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The Impact of Financial Stress on the Iranian Gold, Currency and Stock Markets: A Time-Varying Granger-Causality Approach

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Abstract

This study provides a comprehensive and different sight at the theoretical literature of the relationship between financial stress index and financial markets and presents a new method in order to investigate the nonlinear relationship between the financial stress index and financial markets for Iran's financial system. To that end, the time-varying Granger-causality tests were used. After calculating the financial stress index, the causality between these variable and other variables (gold price, exchange rate, and stock price index) was evaluated. The time-varying causality tests included forward, rolling, and recursive estimators from April 2005 to December 2019. All results were recalculated regarding time series variance heterogeneity for sensitivity assessment. The estimation findings were more credible in terms of variance heterogeneity due to the monthly nature of the data employed and the high probability of variance heterogeneity. The estimation results with variance heterogeneity and time-varying Granger-causality variable test used to investigate the relationship between financial stress and the stock market also revealed no evidence of causality between financial stress and the stock price index using forward and rolling algorithms. Findings indicate that the financial stress is the source of variations in the Iranian gold market, it does not affect the currency or stock markets.

Highlights

- This study explores the causality relationship between the financial stress index and financial markets.
- The financial stress index is the cause of fluctuations in the Iranian gold market.
- There was no significant causality from the financial stress to the exchange rates in Iran.

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1. Introduction

Financial stress can be represented in numerous financial market variables. As recent financial crises have shown, financial stress can destabilize the financial system when it spreads between different markets (Illing & Liu, 2006). As a result, rising financial stress in the financial markets has been a critical subject for research and forecasting (Park & Mercado Jr., 2014; Roye, 2011). Financial stress is a state of mind in which financial markets and economies are on the brink of upheaval (Illing & Liu, 2006). A disruption in the regular operation of financial markets is referred to as financial stress (Ekinci, 2013; Hakkio & Keeton, 2009; Louzis & Vouldis, 2013). Shocks and the vulnerable financial system induce financial stress.

Iran's economy has experienced periods of stress. Iran's economy has negative financial stress in periods of 13 years (1991,1992,1995,1996, 2001, 2003, 2004, 2005, 2007, 2010, 2013, 2015, and 2017) and in periods of 9 years (1993, 1994, 1997, 1998, 1999, 2008, 2011, 2012, and 2015) has positive financial stress, which respectively has led to an decrease and an increase in economic growth in the country. The years of depression and negative financial stress have been the persistence more than the years of development and positive financial stress, so effect of financial stress on economic growth was negative and significant (Heidarian et al., 2019). According to the literature, the financial stress associated with banking, foreign currency, and stock markets is crucial in linking the financial stress index (FSI) and assets (Apostolakis & Papadopoulos, 2015; MacDonald et al., 2018). Furthermore, various studies on the interaction between financial markets hold that the degree of interconnectedness between these markets is affected by financial stress and crisis periods (Jondeau & Rockinger, 2006; Mokni & Mansouri, 2017). Kliesen & Smith (2010) state that financial stress is a Multi-scale problem, including various simultaneous or temporally proximal external shocks affecting bank and financial market components. Financial upheaval, currency rate pressure, a mix of depreciation and depletion of foreign reserves, diminishing capital inflows, withdrawals from merging economy equity and debt funds, and bank lending trimmed back all signify stress (Chau & Deesomsak, 2014). Aboura & van Roye (2017) discovered that financial stress had minimal effects on economic dynamics, implying that financial stress had unsymmetrical effects. According to the research cited above, financial stress may have a major impact on the macroeconomic and financial variables of countries. Several studies have found that financial stress has been demonstrated to influence real or financial variables as well as monetary policy. Still, Slingenberg & De Haan (2011) have argued that FSIs are essentially difficult to anticipate, with a limited potential forecasting value. Davig & Hakkio (2010) have studied the effects of financial stress on real economic activity has concluded that the US economy is in a distressed state between periods of low financial stress and high economic activity as well as high financial stress and low economic activity.

There is a significant body of empirical research evidence on potential transmission routes from the FSI to financial asset markets when considering the influence of financial stress on financial asset prices. Researchers have examined the reciprocal causality between the FSI and real assets in particular (Bouri et al., 2018; Das et al., 2019; Das et al., 2018; Kocaarslan et al., 2019; Nazlioglu et al., 2015). Das et al. (2018) used the causality-in-quantiles technique to examine the relationship between gold, crude oil, stocks, and financial stress. In terms of financial stress, reciprocal causality was discovered for gold, whereas stocks might have an influence on financial stress. Many studies have adopted quantitative methodologies to examine the connections between financial stress and macroeconomic factors, taking into account regime shifts and asymmetry. In addition, the link between financial stress and financial markets is now being investigated (Adam et al., 2018; Bouri et al., 2018; Das et al., 2018). (Apostolakis & Papadopoulos, 2015; Ishrakieh et al., 2020) have studied the relationship between financial stress and exchange rates. They concluded that securities markets transference of financial stress not only to foreign exchange markets but also between both domestic and international financial markets.

Financial markets such as the stock exchange, gold market, and foreign currency market have traditionally been regarded as sensitive areas of the financial markets by financial and economic officials. The empirical link between the FSI and financial markets has been investigated in many studies using linear econometric methods, such as Granger-causality techniques, vector regression models, and similar approaches.

In terms of the impact of the FSI on financial variables in the U.S., Gupta et al. (2019) argued that linear models might not suffice to discover any indication of predictability. Given that the argument of Adam et al. (2018) & Gupta et al. (2019) is based on the failure of linear models to establish a competent framework to determine the link between financial stress and macroeconomic and financial factors, we used nonlinear models in our study. Apostolakis et al. (2019) reported that changes in financial stress affected financial markets, indicating the applicability of nonlinear models to investigate the link. Thus, Shi et al. (2020) introduced a time-varying causality test based on two novel approaches: A modified version of Toda & Yamamoto's (1995) Granger-causality test that is powerful to the integration features of time series data, and the utilization of dating algorithms based on Phillips et al. (2015) to acquire the time-varying essence. We incorporated the new date stamping methodologies of Shi et al. (2018) into our study, giving greater insight into possible time-varying Granger-causality linkages, which is also another novelty in this field. Accordingly, we examined the Iranian financial market in further depth by looking at the time-varying causality between financial stress and stock, currency rate, and gold prices in financial markets. Despite prior work using the time-invariant version of Granger-causality tests, it should be noted that the time-varying technique is more suited to study causality in financial markets.

