Analysis of Dynamic Relations Amongst Oil and Gold Prices and TEPIX in Iran's Economy Using SVAR-Asymmetric-BEKK-GARCH Model

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ABSTRACT

Investigation of the evolutions of the stocks, gold, and oil markets in Iran shows clearly that prices of these assets have experienced abrupt fluctuations during the recent past. This indicates the great importance of investigating these fluctuations to see how they are transferred from one financial market to another. When it comes to economic policy setting, such an investigation serves as an efficient economic instrument for realizing increased production and employment, because a proper understanding of the mentioned price fluctuations in the markets contributes to setting appropriate controlling policies. Therefore, the present research investigates the relationship between fluctuations in the gold and oil markets as well as Iran's stock exchange market (SEM) during 2012 – 2022. Data analysis was performed by the SVAR-asymmetric-BEKK-GARCH model. Findings indicated a one-way relationship amongst fluctuations overflown across the considered variables.

Keywords: structural vector autoregression (VAR), asymmetric-BEKK-GARCH, Granger causality, fluctuation overflow.

1. Introduction

Following the financial liberation in the emerging economies, these countries started to receive significant flows of investment, which led to a very sharp increase in the stock market value and market cap in these countries. In the meantime, the emerging economies remained more vulnerable to global instabilities and uncertainties (Reza *et al.*, 2016). Sky-rocketing of the prices of strategic commodities like gold and oil can negatively affect macroeconomy of the emerging economies in a number of ways. An increase in the global price of oil rises average prices and hence inflation rate in oil-importing countries. The gold is usually seen as a protective shield against the inflation. Therefore, economic authorities in these countries seek to add to their gold stocks in response to increased inflation rates. An increase in the oil prices increases the income of the oil-exporting countries, and so is their demand for gold because of its low risk level. That is, a rise in the global oil prices increases the demand for gold at global scale, thereby boosting the gold price. In addition, since the start of electronic trading of the oil and electronic transactions in all markets for commodities in 2006, investors' demands for oil and other commodities have increased significantly. Investors have an extended list of options. They have held bonds and stocks or begun investing in the oil and other commodities trading funds (Akkoc and Civcir, 2019).

Economists and expert financial analysts search for the variables affecting the stock market to understand the market dynamics by means of econometric equations and market-related time series. Following the downturn of the global stock markets in October 1987, researchers concluded that financial markets exhibit a kind of contagiousness (Vardar *et al.*, 2018). Given that the commodities have become a capital asset, investors and other economic players seeking for proliferation of prices are interested in the interactions between the gold and oil prices and the commodity exchange market in the first place (Jain and Biswal, 2016). The first and probably the most important factor affecting the investors' decision-making in the stock market is the so-called stock price index (PI). Numerous factors affect the fundamental evolution of, market parties' views to, and price of incorporations listed on the stock exchange market (SEM). In order to make even better decisions, investors are in need for well-analyzed information from relevant and parallel markets. This indicates the need for clarifying the associations of these markets with the SEM for investment decision-makers to make them able to adopt the best strategies under different conditions. Among other markets, the crude oil and gold markets exhibit the strongest associations with the economic evolutions (Turksoy and Faisal, 2017). The PIX serves as a thermometer to the SEM. Accordingly, an increasing PIX indicates a bull market while a declining PIX characterizes a bear market. Macroeconomic variables affect or are at least related to the PIX in one way or another.

Oil price: Acknowledging the oil-dependency of the Iran's economy and the remarkable share of oil-generated revenues in the annual budget, any increase in the oil prices tends to induce a boom in industries, thereby increasing the profitability of listed companies on SEM, which is reflected as an increase in PIX (Zahedi *et al.*, 2013).

Gold price: The gold and gold coin have been seen as a safe alternative asset for investors in economically tough conditions. Under uncertain economic and political conditions, the capitals tend to outflow from the SEM toward the gold market (Smith, 2002).

Crude oil price index (COPI) is among the most important indices affecting the economic and political decisions made in virtually any country. As a powerful extrinsic variable, the COPI affects a wide spectrum of macroeconomic variables, including the PIX. Description of this association can guide the policy-making toward good monetary and foreign-exchange policies. The oil market is a primary merchant in the world, which usually takes lead when it comes to interaction with other markets. In fact, any change in the oil prices tends to evolve other markets, including the gold market and SEM. Most of the key factors affecting the oil prices are beyond the scope of the financial markets. Indeed, political positions of the oil-producing countries and the demand raised by giant consumers like China and USA impose the largest impacts on the global oil prices (Zarei, 2015). Global oil price affects the foreign exchange rates. For instance, an increase in the oil price pushes down the exchange rates of the currencies of the giant oil consumers. Global gold price is strongly affected by the global oil prices. According to existing economic theories, an increase in the oil prices tends to grow the global inflation rate, under which condition the investors start to modify their portfolio to increase the share of the asset exhibiting the highest tolerance to inflation. This leads to an increase in the demand for and hence price of the gold (Samadi *et al.*, 2009).

As a strategic commodity, the gold has been seen as a competitor and alternative to common currencies. It has well reserved its position as a value-storing asset in political and economic crises. In countries like Iran where advanced and active financial markets (*i.e.*, SEM) are missing and the national currency is constantly devalued by the inflation, people tend to save their assets in actual (non-productive) forms to protect them against the inflation. An actual asset with high liquidity is the gold (Omidi, 2014).

As strategic commodities with no alternatives, gold and oil have grabbed lots of attention in the recent past. In particular, these two commodities can increase global prices and economic uses (Ha LE and Chang. 2011). Given the mentioned introduction, the present study investigates the dynamic relationship between oil and gold prices and Tehran Securities Exchange (TSE) price index (TEPIX).

