.\,CoinPrice_t$	19.2	12.4	3.5	1.65	8.67
4	$G.\,Dolar_t$	17.67	17.4	7	9.75	12.92
5	$G.\,GDP_t$	18	18.55	7.37	0.56	7.54
6	$G.\,Liquidity_t$	5.6	16.35	4.02	0.12	2.31

Systemic risk assessment of macroeconomic variables shows according to the results of table (6) for ΔCoVaR, which is the difference between the CoVaR of a variable in the normal and critical (median) state. For the growth of Tehran Stock Exchange index, it is 3.25 points during one season. This amount has been obtained for the growth of Imam coin, 7.9 units, for the growth of each gram of gold, 3.5 units, for the growth of the exchange rate, 7 units, for the growth of the GDP at the current price, 7.37 units, and for the growth of liquidity, 4.02 units

Also, the evaluation of the MES method, which is a measure of the expected loss in the value of a variable in a specific time, in case of a specific event, for conditions where the value has already decreased by 5% (in this research, this value is assumed to be 5%) is 1% for the Tehran Stock Exchange index. This means that if a certain event occurs and the value of the Tehran Stock Exchange index has already decreased by 5%, the expected loss in the value of the Tehran Stock Exchange index will be 1 unit in one quarter. This value is 1.2 for the growth of Imam coin, 1.65 for the growth of each gram of gold, 9.75 for the exchange rate, 0.56 for the growth of the GDP at the current price and 0.12 for the liquidity growth.

In relation to SES, which is a measure for measuring the worst losses in the value of a variable in a certain time, and the limit of the worst loss determines the amount of value at risk of each variable. In this case, the expected loss of growth of the Tehran Stock Exchange index is 9.4, which means that if a certain event occurs and the value of the total index of the Tehran Stock Exchange will see a maximum loss of 9.4 units in one season compared to the value at risk. This amount has been obtained for the growth of the Imam coin, 9, for the growth of each gram of gold, 8.67 units, for the growth of the exchange rate, 12.92, for the growth of the GDP at the current price, 7.54, and for the growth of liquidity equal to 2.31. Next, in Figure (1-2), the systemic risk volatilities of each variable from the beginning of 2017 to the end of 2012 are shown separately for each systemic risk measure.