Alternatively, this impact is not always consistent across time; it may be present in certain times but not in others, which has been overlooked in previous research. The current study uses the time-varying Granger-causality technique to evaluate the influence of the FSI on the Iranian stock market, gold, and currency rates based on monthly data from April 2005 to December 2019.

the present study contributes to the existing studies. This study applying a newly developed time-varying Granger causality approach of Shi et al. (2018) to explore the causal relationship between stock market, gold, and currency rates. This study explored the different impacts of financial stress in Iran on the volatilities of stock market, gold, and currency rates. There are advantages to using this new approach, in specific, it allows for unclear change points in the causal relationships and also accommodates potential heterogeneity, which is commonly not considered in the existing literature.

The rest of the paper proceeds as follows: Section 2 discusses the literature review. Section 3 presents the data and methodology. Section 4 provides and discusses the empirical results. Section 5 concludes.

2. A Review of the Related Literature

2.1 The Concept of Financial Stress and its Relationship with Financial Markets

Financial stress is a complex web of economic and financial factors whose extreme and critical levels are referred to as financial crises (Monnin, 2017). Financial stress is caused by a weak structure combined with external shocks. Financial fragility describes the vulnerability in the financial system's state and structure; in this scenario, the shock causes stress (Bianco et al., 2011). Although there is currently no consensus on the definition of financial stress, most economists agree on some aspects of the idea. Hence financial stress stems from typical performance problems in financial markets (Monnin, 2017). A period of financial stress is defined as a period in which financial market(s) are in upheaval (Duprey et al., 2017). Since the extension of financial stress is generally caused by growing financial instabilities due to economic disruptions, it will be difficult for the economy and financial markets to return to normal if the extension lengthens excessively (Illing & Liu, 2006).

Cardarelli et al. (2011) analyzed seventeen advanced economies using their FSI index to study the association between financial stress and economic slowdowns. Their findings indicated that financial stress defined by banking difficulties was more likely to be linked to more profound and more prolonged downturns than stress centered on securities or foreign currency markets.

The study and analysis of financial stress indicators reveal that the uncertainty over the underlying value of assets increases during times of stress, leading to substantial price variations in many cases. Investor behavior becomes more uncertain, resulting in the selling of high-risk investments and the purchase of safe investments, such as government bonds or gold, causing a decline in the desire to keep non-cash assets (flight to liquidity) (Hakkio & Keaton, 2009;

Mittnik & Semmler, 2014; Van Roye, 2011). Financial stress is characterized by the uncertainty over the underlying value of assets, the decrease tendency to hold risky assets in the capital market and non-cash assets, selling high-risk investments, purchasing safe investments, such as bonds or gold, and increased information asymmetry between lenders and borrowers of financial assets. In such conditions, information asymmetry creates adverse options, increases average borrower expenses, and results in a fall in the average price of assets in secondary markets (Hakkio & Keaton, 2009). Financial stress also leads to the rise of financial instability, which impedes economic growth and social welfare by disturbing the financial system's functioning (Duca & Peltonen, 2011; Nelson & Perli, 2005).

Apostolakis & Papadopoulos (2014) has concluded that securities markets transfe financial stress to other financial markets among the G7 countries. Financial stress in one financial market creates or exacerbates stress in another, according to Park et al. (2014). According to the FSI, financial stress in developing economies is growing as financial systems become more vulnerable to external shocks. By raising (decreasing) the total stock market index, increasing (decreasing) the liquidity of stocks in the stock market can lead to financial stress (Hakkio & Keaton, 2009; Nelson & Perli, 2005).

The literature, to some extent, deals with how financial market circumstances impact exchange rate portfolio assignments. In an essay published in 2014, Vichet Sum reported that financial stress reduces of the returns on the CRSP Ziman REIT indices and sub-indices.

according to Raddatz & Schmukler (2012), both investors and fund managers transfer their portfolios when faced with a stressful occurrence in their nation or in a foreign place where their investment is exposed. Therefore, during times of financial stress, investors and their fund managers significantly affect capital flows. These capital movements directly influence the exchange rates that are being monitored. Adam et al. (2018) used the Bayesian Markov-switching VAR model to investigate the nonlinear effects of financial stress on exchange rates. They confirm regimes of the reaction of exchange rates to movements in financial stress.

According to Adam et al. (2018), a rise in projected volatility would cause the satellite currency to depreciate in the "flight to safety" regime. According to Ozceleb (2020), high levels of the financial stress index (FSI) can decrease in value the currencies of emerging economies. Baur & Glover (2012) argue that investors with significant amounts of gold in their portfolio are forced to sell part or all of their reserves in times of stock market stress if they run into borrowing or liquidity constraints in other gold reserves in the portfolio. Gold's appeal to investors during times of significant market tension or stress has been frequently discussed in financial journals (e.g., Sanderson, 2015). Many gold price models contain this component of gold, but these tensions have altered stress assessment and interaction with gold. Investors prefer lower portfolio risk to higher portfolio risk, according to Reboredo & Uddin (2016), and frequently invest in

commodities referred to as safe-haven assets under financial hardship. It also shows that gold yield rises in reaction to stock prices and quick stress in financial markets and that shareholders may limit their losses in a market downturn by allocating a portion of their portfolios to gold.

Das et al. (2018) analyze the causation between gold and financial stress in the United States using a nonparametric causality-in-quantile technique. These authors claim that gold and the U.S. FSI have a substantial bidirectional causality.

2.2 Designing Financial Stress Index (FSI)

In the literature, there are a variety of stress indices that incorporate distinct quantities of variables into a single metric. According to Dovern & van Roye (2014), financial stress is generally unobservable, although it is probably reflected in many financial factors. Over time, various FSIs have been established. Principally, the FSI combines some financial market factors into a single statistic that gives an integrated assessment of the financial system's level of instability. These indicators can be applied to detect financial market disruptions in real-time, a crucial step in quick policy response. A wide range of financial stress indices has been created based on market-based indicators in real-time and high frequency related to banking, securities, and foreign exchange markets (Hatzius et al., 2010; Hollo et al., 2012; Bianco et al., 2011).