Research background and literature review

In some cases, existing literature can explain the positive association of oil price and stock prices. The stock prices are probably associated positively to the oil price. When global economy experiences a boom or a previous state of economic depression is improved, global demand for commodities increases, boosting the prices of mineral commodities like crude oil. In addition, if the SEM of a developing economy cooperates with SEMs of developed countries, this cooperation can amplify the results significantly. In oil-exporting companies, an increase in crude price is expected to positively affect the domestic SEM through its revenue and wealth generation impacts. This is a result of increased income for the government and leads to increased public expenditure in fundamental and ultimate projects (Alfayumi, 2009). Higher oil prices imply an immediate transfer of wealth from oil-importing parties to oil-exporting parties, with the size of this transfer depending on the way the oil-exporting countries spend such extra revenues. Should the generated revenue be spent on purchasing domestic goods and services, this extra revenue reinforces the economic activity and return on investment (ROI) of the capital market in the oil-exporting countries. Conversely, an increase in oil price can lead to some sort of agiotage, which probably adds to the stock returns. This positive relationship between the oil and stock prices is supported by Sadowrski (2001). Boier and Filion (2004) found a positive association between the energy stock returns and oil and gas prices. Hamoodeh and Lee (2005) drawn a similar conclusion, stipulating that a growth in oil prices tends to increase stock returns in oil-exporting countries and oil-sensitive industries in the US. Compiling three pieces of literature, Sahoo *et al.* (2012) concluded that a long-term relationship can be established between the crud oil prices and SEMs in India. This study indicated the presence of a long-term causal relationship from the Indian SEMs to the oil prices, with the results of the Granger test further confirming this indirect relationship.

In their study, Nadi Qomi and Farnian (2018) investigated the effects of oil price shocks on the ROI of Iranian SEM by means of Bayesian vector autoregression (BVAR). Their main objective was to explore the effect of the oil price shock on stock returns in Iran using a BVAR model and quarterly time series covering the 2001 – 2015 period. Comparing the impulse-response diagrams, it could be concluded that a shock in the oil market could significantly explain fluctuations in TEPIX, with the socks applied to the TEPIX damped over time. That is, the shorter the considered period, the stronger the effect of the oil price shocks.

Fotros and Hooshidari (2018) investigated the dynamic relations among the oil price, gold price, exchange rate, and TEPIX using the so-called DCC-MGARCH method. Results indicated that, throughout the time, the oil price returns, gold price returns, and currency exchange returns were conditionally correlated to the TEPIX returns.

Amiri and Pirdadeh Beiranvand (2019) investigated uncertainties associated with economic policies and Iranian SEM with a focus on the Markov's regime switching model. In this paper, effects of uncertainties of the economic policies on the stock returns were investigated by using linear and nonlinear (*i.e.*, Markov's switching) models during 1981 – 2016. Their findings highlighted that the presence of uncertainties in the economic policies tends to decline the stock returns. It was further figured out that the stock returns are affected by economic policy uncertainties through a nonlinear model, and that the uncertainties impose stronger and more consistent impacts on the stock returns in presence of stronger regime fluctuations.

Heidarzadeh and Farahani (2019) published a research where they investigated the effects of uncertainties associated with the oil price and foreign exchange rate on the stock returns using whitening linear transformations (WLT) and VAR. They covered the 2001 – 2012 period. Results of uncertainty modeling with the WLT indicated the presence of significant associations between the stock returns, on one hand, and oil price uncertainties and exchange rate uncertainties, on the other hand.

Safariani (2019) investigated the relationship between the exchange rate, oil price, stock prices, and gold price using the Markov's switching (MS) model. This research was aimed at evaluation of the relationships among exchange rate, OPEC's crude oil price, TEPIX, and gold price using a MS-VAR model, with the inflation rate used as a controlling variable. Data from Iran during spring 1991 – winter 2018 was considered. Results confirmed not only positive but also negative associations of exchange rate – gold, exchange rate – stock prices, and stock prices, oil price, with all of these associations being significant both statistically and economically. The explored associations were found to hold true in both regimes.

Hosseini (2019) elaborated on the cointegration of gold, oil, a stock markets and the impact of the exchange rate on these markets in the emerging economies. The required data was collected on a monthly basis for an 18-year period (2000 – 2018) in selected emerging economies (China, India, Russia, South Korea, Indonesia, Turkey, Iran, Poland, Hungary, South Africa, Australia, New Zeeland, Mexico, Chile, and Brazil). In order to realize the research objectives, an autoregressive model with distributed lags for panel data was used; the model included pooled mean group (PMG), mean group (MG), and dynamic fixed effect (DEF) estimators. The modeling results showed that, in the short run, the exchange rate and gold price impose negative impacts on the SEM while the oil price positively affects the SEM. In the long run, however, effects of the oil and gold prices on the SEM were evaluated as positive while that of the exchange rate was negative.

Altibi and Mishra (2015) investigated the overflow of the SEMs in US and Saudi Arabia into the SEMs in the Bahrain, Oman, Kuwait, Qatar, and UAE. For this purpose, they utilized bivariate BEKK-GARCH model. The used data were collected on a weekly basis covering January 1st, 2005 to May 31st, 2013. Findings indicated that the fluctuations were transferred from the US and Saudi Arabia to the markets in the mentioned countries.