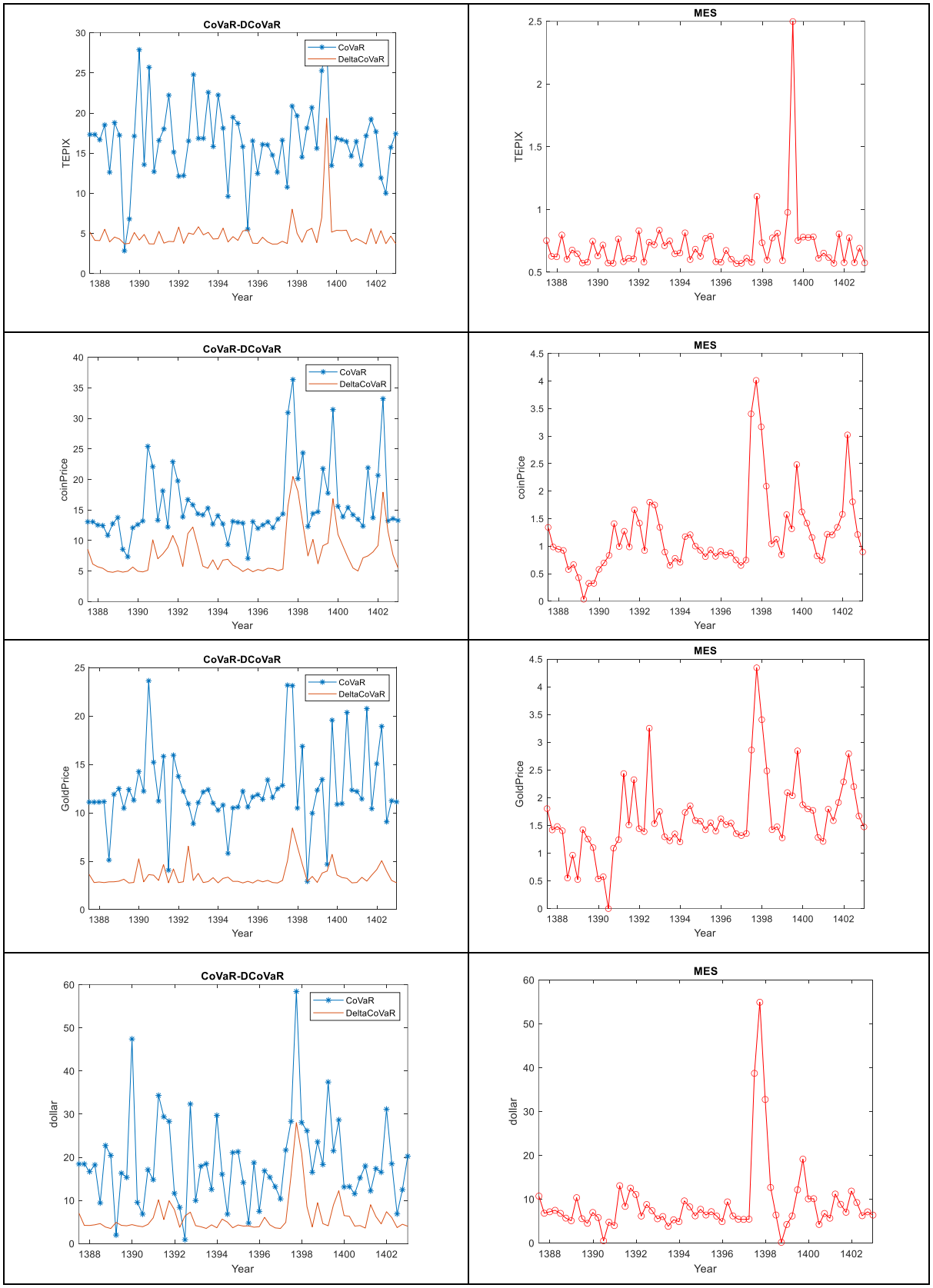

Fig. 1: Systemic Risk Volatility in Type of Different Models

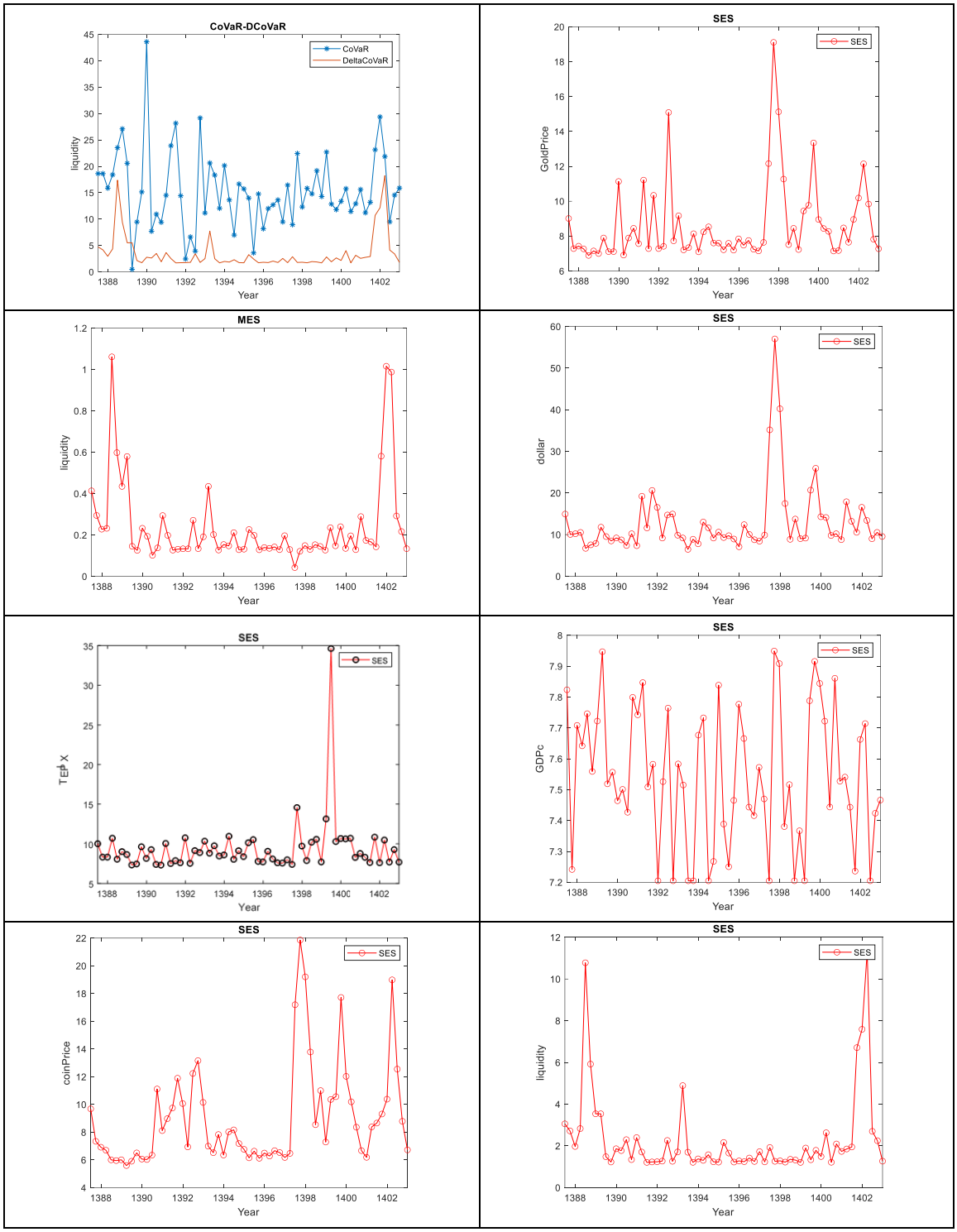

Fig. 2: Systemic Risk Volatility in Type of Different Models

4.4 Analysis of the Fourth Question

Considering that macroeconomic variables are at the mana level and do not have an annual unit root or a seasonal unit root. Therefore, the relationship between variables can be checked using regression

methods and correlation coefficient. In order to calculate the uncertainty of macroeconomic variables, the ARCH autoregressive conditional variance model and the generalized GARCH autoregressive conditional variance model have been used as substitutes for the uncertainty of the variables. For this purpose, the ARCH effect test was first investigated using the ARCH-LM statistic, the results of which can be seen in Table (7).

Table 7: Results of the ARCH Effect Test

Row	Variable	Coefficient	Std. Error	z-statistic	Prob.
1	$G.Tepix_t$	*0.4*	*0.166*	2.4	0.016
2	$G.GoldPrice_t$	*0.18*	*0.00016*	1156	0