The level of the FSI indicates demonstrates the interplay of financial vulnerabilities and quantifies the magnitude of financial shocks (Grimaldi, 2010), making it a viable option for expressing a country's quantifiable financial stress level. Baxa et al. (2013) segment the FSI into banking, securities, and exchange markets to better understand how central banks respond to market stress. An index of financial stress is a single statistic that combines several individual stress indicators representative of the major financial market segments (money, bond, equity, foreign exchange markets, and the banking sector) to measure the current state of insecurity in the financial system. As a result, a slew of FSIs have been developed, the majority of which comprises three subcomponents: the banking sector, the exchange market, and the stock market (Apostolakis & Papadopoulos, 2015; Louzis & Vouldis, 2013). Financial tensions between developed and emerging economies have recently increased because of the growing effect of developing markets on financial asset markets.

FSI is a hybrid index that compresses and conveys stress indicators across many markets (money, securities, stock, and foreign exchange) on a single scale. Because no single theory can characterize financial stress, economists have attempted to formulate financial stress using various indicators to recognize difficult events in a centralized economy. The FSI for the Iranian financial system is offered in this study tailored to fit the peculiarities and features of the Iranian financial system, as well as stress scales from three other markets. The distinct aspects of financial stress in the banking, capital, and exchange rate markets have been chosen to assess financial stress. Economists argue that the three markets mentioned above are the three sub-indices that may be used to gauge financial

stress on its whole. However, the indicators for financial stress in global markets vary in terms of the number of time components, frequency of data, and weighting methodologies. Due to a lack of daily and weekly data in Iran, the following variables with monthly frequency were used to generate financial stress sub-indices from April 2005 to December 2019. Finally, these sub-indices were combined to form a single index.

According to related literature, Financial stress index (FSI) was constructed for the Iran financial system using indicators from the main components of financial system. This paper uses the FSI provided by Aboura & van Roy (2017) and Cardarelli et al. (2011) by applying changes such as the type of variables and calculating the fluctuations of each of the variables.

Correspondingly, this paper uses banking sector, equity market and foreign exchange market indicators in developing FSI for Iran. Details regarding these subindices are as follows:

The banking sector stress index: The banking sector's beta coefficient, which is calculated by dividing the covariance of the return of the total stock market index r_m and the return of the banking stock index r_b on the variance of the total stock market index's return, indicates the banking sector's risk compared to other sectors of the economy, the formula of which is:

$$\beta = \frac{\mathrm{cov}(r_m, r_b)}{r_b}.$$

This indicator represents a rapid and anomalous decline in bank stock prices compared to the general stock market price index during times of extreme stress. The stock index of the Tehran Stock Exchange and the banks were taken from the Tehran Stock Exchange Organization's official publications. The Central Bank's total time series and monthly economic indicators (different years) also used to extract exchange rate statistics and information.

Securities market stress index: Using the usual rolling deviation approach, stock market returns is computed as the stress index of securities market (moving average of standard deviation). This variable evaluates and estimates changes in the underlying value of assets as a source of uncertainty in financial investor behavior.

Foreign exchange market stress index: The exchange rate and its swings are some of the characteristics that can create significant financial stress and rapid changes in people's behavior in the foreign exchange market, according to the Foreign Exchange Market Stress Index. In addition, the exchange rate changes in Iran are one of the main indicators in assessing the stress of financial markets, due to the Iranian economy's strong reliance on oil income and imports. The standard rolling deviation approach has been used to calculate exchange rate swings (moving average of standard deviation). The informal (free) market exchange rate exchange rate indicates each foreign currency's domestic price, which in this case the free market rate of the rial against the U.S. dollar. the FSI is given by:

FSI = bank beta + Securities market stress + Foreign Exchange Market stress

3. Data and Research Methods

3.1 Data

The monthly data from April 2005 to December 2019 were used in this study. The data consisted of the following:

Financial stress: Financial stress is defined as a disruption in financial markets, as previously stated. The previous sub-section explained how to calculate financial stress.

Exchange rate: The exchange rate is the rate at which the dollar is exchanged for the Rial on the informal (free) market. For the study period, statistics for this variable were taken from the Central Bank of Iran's monthly releases.

Stock Price Index: The performance index of the Tehran Stock Exchange is the entire stock index. This variable's data is gathered every month from the Tehran Stock Exchange's publications.

The price of the old design Bahar Azadi coin: The price of the old design Bahar Azadi Gold Coin was used to gauge the performance of the gold market. This variable's data was likewise collected from the related database in the government.

3.2 Methods

following the model of Shi et al. (2018). The lag-added VAR model with a maximum integration order of d can be specified as Eq.(1):

$$y_t = \prod x_t + \varepsilon_t , \qquad t = 1. \dots \dots . T \tag{1}$$

Where $y_t = (y_{1t} . y_{2t})'$, $x_t = (1, y'_{t-1} \dots \dots . y'_{t-p})'$, $\prod_{2\times(2p+1)} = [\Phi_0, \Phi_1, \dots\dots \Phi_p]$.

Suppose that $\widehat{\prod}$ is the ordinary least squares (OLS) estimator of $\prod$, and $\widehat{\Omega} = T^{-1} \sum_t^T \widehat{\varepsilon_t} \widehat{\varepsilon_t}'$ is the OLS estimator of the error covariance matrix Ω.

Let $\widehat{\varepsilon_t} = y_t - \widehat{\prod} x_t$ be the regression residuals, and $X' = (x_1, \dots\dots\dots, x_T)$ the observation matrix of the regressors in Eq. (1). To test the null hypothesis H_0 about y_{2t} does not Granger cause y_{1t}, the standard Wald statistic w was used as:

$$w = [R\ vec\ (\widehat{\prod})]'[R\ \Omega' \otimes (X'X)^{-1} R']^{-1} [R\ \ vec\ (\widehat{\prod})] \tag{2}$$

vec $(\widehat{\prod})$ signifies the row vectorization $2 \times (2p + 1) \times 1$ coefficients of, and R is a $p \times 2\ (2p + 1)$ matrix on the parameter. Each row is based on the non-causal null hypothesis, with coefficients set to zero.there are p coefficients on the lagged values of y_{2t} in Eq (1). Under the null hypothesis and assumption of conditional homoskedasticity, Dolado & Lutkepohl (1996) and Toda & Yamamoto (1995) demonstrated that this Wald statistic had the standard χ^2_p asymptotic null distribution, where p was the number of zero limitations in the test.