Avri *et al.* (2015) presented a study where they devised CCC-GARCG, DCC-GARCH, BEKK-GARCH, and VAR-GARCH models to investigate the transfer of returns and fluctuations in between the global gold price and Chinese SEM during March 22nd, 2014 – March 31st, 2011. Results indicated evidences of two-way fluctuation transfers between the gold market and SEM. It was figured out that a previous sock in the gold market affects the shocks and fluctuations experienced in the SEM. They finally depicted the superior performance of the VAR-GARCH model compared to other multivariate GARCH schemes.

In their study, Jain and Biswal (2016) investigated the dynamic relationship among the oil and gold prices, exchange rate, and SEM in India using the DCC-GARCH model. Results showed that a decline of the gold and crude oil prices tends to devalue the Indian rupee and the Indian PIX. Their findings further suggested that the dynamic policy-setting in India is practiced to control the exchange rate and SEM fluctuations by means of oil and crude oil prices.

Bouri *et al.* (2017) investigated the nonlinear relationship (*i.e.*, correlation) among oil and gold prices and the Indian SEM using ARDL method. Results showed that the Indian PIX is positively affected by the oil and gold prices through a nonlinear relationship. The results further showed the presence of a two-way inverse association between the gold and oil price fluctuations.

Akkoc and Civcir (2019) performed a study where they considered the dynamic association between strategic commodities and the SEM in Turkey using the SVAR-DCC-GARCH model. Results indicated a flow from the gold and oil market toward the Turkish SEM. In the meantime, larger fluctuations were observed in the gold market and their impacts were stronger on the SEM rather than the oil market. This suggests that the gold cannot be seen as a safeguard against the risk of fluctuations. Authors concluded that Turkey needs proper dynamic macroeconomic policies to control eventual impacts following a global crisis.

El Bouri *et al.* (2021) studied the dynamicity of the overflown impacts on realized estimators of returns distribution in SEM, crude oil markets, and gold markets in the US. They used 5-min data covering April 11th, 2006 to April 29th, 2019 to calculate perceived daily fluctuations, perceived skewness, perceived elongation, and mutations. Overflow dynamicity was detected by time-variant parameter (TVP)-VAR model, indicating the evolution of overflows in different periods of crisis. According to the results, it seems that all overflows are intensified during the crisis periods.

Wali Mensi *et al.* (2022) investigated variable-frequency overflows and association of the US SEMs with gold and oil markets, not to mention the consequences of this association for the portfolio management. They reported that the overflow intensity declines when gold and oil assets are added to portfolio. In addition, the markets were found to be related through heterogeneous associations which are dependent on the time horizon and market conditions.

Research hypotheses

1) Brent oil overflow fluctuations affect the TEPIX.
2) Gold ounce price overflow fluctuations affect the TEPIX.
3) Brent oil overflow fluctuations affect the gold ounce price in Iran.
4) A one-way association exists between the Brent oil overflow fluctuations, on one hand, and gold ounce price and MES, on the other hand.
5) Shock transfers between variables occur in a weak or delayed manner.

Materials and research methodology

In this study, we used daily data of TEPIX, Brent oil price, and gold ounce price during 2012 – 2022. For the sake of analysis, we used the returns data. *i.e.*, the logarithmic difference between successive periods.

$$r_t = ln\frac{P_t}{P_{t-1}} \quad (1)$$

General equation for calculating the TEPIX is given below (Laspeyres Price Index):

$$TEPIX = \frac{Total\ present\ value\ of\ listed\ stocks}{Total\ reference\ value\ of\ listed\ stocks} \quad (2)$$

TEPIX is an arithmetic average over equally weighted market values of all listed companies. The value of TEPIX at time *t* can be obtained through the following equation:

$$TEPIX_t = \lambda\frac{\sum_{i=1}^{n} C_i P_{it}}{\sum_{i=1}^{n} C_i P_{ib}} \quad (3)$$

The parameter λ is a normalizer coefficient to ensure a TEPIX of 100 at the reference time. On the other hand, this coefficient further accounts for future changes in the listed companies or their stocks. C_i measures the number of stocks published by the i^{th} corporation, P_{it} is the stock price of the i^{th} corporation at time *t*, *b* is the base time (2011) and *a* is total number of stocks in the portfolio of the TEPIX. In general, the TEPIX has been designed in such a way to indicate price movements for the traded stocks (through the supply-demand mechanism) in the SEM (Raei and Pooyan Far, 2010).

Figure 1 shows the behavior of the used data throughout various years. Based on this figure, it is evident that the oil price has been relatively constant during the three first years, but then has declined since 2014 until 2020. Afterwards, however, the oil prices have followed a strictly increasing trend. When it comes to the gold ounce price, an initially decreasing trend is evident during the first five years of study, followed by an increasing trend since 2017. TEPIX has followed an almost exponential trend. Indeed, it has remained more or less constant at a minimum level during the first 7 years of this study, after when an increasing trend of TEPIX is observed.