3	$G.CoinPrice_t$	*0.313*	*0.07*	4.35	0
4	$G.Dolar_t$	*0.9*	0.04	20.18	0
5	$G.GDP_t$	*0.449*	*0.064*	6.97	0
6	$G.Liquidity_t$	*0.318*	0.16	1.97	0.04

The results of Table (7) 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 chosen to calculate the uncertainties of macroeconomic variables, and the results of the models can be seen in Table (8).

Table 8: Estimation Results of GARCH(p,q) Models

Row	Variable	GARCH(p,q) Models
1	$G.Tepix_t$	*C=134 RESID (-1) ^2=0.272 GARCH (-1) =0.069* *AIC=8.228 SC=8.36 HQ=8.28*
2	$G.GoldPrice_t$	*C2=54.85 RESID (-1) ^2=0.37 RESID (-2) ^2=-0.34 RESID (-3) ^2=0.2* *GARCH (-1) =0.6 GARCH (-2) =0.73 GARCH (-3) =-0.74* *AIC=8.29 SC=8.56 HQ=8.4*
3	$G.CoinPrice_t$	*C=6.73 RESID (-1) ^2=0.8 GARCH (-1) =0.35* *AIC=8.18 SC=8.31 HQ=8.23*
4	$G.Dolar_t$	*C2=1.97 RESID (-1) ^2=0.97 RESID (-2) ^2=--0.84 GARCH (-1) =0.67* *GARCH (-2) =0.2* *AIC=7.55 SC=7.76 HQ=7.63*
5	$G.GDP_t$	*C2=321 C3=0.86 C4=0.16 C5=0.11 C6=0.33 C7=0.3* *AIC=8.52 SC=8.76 HQ=8.61*
6	$G.Liquidity_t$	*C=2.15 RESID (-1) ^2=1.23 GARCH (-1) =0.262* *AIC=6.03 SC=6.17 HQ=6.08*