Phillips et al. (2015) & Hurn et al. (2016) described three tests based on the Wald statistics of supremum norm (sup) for identifying changes in causality utilizing a recursive evolving algorithm and rolling window. The Wald statistic obtained for each subsample regression is expanded by $w_{f_2}(f_1)$ for each observation of interest $(f \in [f_0, 1])$,and the sup Wald statistic is defined as:

$$sw_f(f_0) = \sup_{f_2 = f, f_1 \in [0, f_2 - f_0]} w_{f_2}(f_1)$$

Let f_0 and f_e represent the beginning and end of the causal relationship, respectively. They are derived from the initial chronological data in which the test statistic either exceeds or falls below the critical threshold. The rolling and recursive developing algorithms' dating rules are as follows:

Forward:

$$\hat{f}_e = \inf_{f \in [f_0, 1]} \{f: W_f(0) > cv\}, \quad \hat{f}_f = \inf_{f \in [\hat{f}_e, 1]} \{f: W_f(0) < cv\}, \tag{3}$$

Rolling:

$$\hat{f}_e = \inf_{f \in [f_0, 1]} \{f: W_f(f - f_0) > cv\}, \quad \hat{f}_f = \inf_{f \in [\hat{f}_e, 1]} \{f: W_f(f - f_0) < cv\}, \tag{4}$$

Recursive Evolving:

$$\hat{f}_e = \inf_{f \in [f_0, 1]} \{f: SW_f(0) > scv\} \text{and} \quad \hat{f}_f = \inf_{f \in [\hat{f}_e, 1]} \{f: SW_f(0) < scv\}, \tag{5}$$

The equivalent critical values of the w_f and SW_f statistics are cv and scv, respectively.

4. Empirical Results

A four-variable VAR model was used to examine the impact of financial stress on Iran's gold, currency, and stock markets. These variables included the FSI, the logarithm of the gold price (LGP), the logarithm of the exchange rate (LER), and the logarithm of a total stock index (LSP). The data were collected every month from April 2005 to December 2019.

The statistics and information of other variables were also taken from the time series database and the Central Bank of Iran. Figs. 1, 2 shows the time series of financial stress data, and logarithmic series of other variables.

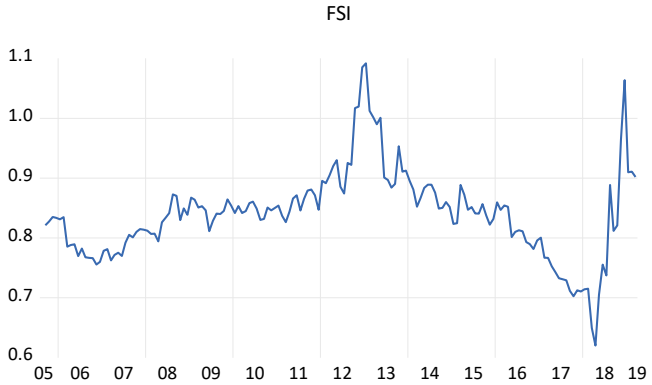


Figure 1. The time series of FSI in Iran

Source: *Research Findings*

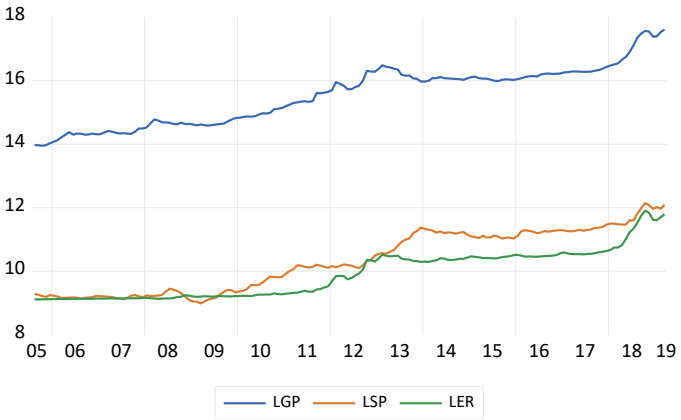


Figure 2. Logarithm series of the exchange rate, stock, and gold index in Iran
Source*: *Research Findings

The stationarity of the variables and their co-integration were examined using the augmented Dickey-Fuller unit root test (ADF) to get information on the system co-integration. The results have been reported with both intercept and intercept with time trend in Table 1. All variables have a unit root and are integrated to the first order, as shown in Table 1. As a result, the VAR equation system's greatest level of co-integration should be considered one. Thus, the intercept and the temporal trend are included in the estimated model, and the parameter d is set to one. Then, using forward, rolling, and recursive estimators, the causality between financial stress and the logarithm variables of the gold price, exchange rate, and stock price index was explored. With a maximum lag of 6, the Schwartz criterion (BIC) was used to find the best lag pattern.

The results of test statistics and critical values of 5% determined using bootstrap simulation for forward, rolling, and recursive estimators are shown below. These algorithms have a minimum window size of 5 years or 60 months. These estimates were made without taking into account variance heterogeneity. The calculations and estimations were performed using Eviews and MATLAB software.