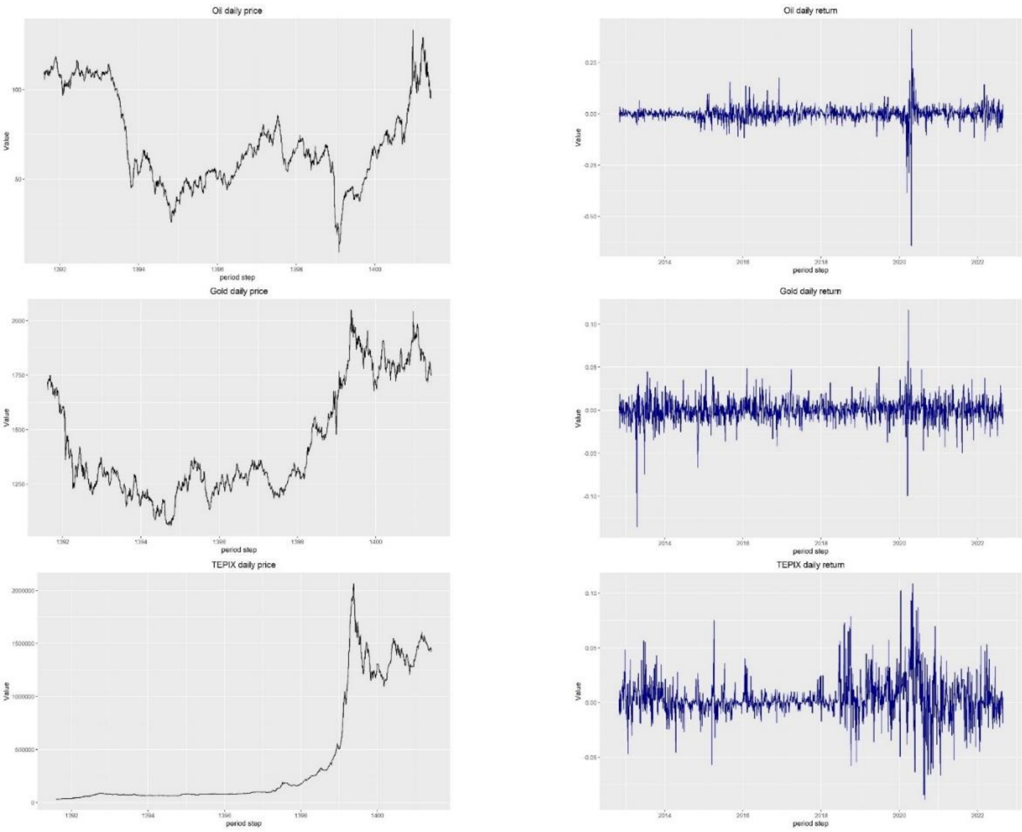

Figure 1. Diagrams of daily prices and returns.

Table 1 lists descriptive statistics on the returns of the studied variables. As seen, a total of 1359 periods (*i.e.*, 1359 days) were considered for each variable. Obtained values of standard deviation indicate that the Brent oil price has exhibited the largest fluctuations, as compared to the gold price and TEPIX. This is further evident on the returns diagram in Figure 1. Considering the negative skewness for the Brent oil and gold ounce price, these two variables are left-skewed while TEPIX exhibits right-skewness. On the other hand, all of the three variables exhibit elongations beyond the (-2, 2) interval, ruling out the normality of their returns.

According to the histograms depicted in Figure 2, elongation of the three variables indicate their non-normality.

Table 1. Descriptive statistics of the returns of the studied indices.

Statistic / Indices	Brent oil	Gold ounce	TEPIX
No. of observations	1359	1359	1359
Minimum	-0.6437	-0.13562	-0.08839
Maximum	0.41202	0.11632	0.10888
1st quadrant	-0.01351	-0.00594	-0.00372
3rd quadrant	0.01354	0.00596	0.0084
Mean	-0.00007	0.00002	0.00281
Median	0.00138	0	0.00089
Standard deviation	0.04047	0.01344	0.01788
Skewness	-2.91959	-0.62114	0.704
Elongation	64.33038	15.37622	6.16979

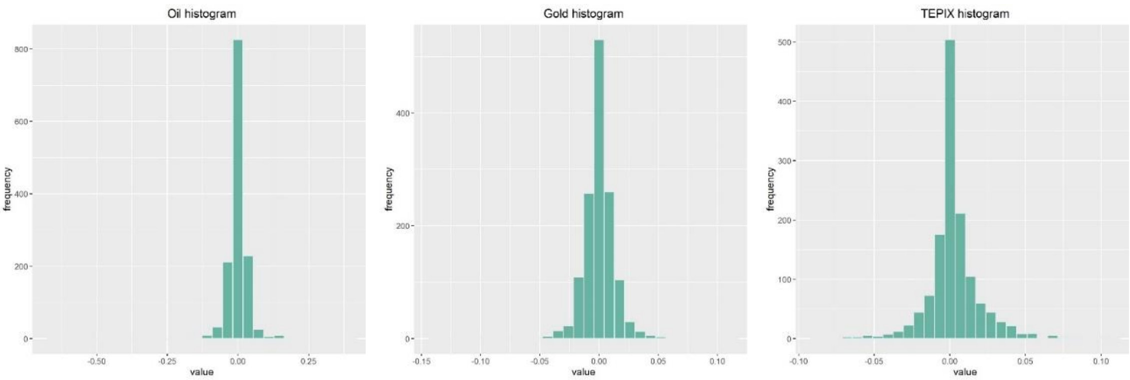

Figure 2. Histograms of the used data.

Vector autoregression (VAR) and structural VAR (SVAR) models

The VAR was first introduced by Sims (1986) for investigating dynamic interactions between associated time series data. A VAR model includes one equation for each variable, which explains the variable evolution with its particular lags as well as the lags of other variables, in such a way that all variables are symmetrically considered as intrinsic. The VAR model can be expressed as follows:

$$\boldsymbol{y}_t = A_1\boldsymbol{y}_{t-1} + \cdots + A_p\boldsymbol{y}_{t-p} + \boldsymbol{u}_t \tag{4}$$

in which $\boldsymbol{y}_t$ represents intrinsic variables, A_i $(i = 1, \dots, p)$ is the matrix of coefficients, and u_t is the residuals vector (white noise).