Table 9: Average of unconditional correlation between variables

Row	Variable	$G.Tepix_t$	$G.GoldPrice_t$	$G.CoinPrice_t$	$G.Dolar_t$	$G.GDP_t$	$G.Liquidity_t$
1	$G.Tepix_t$	*1*					
2	$G.GoldPrice_t$	*0.32*	*1*				
3	$G.CoinPrice_t$	*0.35*	*0.89*	1			
4	$G.Dolar_t$	*0.35*	0.84	0.86	1		
5	$G.GDP_t$	*0.11*	*0.24*	0.19	0.19	1	
6	$G.Liquidity_t$	*-0.04*	-0.07	-0.05	-0.05	0.03	1

The conditional variance calculated according to table (8) is selected as a substitute for the uncertainty of macroeconomic variables. After estimating the models, to check the contagion between parts of the vector autoregression 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 macroeconomic variable is calculated. The results can be seen in Table (9).

Based on the values of table (9), the correlation of liquidity growth with the growth of the total index of Tehran Stock Exchange and gold price growth, the correlation of exchange rate growth and liquidity growth, as well as the correlation of coin price growth is negative and the correlation between other macroeconomic variables is positive. The highest correlation between coin price growth and gold price growth and currency price growth is 0.89 and 0.86. Also, the correlation between currency price growth and gold price growth is 0.84.

The result of examining the degree of impact and impact and spillover effect of macroeconomic variables using the TVP-VAR model to calculate the total dynamic relationship between macroeconomic variables, the average values of the calculated values can be seen in table (10).

Table 10: The Relationship between Aggregate Dynamics and Variables

Row	Variable	$G.Tepix_t$	$G.GoldPrice_t$	$G.CoinPrice_t$	$G.Dolar_t$	$G.GDP_t$	$G.Liquidity_t$	From
1	$G.Tepix_t$	72.41	8.71	9.02	6.92	2.19	0.75	27.59
2	$G.GoldPrice_t$	4.46	38.55	28.13	26.54	2.16	0.16	61.45
3	$G.CoinPrice_t$	4.47	27.27	37.3	28.60	2.03	0.33	62.7
4	$G.Dolar_t$	4.27	26.26	30.82	37.37	1.00	0.28	62.63
5	$G.GDP_t$	4.2	4.97	2.27	2.14	87.57	1.2	12.43
6	$G.Liquidity_t$	0.77	0.7	2.14	0.70	9.85	85.85	14.15
7	to	17	70.58	73.44	70.54	18.32	4.17	278.58
8	Inc. Own	75	107.25	109.79	106.11	102.97	87.43	-
9	Net	-24	7.25	9.79	6.11	2.97	-12.57	39.80