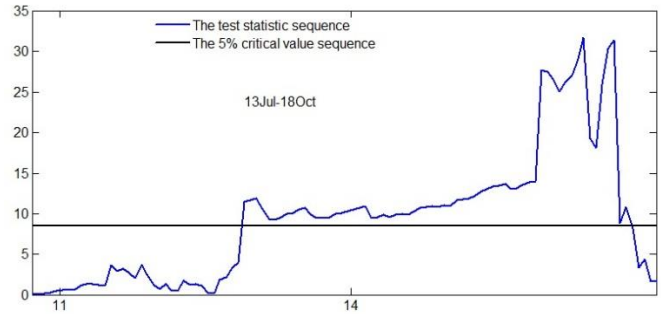
Table 1. The unit root test (ADF) results

VARIABLE NAME	In level		With one-time differentiation	
	With intercept	With trend and intercept	With intercept	With trend and intercept
LFSI	-0.052 (0.664)	-2.848 (0.182)	-11.351 (0.000)	-11.322 (0.000)
LGP	0.169 (0.969)	-1.684 (0.754)	-8.534 (0.000)	-8.549 (0.000)
LER	0.861 (0.994)	-1.685 (0.753)	-5.224 (0.000)	-5.478 (0.000)
LSP	0.439 (0.984)	-2.443 (0.355)	-8.575 (0.000)	-8.658 (0.000)

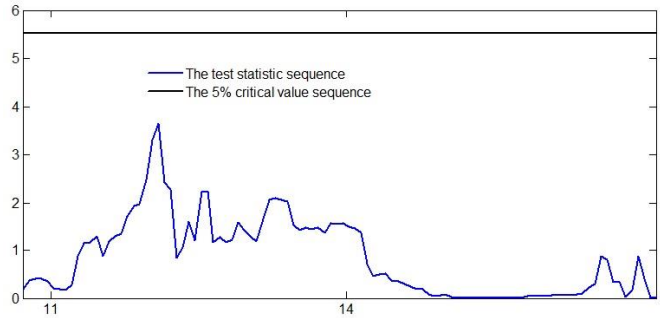
***Source*:** *Research Findings*

The findings of the time-varying Granger-causality test from FSI to LGP are shown in Fig. 3. According to the forward statistics, financial stress was the cause of the logarithm of the gold price in Iran from April 2014 to March 2018, but there was no direct association between FSI and LGP in other months. The results of rolling statistics differed from prior data; thus, the causality between financial stress and the price of gold could be seen in numerous instances during the study period. As shown, there was a causality between FSI and LGP from July 2013 to July 2014, October 2014 to March 2015, May 2016, August to November 2016, April to May 2017, and August 2017 to February 2018, but not from other months. The recursive statistics showed that financial stress was the cause of the gold price Granger casualty from July 2013 to October 2018, but there was no such association in other months. Forward and recursive statistics provide extremely similar findings. Meanwhile, the causality between financial stress and gold price is not obvious in all three figures before 2013 and after 2018.

a) Forward



b) Rolling



c) Recursive

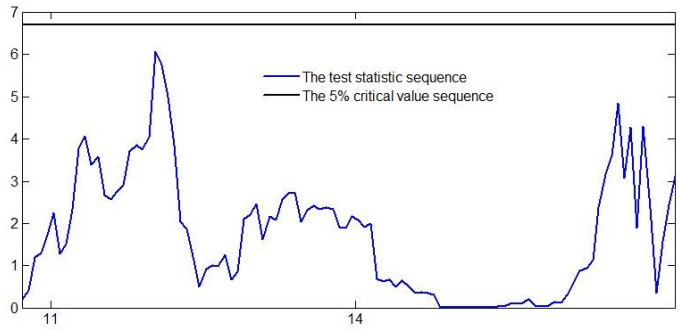


Figure 3. The results of the causality from FSI to LGP based on triple statistics of the time-varying Granger-causality test

***Source*:** *Research Findings*

The findings of a time-varying Granger-causality test from FSI to LSP are shown in Fig. 4. According to the findings of recursive test statistics, the causality between financial stress and the logarithm of stock prices was only detected from May to June 2012, and there was no such relationship in other months. Strong evidence for causality between financial stress and the stock price index cannot be discovered based on all three statistics.

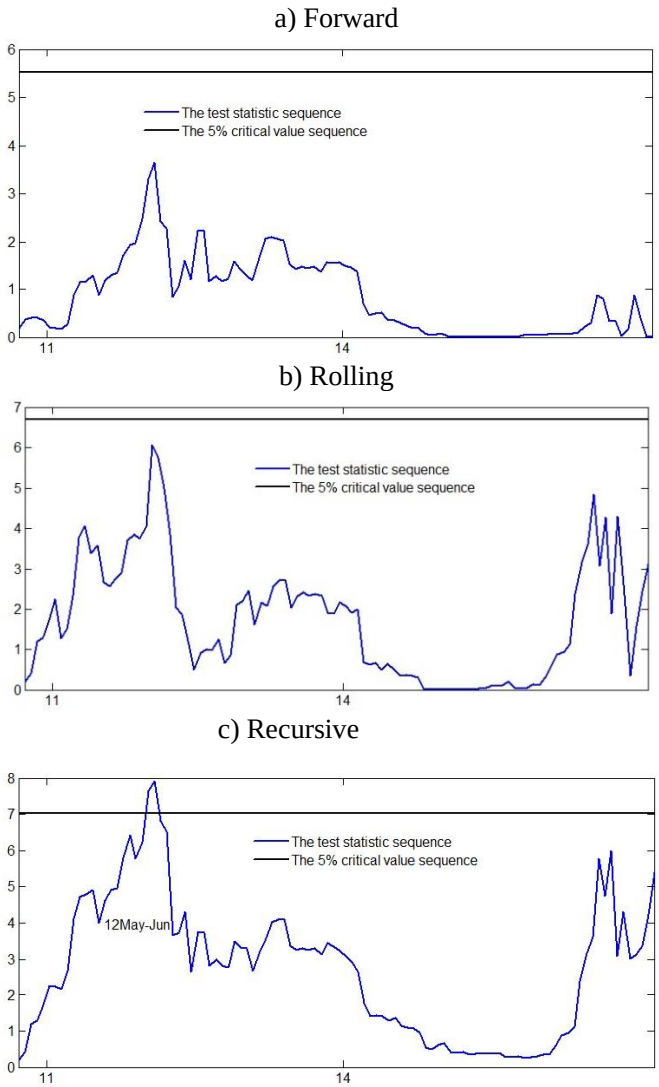


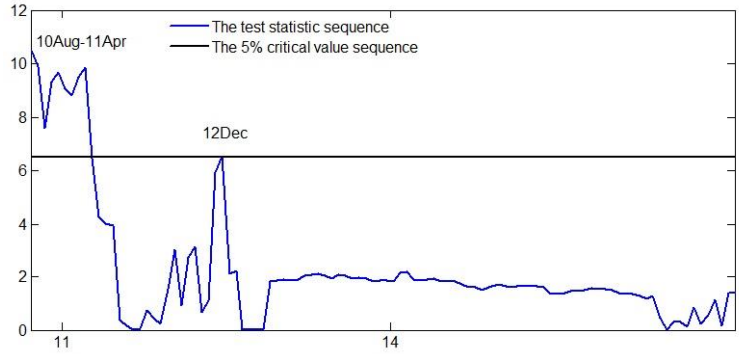
Figure 4. The results of the causality from FSI to LSP based on triple statistics of the time-varying Granger-causality test
Source*: *Research Findings