The VAR offers the unique advantage of investigating the intrinsic nature and interactions among multiple variables encountered in the form of time series data, although it cannot handle interactions among multiple variables in the current period and their intrinsic structure. In order to improve the VAR, Sims (1986) ignored the reducing effects of the variables in the current period to propose the SVAR model [1]. An SVAR model is defined as follows:

$$\boldsymbol{y}_t = A_1^*\boldsymbol{y}_{t-1} + \cdots + A_p^*\boldsymbol{y}_{t-p} + B\varepsilon_t \tag{5}$$

Here we assume that the structural errors (structural shocks vector), ε_t, are white noise and non-correlated. The matrix A_i^* $(i = 1, \dots, p)$ includes structural coefficients that represent instantaneous responses of shocks to $\boldsymbol{y}_t$ and are generally different from their reduced counterparts. B is a matrix that depicts the linear relationships between structural shocks and reduced counterparts.

To observe this, Equation (5) is multiplied by the inverse of A to come up with the following equations:

$$\boldsymbol{y}_t = A^{-1}A_1^*\boldsymbol{y}_{t-1} + \cdots + A^{-1}A_p^*\boldsymbol{y}_{t-p} + A^{-1}B\varepsilon_t$$
$$\boldsymbol{y}_t = A_1\boldsymbol{y}_{t-1} + \cdots + A_p\boldsymbol{y}_{t-p} + \boldsymbol{u}_t \tag{6}$$

An SVAR model can be used to detect shocks by applying constraints to matrices A and B. Eventually, although the SVAR model is a structural model in nature, it is obtained from a reduced VAR model into which some constraints for A and B are introduced. Noteworthily, reduced residuals of a SVAR model can be described as follows:

$$u_t = A^{-1}B\varepsilon_t \tag{7}$$

Indeed, the relationship between the structural shocks and reduced shocks can be expressed as $Au_t = B\varepsilon_t$. On the other hand, one can recover the corresponding variance-covariance in the form of $A^{-1}BB^T(A^{-1})^T$.

The SVAR is a VAR-based method into which various intrinsic variables in the economic system are introduced (Dangi and Pagan, 2009; Bala and Alhassan, 2017). It can demonstrate instantons structural relationships among variables in a system. The problem of parameter overflow in the VAR model can be effectively tackled by applying proper constraints. In addition, the SVAR provides for a greater explanatory power for the economic performance, making it widely accepted for the analysis of interactions among time-series data.

Structural shocks were identified by Cholesky decomposition of the variance-covariance matrix of residuals of the VAR model. In order to characterize Equation (7), one needs to apply particular constraints assuming that some structural shocks impose no simultaneous impacts on particular intrinsic variables. According to the Cholesky decomposition, matrices A and B are identified as a lower triangular matrix and a diagonal matrix, respectively (with k intrinsic variables, one may expect $k \times k$ matrices A and B). the main drawback of this method is that one must consider the order of variables. The Granger causality test was used to tackle this drawback [3].

Asymmetric-BEKK-GARCH model

In this study, the SVR-asymmetric-BEKK-GARCH approach was adopted for transmissibility study (intensity, direction, and symmetry) and identification of such concepts as priorities of the Brent oil price, gold price, and TEPIX. This model indicates not only the transmissibility, but also fluctuations and inter-variable interactions at shocks.

Experimental methodology is composed of three stages. First, multivariate SVAR was evaluated and residuals were obtained. Second, residuals of the SVAR model (ε_{it}) were normalized by being divided by conditional standard deviations of the tGARCH model for the corresponding variable ($\sigma_{i,t}$) (*i.e.*, the proper GARCH model is selected for each residuals vector based on the Akaike information criterion (AIC)), and the results were denoted by $\delta_{i,t}$:

$$\delta_{i,t} = \frac{\varepsilon_{i,t}}{\sigma_{it}} \tag{8}$$

In the present research, an asymmetric-BEKK-GARCH model was used to investigate overflow fluctuations among different variables, as explained in the following. Conditional average value can be expressed as below:

$$\boldsymbol{r}_t = \mu_t + \varphi\boldsymbol{r}_{t-1} + \boldsymbol{\epsilon}_t \tag{9}$$

where $\boldsymbol{r}_t$ is the vector of standardized residuals from the SVAR, μ_t is mean of fixed factors in the SVAR, φ ua the matrix of coefficients, and $\boldsymbol{\epsilon}_t$ is the residuals vector.

$$\boldsymbol{r}_t = \begin{pmatrix} \delta_t^{Oil} \\ \delta_t^{Gold} \\ \delta_t^{TPIX} \end{pmatrix}, \qquad \boldsymbol{\epsilon}_t = \begin{pmatrix} \epsilon_t^{Oil} \\ \epsilon_t^{Gold} \\ \epsilon_t^{TPIX} \end{pmatrix}$$

In order to study three intrinsic variables in this study, it was found that the multivariate asymmetric-BEKK-GARCH (1,1) model gives the best results. In this model, the error term in Equation (9) can be expressed as follows [2]:

$$\boldsymbol{\epsilon}_t = H_t^{\frac{1}{2}} z_t$$

where H_t is the conditional covariance matrix of errors and $z_t \sim N(0, I_k)$ takes the form of a d_{ii}. Croner and NG (1998) proposed a procedure for building the variance-covariance matrix. The following equation was devised to build the conditional covariance matrix for the studied variables in this work.