Based on the results of table (10), about 72.41% of the volatilities of the total growth index of Tehran Stock Exchange are caused by this variable and 27.59% are caused by other variables. So that 8.71% of its volatilities are caused by the growth of gold price and 9.02% of volatilities are caused by the growth of coin prices, 6.92% are caused by the growth of the exchange rate, 2.19% of the GDP at current prices and 0.75% are caused by the growth of liquidity. Also, the effect of the total growth index of Tehran Stock Exchange on the growth of the coin price, the growth of the price of gold per gram, the growth of the exchange rate, the growth of the GDP at current prices and the growth of liquidity has 4.47, 4.46, 4.27, 4.2 and 0.77%, respectively. Also, about 38.55% of gold price volatilities are caused by this variable and 61.45% are caused by other variables. So that 4.46% of its volatilities are caused by the growth of the total index of the Tehran Stock Exchange, 28.13% of the volatilities are caused by the growth of the coin price, 26.54% are caused by the growth of the exchange rate, 2.16% are caused by the growth of the GDP at current prices, and 0.16% are caused by the growth of liquidity. Also, the effect of gold price growth on coin price growth, exchange rate growth, total index growth of Tehran Stock Exchange, gross domestic product growth at current prices and liquidity growth is 27.27, 26.26, 8.71, 4.97 and 0.70%, respectively. About 37.3% of the volatilities in the price of Imam coins are caused by this variable and 62.7% are caused by other variables. So that 4.47% of its volatilities are caused by the growth of the total index of the Tehran Stock Exchange, 27.27% of the volatilities are caused by the growth of the gold price, 28.6% are caused by the growth of the exchange rate, 2.03% are caused by

the growth of the GDP at current prices, and 0.33% are caused by the growth of liquidity. Also, the effect of the Imam coin price growth on the growth of foreign exchange, gold, the growth of the total index of the Tehran Stock Exchange, the growth of the GDP at current prices, and the growth of liquidity has 30.82, 28.13, 9.02, 2.27 and 2.14%, respectively. About 37.37% of exchange rate growth volatilities are caused by this variable and 62.63% are caused by other variables. So that 4.47% of its volatilities are caused by the growth of the total index of the Tehran Stock Exchange, 26.26% of the volatilities are caused by the growth of the gold price, 30.82% are caused by the growth of the coin price, 1% are caused by the growth of the GDP at current prices, and 0.28% are caused by the growth of liquidity. Also, the effect of exchange rate growth on the growth of the coin price, the growth of the gold price per gram, the growth of the total index of the Tehran Stock Exchange, the growth of the gross domestic product at current prices, and the growth of liquidity has 28.6, 26.54, 6.92, 2.14 and 0.70%, respectively. About 87.57% of GDP growth volatilities are caused by this variable and 12.43% are caused by other variables. So that 4.2% of its volatilities are caused by the growth of the total index of the Tehran Stock Exchange, 4.97% of the volatilities are caused by the growth of the gold price, 2.27% are caused by the growth of the coin price, 2.14% are caused by the growth of the exchange rate, and 1.2% are caused by the growth of liquidity. Also, the effect of GDP growth at current prices on liquidity growth, total index growth of Tehran Stock Exchange, gold price growth, coin price growth, and exchange rate growth have 9.85, 2.19, 2.16, 2.03 and 1%, respectively. About 85.55% of liquidity growth volatilities are caused by this variable and 14.15% are caused by other variables. So that 0.77 %of its volatilities are caused by the growth of the total index of the Tehran Stock Exchange, 0.7 % are caused by the growth of gold prices, 2.14 % are caused by the growth of coin prices, 0.7 % are caused by the growth of the exchange rate, and 9.85 % are caused by the growth of the gross domestic product at current prices. Also, the effect of liquidity growth on the growth of gross domestic product at current prices, the growth of the total index of the Tehran Stock Exchange, the growth of the coin price, and the growth of the exchange rate has 1.2, 0.75, 0.33, 0.28 and 0.16 %, respectively. 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 (3), the overall trend of communication between macro variables, the impact of positive news and negative news can be seen with the method of frequency communication. Based on the results of this graph, firstly, in the time period under investigation, negative news has a dominant influence in shaping the communication between variables, and the influence of this news has been on the rise since 2017.