Fig. 5 shows the results of the time-varying Granger-causality test from FSI to LER. The causality to the results of all three test statistics was found only in short periods. According to forward test statistics, financial stress was the Granger-causality for exchange rate swings from August 2010 to April 2011, as well as in December 2012. There was a causality between FSI and LER according to rolling statistics from August to September 2010, November 2010, April 2011, and August to October 2017, and this relationship has not been detected at other

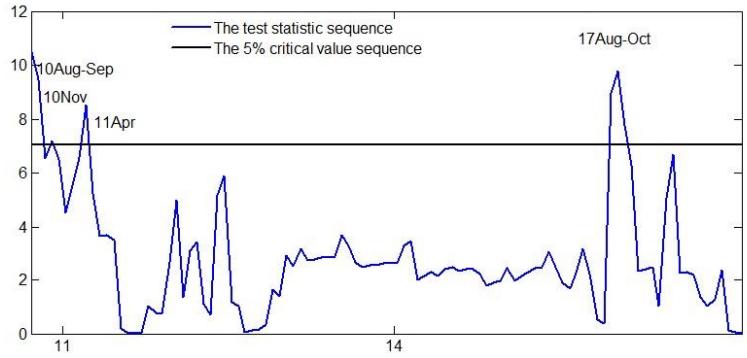
times. In addition, the findings of recursive test statistics suggested a causality between FSI and LER from August to September 2010, November 2010 to April 2011, August 2017 to March 2018, and June to October 2018. This relationship was not detected in other months. At the start of the research period, the findings of all three statistics were similar.

The sensitivity of the results was examined to assess the strength of the acquired results. The likelihood of variance heterogeneity in time series was relatively high given the monthly data. Thus, for sensitivity analysis, all tests had to be repeated in terms of variance heterogeneity in the model. Hurn et al. (2016) proposed several new statistics. Critical bootstrap values were also employed here at a significance level of 5%, and the maximal system integration order was set to one. A minimum window size of 60 views was also considered.

a) Forward



b) Rolling



c) Recursive

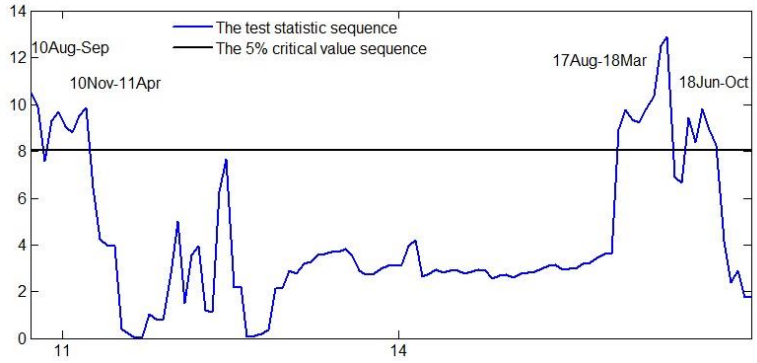


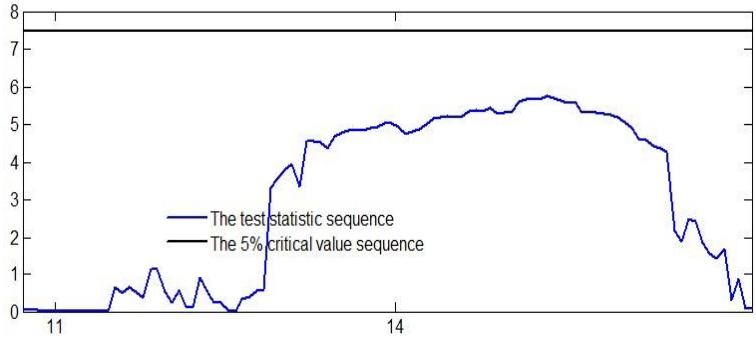
Figure 5. The results of the causality from FSI to LER based on triple statistics of the time-varying Granger-causality test
***Source*:** *Research Findings*

The following Fig. 6. Fig. 7, and Fig. 8 show the findings of forward, rolling, and recursive test statistics in terms of variance heterogeneity to analyze the causality of FSI to the financial markets stated. As shown, including variance heterogeneity in the test findings significantly impacted the outcomes. As a result of the monthly nature of the data, the current results are more robust and dependable than earlier tests' results (without heterogeneity).

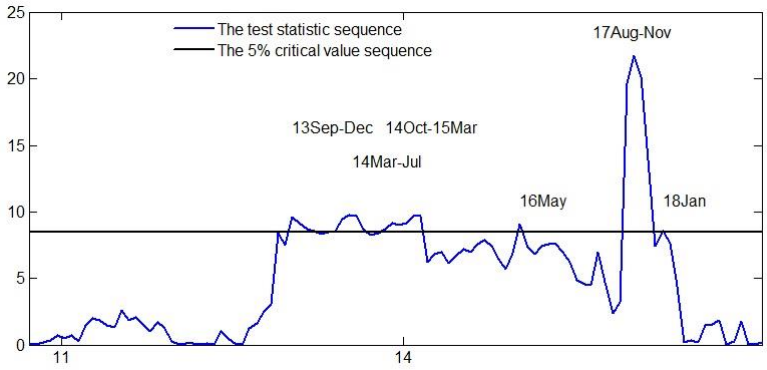
The forward algorithm does not reveal any indication of causality between financial stress and the gold price logarithm (Fig. 6). However, according to the two rolling and recursive algorithms, there is no causality between FSI and LGP before 2013 and after 2018, although financial stress has been the source of Granger variations in gold prices in Iran from 2013 to 2018. According to rolling test results, there was a causality between FSI and LGP from September to December 2013, March to July 2014, October 2014 to March 2015, May 2016, August to November 2017, and January 2018.