$$H_t = C'C + E'H_tE + D'\boldsymbol{\epsilon}'_{t-1}\boldsymbol{\epsilon}_{t-1}D + Q'\tau_{t-1}\tau'_{t-1}Q \tag{10}$$

$$C = \begin{pmatrix} c_{11} & c_{12} & c_{13} \\ 0 & c_{22} & c_{23} \\ 0 & 0 & c_{33} \end{pmatrix}, \quad D = \begin{pmatrix} d_{11} & d_{12} & d_{13} \\ d_{21} & d_{22} & d_{23} \\ d_{31} & d_{32} & d_{33} \end{pmatrix},$$

$$E = \begin{pmatrix} e_{11} & e_{12} & e_{13} \\ e_{21} & e_{22} & e_{23} \\ e_{31} & e_{32} & e_{33} \end{pmatrix}, \quad Q = \begin{pmatrix} q_{11} & q_{12} & q_{13} \\ q_{21} & q_{22} & q_{23} \\ q_{31} & q_{32} & q_{33} \end{pmatrix}.$$

where *C* is the lower triangular matrix of constants, indicating the direction of momentums and overflow of fluctuations among different variables in the matrices *D* and *E*. Regarding the diagonal and non-diagonal elements of the mentioned matrices, Kamg *et al*. (2011) stipulated that the diagonal elements of the matrix *D* are induced by the ARCH of the variables themselves. That is, significance of the d_{ii} s indicates that the conditional variances are affected by preceding square errors. Similarly, diagonal elements of the matrix *E* demonstrate their GARCH effects. In this case, significance of the variance with the lag e_{ii} shows that the current conditional variance is affected by the preceding conditional variance. Regarding the non-diagonal elements of the matrices *D* and *E*, the authors believed that these elements indicate how moments and fluctuations are transferred through the variables over time. For instance, the error terms d_{ij} indicate the direction of moments, while the covariance terms e_{ij} refer to the direction of fluctuation transfer. Focusing on the elements of the matrix *Q*, Majumder and Nag (2018) stipulated that the diagonal elements of this matrix denote the variable response to its previous negative shocks, while non-diagonal elements q_{ij} measure negative shocks of the variable *j* on the variable *i*.

In fact, Equation (10) relates the fluctuation overflows of the crude price, gold price, and SEM over time to error terms and preceding-periods conditional fluctuations. The error terms measure direct impacts of shock transfer while preceding-periods conditional fluctuations directly determine the risk transfer across markets.

Therefore, the asymmetric-BEKK-GARCH model was estimated and coefficients of transmissibility, fluctuation, and symmetry were obtained in a final stage.

Results and discussion

In order to properly express the SVAR model, we began by statistically refining the data. An important test for refining the model variables was the stationarity test or the unit root test. If the model variables are either non-stationary or have a unit root, the model assessment for stationarity will render problematic. According to Table 2, the results show that the generalized Dickey–Fuller stationary test on the model variables reject the hypothesis of the presence of a unit root, thereby confirming the stationarity of the considered variables. Results of ARCH effects test with the null hypothesis of the presence of such effects indicate the rejection of the null hypothesis, indicating the presence of heteroscedastic effects in the model for Brent oil price, gold price, and TEPIX as the model variables. These findings justify the use of the GARCH models for accomplishing the objectives of the present research. Indeed, in order to standardize the residuals of the SVAR model, we used the conditional variance, as applied in the GARCH model, for each variable (Equation 5). According to the Shapiro–Wilk test, the hypothesis of non-normality of the returns on Brent oil price, gold price, and TEPIX was confirmed, with the same conclusion previously drawn based on the values of standard deviation in Table 1 and histograms in Figure 2.

Once finished with an initial refinement of the intrinsic variables (Brent oil, gold ounce, and TEPIX) optimal lag selection for the VAR model was performed as the next step (Table 3). Results of non-normality assessment of the returns (Table 2) suggests the use of the Granger causality test. Considering non-normal distribution of error, the Granger causality test is used to identify constraints and adjust the introduction of variables into an SVAR model. The Granger causality test was applied by using a three-variable VAR model regardless of stationarity of the variables. Therefore, in order to express the VAR model, we obtained the optimal lag.

Table 2. Initial tests on returns on the studied indices at a significance threshold of 0.01.

Indices	Shapiro–Wilk		Generalized Dickey–Fuller		ARCH effects	
	Statistic	Significance	Statistic	Significance	Statistic	Significance
Oil	0.71	< 0.01	-9.4	< 0.01	221.91	< 0.01
Gold	0.89	< 0.01	-12.05	< 0.01	59.78	< 0.01
TEPIX	0.88	< 0.01	-8.49	< 0.01	207.49	< 0.01

Table 3. Optimal lag for VAR model.

Lags	AIC	Hannan-Quinn information criterion (HQIC)	Schwarz information criterion (SIC)
Optimal lag	8	7	1
1	-23.14	-23.12	-23.10
2	-23.15	-23.12	-23.07

Lags	AIC	Hannan-Quinn information criterion (HQIC)	Schwarz information criterion (SIC)
3	-23.19	-23.15	-23.07
4	-23.19	-23.13	-23.04
5	-23.20	-23.13	-23.02
6	-23.23	-23.14	-23.01
7	-23.25	-23.16	-23.00
8	-23.26	-23.15	-22.97

According to Table 3 and the number of observations in this study, optimal lag was set according to the minimum AIC (*i.e.*, 8). Now, VAR model fitting was practiced with a lag of 8 periods. This is done for two reasons:

1) Application of VAR model in the Granger causality test, and extraction of modeling residuals (u_t), and
2) Calculating the residuals for the SVAR model (ε_t).