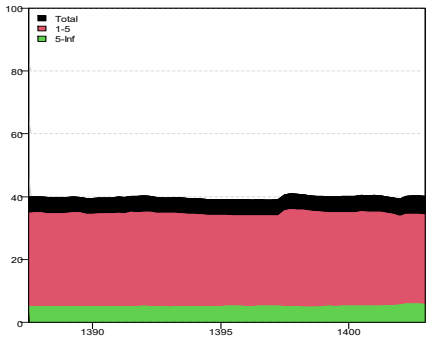

Fig. 3: The Overall trend of Relationships between Variables

5 Discussion and Conclusions

Considering that volatility or fluctuation is one of the factors that create systemic risk, there-fore, according to the review of seasonal data from the beginning of 2007 to the end of 2023 and based on the results obtained, the highest amount of entropy based on the six entropy methods used among macroeconomic variables, respectively, is Total index of Tehran Stock Exchange, price of Imam coin, gold price per gram, dollar rate, liquidity growth, gross domestic product at current price, inflation rate, oil revenues, OPEC oil price, gold price per ounce, interest rate (short term), interest rate (long term) and gross domestic product at current price are fixed price in 1390. The comparison of the results of different entropy methods shows that regardless of the amount of fluctuation calculated by each method, except for the total index of Tehran Stock Exchange and the price of Imam coin, the ranking of other macroeconomic variables is the same in all entropy methods. Regarding the entropy of the total index of Tehran Stock Exchange, the rank of this index is one in Shannon entropy and second in other entropies. Also, the entropy of Imam's coin price is ranked second in Shannon's method, but it is ranked first in other entropy methods. The results of using different entropy methods in the macroeconomic sector show that the use of each of the entropy methods has the same results in ranking the amount of entropy (fluctuation). Also, in terms of the amount of entropy (volatility), the highest amount of fluctuation in the Shannon entropy method is for the total index of Tehran Stock Exchange and the lowest amount of fluctuation is for the annual interest rate, and the range of fluctuation calculated in this method is very high. The ratio of calculated values in other entropy methods was lower than the mentioned two methods.

The results obtained from calculating the systemic risk of the growth of six macro-economic variables selected from different methods show that, based on the value-at-risk delta measure, the biggest contribution to creating systemic risk is related to the variables of Imam coin price growth, GDP growth at current prices, and exchange rate growth, which have about twice as much impact as the three variables of liquidity growth, gold price growth, and total index growth. Therefore, in order to prevent inflammation and severe volatilities in macroeconomic indicators, it is necessary to make appropriate policies, continuous monitoring and take preventive measures in relation to the volatilities of macroeconomic variables according to the prioritization. Based on the measure of the final deficit of the case, the highest expected final drop or systemic risk will be created for the growth of the exchange rate. The three variables of gold price growth, Imam coin price growth, and total index growth of Tehran Stock Exchange have almost the same impact. In addition, the impact of this shock has the least effect on liquidity growth. Therefore, in the critical conditions of the macroeconomic variables, based on the results of this measure, the policy makers should focus on the growth of the currency price. The results of the systematic expected loss measure show that the systemic risk caused by the worst losses in the value of a variable in a specific time horizon that determines the limit of the worst loss is the value at risk of each variable is related to the growth of the exchange rate and the least impact is on the growth of liquidity. Therefore, it is necessary for the policy maker to focus more on currency price volatilities. The comparison of the results obtained from the re-search findings shows that in all three measures used in this research, exchange rate volatilities have the greatest impact on the systemic risk of macroeconomic variables in Iran, and coin price volatilities are the second most influential. Therefore, exchange rate volatilities can be introduced as the initiator of volatilities (contagion) and the cause of systemic risk in Iran's economy. This issue has arisen after the unprecedented increase of the exchange rate in recent years due to the sanction of the Central Bank of Iran by SWIFT, and it reveals the importance of the exchange rate in the financial markets and macroeconomics more than ever. The results

obtained from the systemic risk assessment of macroeconomic variables are consistent with the research results of [37], Mehregan and Ahmadi Ghomi in 2014 [33], and Teymoori et al. [51] And it is contrary to the result [20], which introduced the oil market as the starting point of contagion in financial markets, although in this research, the second place of contagion in financial markets was introduced, the ex-change rate. Of course, the reason for this discrepancy may be related to the time period of the data of the statistical com-munity of this research, including the time series data of prices in the oil markets, Tehran Stock Exchange, currency and gold and in the period of 23rd December 2017 to 16th December 2015 and on a weekly basis.