According to recurrent test statistics, financial stress was the Granger-causality of fluctuations in gold prices from February to July 2014, November 2014 to March 2015, November 2016 to February 2017, and May 2017 to August 2018. The findings of the two most recent test statistics had a substantial overlap.

a) Forward



b) Rolling



c) Recursive

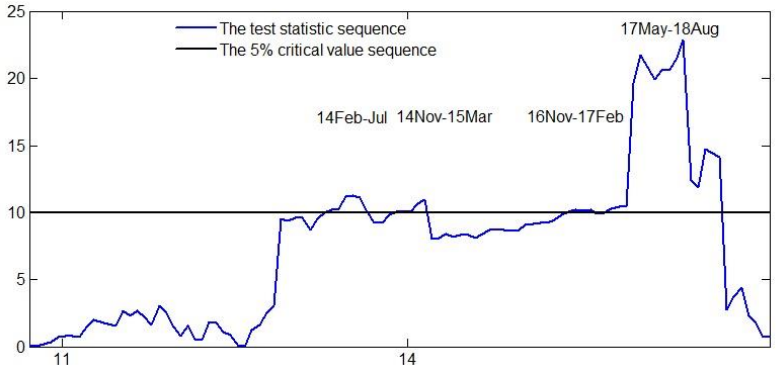


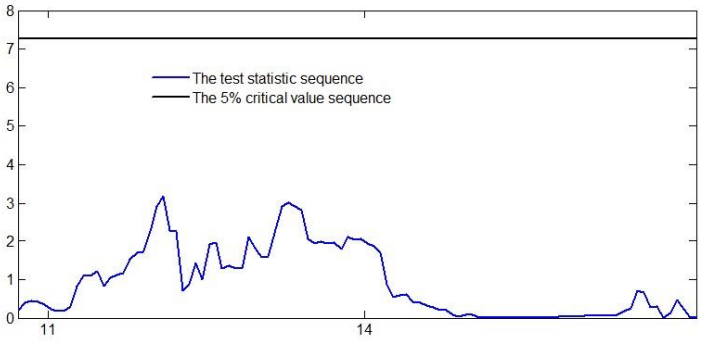
Figure 6. The results of the causality from FSI to LGP based on triple statistics of the time-varying Granger-causality test (with variance heterogeneity)

***Source*:** *Research Findings*

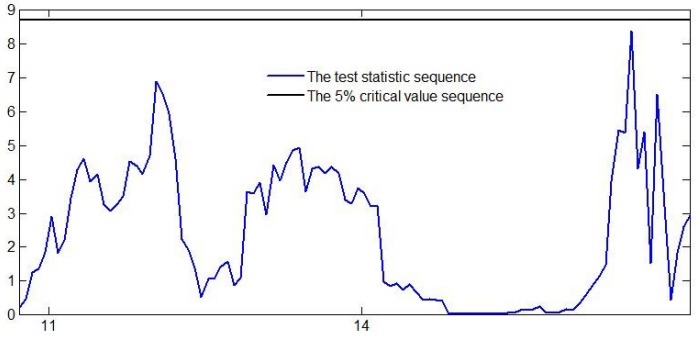
The findings of the causality from FSI to LSP based on triple statistics of the time-varying Granger-causality test are shown in Fig.7. As shown in Fig.7, there is no indication of causality from financial stress to the stock price index, according to forward and rolling algorithms. Only in June and August 2018, according to the recursive algorithm's findings, was there a causality from FSI to LSP.

As a result, financial stress was not the source of Granger variations in the stock price index over the research period. The findings from the investigation of FSI to LER causality were likewise quite comparable to the association between financial stress and stock prices.

a) Forward



b) Rolling



c) Recursive

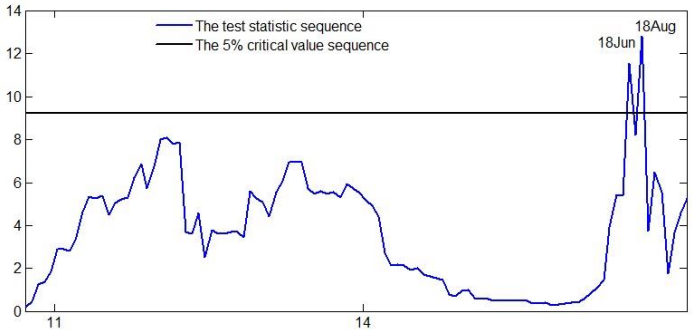
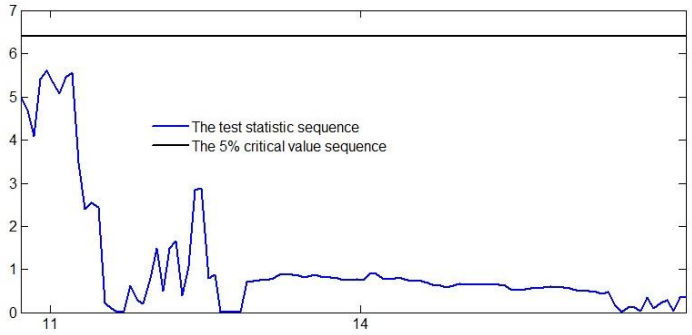


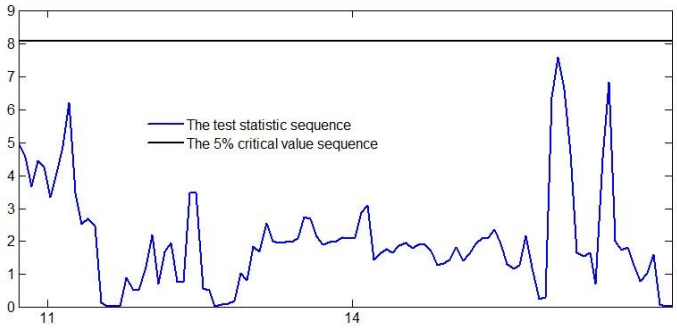
Figure 7. The results of the causality from FSI to LSP based on triple statistics of the time-varying Granger-causality test (with variance heterogeneity)
Source: *Research Findings*