According to the results of the Granger causality test (Table 4), the Brent oil imposes a one-way impact on the gold ounce and TEPIX. That is, the oil serves as a cause to both gold and TEPIX.

Table 4. Results of granger causality test at significance level of 5%.

Causality direction	Statistic	Degree of freedom (DoF)	Significance	Status
19.37	8	0.0130	19.37	Significant causality
45.89	8	< 0.01	45.89	Significant causality
15.19	8	0.0555	15.19	-
8.54	8	0.38	8.54	-
5.67	8	0.684	5.67	-
9.84	8	0.276	9.84	-

According to Table 4, the orders of considered variables (Brent oil, gold ounce, and TEPIX) and constraints in the matrices *A* and *B* were set as below, as per the Cholesky decomposition:

$$A = \begin{pmatrix} 1 & 0 & 0 \\ C(1) & 1 & 0 \\ C(2) & 0 & 1 \end{pmatrix}, \quad B = \begin{pmatrix} C(3) & 0 & 0 \\ 0 & C(4) & 0 \\ 0 & 0 & C(5) \end{pmatrix}$$

where the first row and column in both matrices refer to the intrinsic variable of the Brent oil, while the second and third rows and columns refer to the gold ounce and TEPIX, respectively – the order of variables are expressed then. The element a_{21} refers to simultaneous effect of the Brent oil on the gold, while the element a_{31} highlights the simultaneous effect of the Brent oil price on the TEPIX. Now, given the matrices *A* and *B*, the relationship between structural socks and reduced ones through the $Au_t = B\varepsilon_t$ can be expressed as follows:

$$\begin{pmatrix} 1 & 0 & 0 \\ C(1) & 1 & 0 \\ C(2) & 0 & 1 \end{pmatrix} \begin{pmatrix} u_t^{Oil} \\ u_t^{Gold} \\ u_t^{TPIX} \end{pmatrix} = \begin{pmatrix} C(3) & 0 & 0 \\ 0 & C(4) & 0 \\ 0 & 0 & C(5) \end{pmatrix} \begin{pmatrix} \varepsilon_t^{Oil} \\ \varepsilon_t^{Gold} \\ \varepsilon_t^{TPIX} \end{pmatrix} \quad (11)$$

In order to extract the SVAR residuals matrix and apply the constraints, Equation (11) was rewritten as follows:

$$\left[\begin{pmatrix} 1 & 0 & 0 \\ C(1) & 1 & 0 \\ C(2) & 0 & 1 \end{pmatrix} \begin{pmatrix} u_t^{Oil} \\ u_t^{Gold} \\ u_t^{TPIX} \end{pmatrix}\right]^T \begin{pmatrix} C(3) & 0 & 0 \\ 0 & C(4) & 0 \\ 0 & 0 & C(5) \end{pmatrix} = \begin{pmatrix} \varepsilon_t^{Oil} \\ \varepsilon_t^{Gold} \\ \varepsilon_t^{TPIX} \end{pmatrix} \quad (12)$$

Now we estimate the coefficients in matrices *A* and *B*. As reported in Table 5, all results were significant at a significance level of 0.05.

Table 5. Results of SVAR model.

Parameter	Coefficient of determination	Standard error	Statistic	Significance
$\boldsymbol{C(1)}$	-0.035943	0.009253	-3.88454	0.0001
$\boldsymbol{C(2)}$	-0.026214	0.011643	-2.25147	0.0244
$\boldsymbol{C(3)}$	0.039065	0.000752	51.98076	< 0.01
$\boldsymbol{C(4)}$	0.013286	0.000256	51.98076	< 0.01
$\boldsymbol{C(5)}$	0.016718	0.000322	51.98076	< 0.01

Therefore, applying a matrix multiplication in Equation (12), the SVAR system of equations is obtained as follows:

$$\varepsilon_t^{Oil} = \frac{1}{C(3)}\, u_t^{Oil}$$
$$\varepsilon_t^{Gold} = \frac{C(1)}{C(4)}\, u_t^{Oil} + \frac{1}{C(4)}\, u_t^{Gold} \quad (13)$$
$$\varepsilon_t^{TPIX} = \frac{C(2)}{C(5)}\, u_t^{Oil} + \frac{1}{C(5)}\, u_t^{TPIX}$$

Accordingly, calculating the (ε_t^{Oil} ε_t^{Gold} ε_t^{TPIX}), one can obtain SVAR residuals matrix to be used in the asymmetric BEKK-GARCH model. For this purpose, first, the conditional variances extracted by the TGARCH model with JSU (Johnson SU) distribution for the three variables (*i.e.*, returns on Brent oil, gold ounce, and TEPIX) were used to standardize the columns of the SVAR residuals matrix composed of three vectors (ε_t^{Oil} ε_t^{Gold} ε_t^{TPIX}), as per Equation (8). Next, standardized residuals are applied for compiling the asymmetric -BEKK-GARCH model. The coefficients extracted from this model at a significance level of 0.05 are listed in Table 6 (very small, near-zero significance levels are denoted by < 0.01).

According to Table 6, the ARCH effects (*e.g.*, transmissibility) for the Brent oil, gold ounce, and TEPIX on the diagonal of the matrix *D* were all significant. As expected considering the results of the Granger causality test, transmissibility of the Brent oil prices to the gold ounce and TEPIX was evaluated as significant. None of the other transmissibility coefficients rendered significant. According to the obtained levels of the GARCH effects or fluctuations, the elements on the main diagonal of the matrix *E* were all significant. The coefficients of fluctuations of the gold ounce to Brent oil and TEPIX and also those of TEPIX to Brent oil and gold ounce were significant. Regarding the coefficients indicated in Matrix *Q*, which is related to the shock effects, the coefficient on the main diagonal for the gold ounce (reflecting responsiveness of the gold ounce to negative shocks in previous periods) rendered significant, with all other coefficients ended up insignificant.