In relation to the impact of macroeconomic variables on each other, 72.41% of the growth volatilities of the total index of the Tehran Stock Exchange are caused by this variable and 27.59% are caused by other variables, especially the growth of the gold price and the growth of the coin price. Therefore, it can be concluded that other factors and variables affect the volatilities of the total index of Tehran Stock Exchange. In this regard, the contribution of negative news in a completely different way compared to other research variables is evident in the net dynamic integration of the growth index of the Tehran Stock Exchange, which can be one of the reasons for the low impact of other research variables. This issue can be seen for the growth of GDP at current prices and the growth of liquidity. Also, 61.45% volatilities in gold price growth are caused by other variables, especially coin price growth and ex-change rate growth. Also, 62.7% of Imam coin price volatilities are caused by other variables, especially gold price growth and exchange rate growth. In addition, 62.63% of exchange rate growth volatilities are caused by other variables, especially, the growth of coin prices and gold price growth, and 87.57% of GDP growth volatilities are caused by this variable, and 12.43% are caused by other variables. So that 4.2% of its volatilities are caused by the growth of the total index of the Tehran Stock Exchange, 4.97% of the volatilities are caused by the growth of gold prices, 2.27% are caused by the growth of coin prices, 2.14% are caused by the growth of the ex-change rate, and 1.2% are caused by the growth of liquidity. Therefore, it can be concluded that other factors and variables affect the volatilities of the GDP at current prices. The results of the net analysis of the spillover effect of each macroeconomic variable (pure dynamic integration of the system variables) also indicate that the growth variable of the total index of the Tehran Stock Exchange and the growth of liquidity receiving the spillover effect from other variables and other variables are injecting the spillover effect, and in the meantime, the share of negative news (pink) is much higher than positive news (green) or positive effects, and the impact of this news has been on the rise since 2017. In addition, exchange rate volatilities, Imam coin price vola-tilities, and gold price volatilities per gram inject more than 55% of the overflow into each other. In addition, the net contagion criterion indicates that the intra-system dependence between the variables used in this research is an average of 39.8%, 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 aver-age net contagion, the obtained results are acceptable. The results of this research are in line with the research results of [38] regarding the positive and two-way relationship between the currency and gold markets during the research period, as well as [18] (investigating the existence of financial contagion between currency, coin and stock markets) and con-firming the evidence of the phenomenon of contagion only between currency and coin markets. On the other hand, the results of [35] regarding the one-way spillover from exchange rates, gold and commod-ities to stocks and the one-way spillover of volatility from stocks to exchange rates, as well as the findings of [2] confirming the positive effect of exchange rates on the stock exchange during the years 1377 to 1384 are not in line with seasonal data, which could be due to the period under review. This

Research Limitations include: some macroeconomic variables such as short-term interest rate and long-term interest rate, due to the nature of these variables which are usually constant during a year, the method used in this research to select the final variables based on the amount of fluctuation using entropy methods may not have explained their effect correctly.The number of methods used in the research, as well as the many of macroeconomic variables, although it resulted in obtaining a comprehensive and complete analysis, but it made the research implementation time long and caused complexity in the analysis of the results and the lack of resources to use entropy methods to compare research results has been one of the limitations of the research. Finally, the Research enhancing of knowledge is: In using six entropy methods, the results indicate that the use of each of the entropy methods will achieve the same priorities regardless of the calculated value, The approach of this research evaluated all the dimensions of the problem, and none of the internal researches has been done with this approach and comprehensively. Therefore, the obtained results are highly reliable. In addition to the quantitative results obtained in different parts of the research, the impact of positive and negative news in different years in the macro economy and 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 number of volatilities, systemic risk and the contagion of volatility of variables is clearly visible. The end our Suggestion is: According to the findings of the research, exchange rate volatilities are the initiator of volatilities (contagion) and the cause of systemic risk in Iran's economy. Due to the identification of the exchange rate as the most influential macroeconomic variable, in relation to the items proposed at the beginning of the discussion and suggestions section, research plans should be defined in relation to the exit from the currency neutrality conditions and the solutions to provide foreign exchange and Due to the impact of news, especially negative news in the emergence of systemic risk and contagion of volatility in macroeconomic variables and industry indicators, special attention should be paid to behavioral finance studies.

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