Fig. 8 illustrates no indication of causality between financial stress and exchange rates based on forward and rolling statistics. According to the recursive algorithm's findings, the FSI was the Granger-causality variable of LER only from February to March 2018. As a result, it can be concluded that financial stress has no significant impact on currency rates in Iran.

a) Forward



b) Rolling



c) Recursive

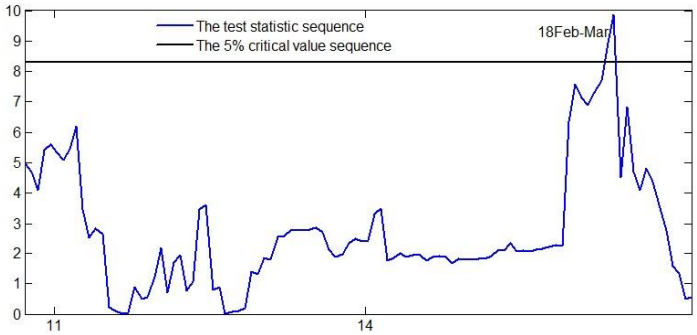


Figure 8. The results of the causality from FSI to LER based on triple statistics of the time-varying Granger-causality test (with variance heterogeneity)
***Source**: Research Findings*

As shown, the results of statistics with heterogeneity differ significantly from those of statistics without heterogeneity. Since the data utilized in the study are monthly, and the existence of variance heterogeneity in monthly data is stressed from an econometric standpoint, the findings of the statistics of the three tests with heterogeneity serve as the foundation for the research's overall conclusion.

The estimation results with variance heterogeneity and time-varying Granger-causality variable test used to investigate the relationship between financial stress and the stock market also revealed no evidence of causality between financial stress and the stock price index using forward and rolling algorithms.

The financial stress variable was the Granger-causality of the exchange rate algorithm only from February to March 2018, according to the results of the recursive algorithm. Therefore, there was no significant causality from the financial stress to the exchange rates. according to the two rolling and recursive

algorithms, there was no causality from the FSI to the LGP before 2013 and after 2018, but financial stress was the Granger-causality of the gold price shift in Iran from 2013 to 2018. These results are consistent with the findings of Reboredo & Uddin (2016) and Das et al. (2018), show that gold yield rises in reaction to quick stress in financial markets and that shareholders may limit their losses in a market downturn by allocating a portion of their portfolios to gold.

5. Concluding Remarks

This study aimed to investigate the Granger-causality relationship between the FSI and the financial markets in Iran during 2005- 2019. In this respect, this paper uses banking sector, equity market and foreign exchange market indicators in developing FSIs for Iran. The following three methodologies were employed from April 2005 to December 2019 to determine changes in the causality between financial stress and gold price variables, exchange rate, and stock market index. The methods employ subsample tests of Granger-causality inside a lag-augmented vector autoregressive framework and include a forward recursive algorithm, a rolling window algorithm, and a recursive evolving algorithm. In the development of recursive testing algorithms, bootstrap approaches are employed to manage family-wise size.

For the tests, a minimum window size of 60 months was employed. The system's maximum order of integration was assumed to be one, and critical values of 5% were utilized, simulated based on the bootstrap approach. The results of the estimation without variance heterogeneity revealed that the causality of financial stress to the price of gold was not evident in all three statistics before 2013 and after 2018. There is evidence of causality between financial stress and gold at other times; however, these periods were different based on the results of the three statistics, but the forward and recursive statistics were extremely consistent with each other.

Estimating the time-varying Granger-causality variable from financial stress to the stock market index revealed no causality during the study period based on the values of forward and rolling statistics and critical values of Bootstrap at a significance level of 5%. According to the findings of recursive test statistics, the causality from financial stress to the logarithm of stock prices was detected only from May to June 2012, and there was no such association in other months. Strong evidence of causality between financial stress and stock price index cannot be identified based on all three statistics.

According to the findings of all three test statistics, the time-varying Granger-causality test variable from financial stress to exchange rate likewise revealed only causality from financial stress to the LER in short periods. The findings of all three statistics for the association between these two variables overlapped at the start of the research period.

The estimations were made with variance heterogeneity due to the monthly nature of the data and the high likelihood of variance heterogeneity in time series based on the econometric literature. The results of this stage were considerably

different from the previous stage's results, which did not account for variance heterogeneity. The statistics reported by used in this step were proposed by Hurn et al. (2016). Critical bootstrap values were also employed here, with a significance threshold of 5% and a maximum system integration order of one assumed. A minimum window size of 60 views was required. Accordingly, there was no indication of a causal relationship between financial stress and the LGP using the forward algorithm. However, according to the two rolling and recursive algorithms, there was no causality from the FSI to the LGP before 2013 and after 2018, but financial stress was the Granger-causality of the gold price shift in Iran from 2013 to 2018.

The estimation results with variance heterogeneity and time-varying Granger-causality variable test used to investigate the relationship between financial stress and the stock market also revealed no evidence of causality between financial stress and the stock price index using forward and rolling algorithms. According to the recursive algorithm's findings, only in June and August 2018 did the FSI and the stock index algorithm have causality.

Consequently, financial stress does not the Granger-causality of the stock price index over the research period. The findings for investigating the causality from the FSI to the exchange rate algorithm were likewise highly correlated with those for the association between financial stress and stock prices. Thus, there was no causality between financial stress and exchange rates based on forward and rolling statistics.

The financial stress variable was the Granger-causality of the exchange rate algorithm only from February to March 2018, according to the results of the recursive algorithm. Therefore, there was no significant causality from the financial stress to the exchange rates in Iran. Hence, it can be argued that the financial stress index is the cause of fluctuations in the Iranian gold market, but not the Granger-causality of the currency and stock markets.

Therefore, given that financial stress can lead to financial crises, so planners and policymakers must have sufficient control over the creation of financial stress. Especially in the gold market, that result of the study showed the existence of a causal relationship between financial stress and this market.

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