Table 6. Results of applying the BEKK model on standardized residuals of SVAR using conditional standard deviations from TGARCH model.

Parameters	Estimated coefficient	Standard error	Statistic	Significance
ARCH (1,1)	0.171	0.029	5.953	< 0.01
ARCH (1,2)	-0.194	-0.055	3.563	< 0.01
ARCH (1,3)	-0.112	-0.037	3.004	0.003
ARCH (2,1)	-0.011	-0.011	1.005	0.315
ARCH (2,2)	0.268	0.012	23.086	< 0.01
ARCH (2,3)	0.015	0.018	0.799	0.424
ARCH (3,1)	0.001	0.013	0.062	0.951
ARCH (3,2)	-0.022	-0.023	0.96	0.337
ARCH (3,3)	0.273	0.013	20.957	< 0.01
GARCH (1,1)	0.946	0.019	50.98	< 0.01
GARCH (1,2)	-0.026	-0.041	0.644	0.52
GARCH (1,3)	-0.058	-0.032	1.803	0.071
GARCH (2,1)	0.022	0.009	2.628	0.009
GARCH (2,2)	0.896	0.015	59.812	< 0.01
GARCH (2,3)	-0.031	-0.011	2.766	0.006
GARCH (3,1)	0.027	0.008	3.422	0.001
GARCH (3,2)	0.032	0.015	2.119	0.034
GARCH (3,3)	0.919	0.009	98.179	< 0.01
Asymmetry (1,1)	0	0.182	0	1
Asymmetry (1,2)	-0.128	-0.342	0.374	0.709
Asymmetry (1,3)	0.095	0.173	0.549	0.583
Asymmetry (2,1)	-0.007	-0.035	0.209	0.834
Asymmetry (2,2)	0.214	0.074	2.91	0.004
Asymmetry (2,3)	0.002	0.05	0.046	0.963
Asymmetry (3,1)	-0.001	-0.071	0.01	0.992
Asymmetry (3,2)	-0.014	-0.121	0.113	0.91
Asymmetry (3,3)	0.137	0.139	0.987	0.324

Conclusion

Dynamic correlation means all the events that happened in the period under review and each of them affected the correlation of oil price, coin or stock market. For example, the political situation and issues, Iraq's attack on Kuwait, the two wars that happened in Iraq, the economic crisis in Southeast Asia, the boom in the housing market, the American terrorist attack, China's economic growth, the global financial crisis, economic sanctions, etc. Each of them has affected the total demand side and the supply side of each of these variables, they have caused a change in the correlation between the variables. The stock market has not yet been able to gain its rightful place in Iran's economy and is facing various challenges. In any case, knowing more about the behavior of this market in Iran can be useful for investors and policy makers in this area. be useful in this regard, explaining the behavior of the stock price index is of particular importance. Many applied studies in developed markets show that stock returns fluctuate with changes in macroeconomic variables, therefore, it is expected that the total stock index has a strong relationship with macroeconomic variables.

The reason for this can be that the real value of the shares depends on the present value of the profit and the yield of the share, which is also distributed in such a way that it is separate from the performance of the company (because the factor of discounting the value of the shares is determined outside the company) Therefore, these profits and values are influenced by the real economic activities, therefore, there must be a connection between the fundamental economic factors and stock prices. Also, due to the large amount of export income and the government's annual budget from oil exports, Investigating the effect of oil market shocks on Iran's economy is of particular importance, so that global oil market shocks can have a great impact on the entire structure of Iran's economy. Financial markets are among the most important arenas affecting national economies. Securities exchange markets (SEMs) represent a key element of financial markets. Identification of the factors affecting this market can greatly help investors orient their capitals. Investigation of evolutions of the SEM alongside gold and oil markets in Iran shows it clearly that the prices of these assets have experienced abrupt fluctuations in the recent past. This indicates the great importance of investigating these fluctuations to see how they are transferred from one financial market to another. When it comes to economic policy setting, such an investigation serves as an efficient economic instrument for realizing increased production and employment, because a proper understanding of the mentioned price fluctuations in the markets contributes to setting appropriate controlling policies. Therefore, the present research investigates the relationship among these fluctuations and their transmissibility across markets for Brent oil, gold ounce, and TSE.

In order to investigate the relationship across the mentioned markets, in this study, we used SVAR-asymmetric-BEKK-GARCH model. Granger casualty test, which considered abnormal distribution of errors, was used to characterize the model and report causal relations.

First, the causal association of the Brent oil price, gold ounce price, and TEPIX was evaluated by the Granger casualty test. According to the results, the Brent oil price fluctuations were found to serve as a cause to fluctuations in the gold price and TEPIX. Given the causal associations across the intrinsic variables, constraints were applied to the SVAR model.

Table 6 reports the results of incorporating the standardized residuals of the SVAR model into the asymmetric-BEKK-GARCH model. Indeed, Table 6 demonstrates the shock transfer across the markets for the Brent oil, gold, and TEPIX. Previous shocks in the Brent oil price were found to affect the current fluctuations in this variable (ARCH (1,1)). On the other hand, stationarity of fluctuations is evident in this market, as GARCH (1,1) was larger than ARCH (1,1). The shock transfer from the Brent oil price to the gold ounce was also evident, although the value of ARCH (1, 2) (*i.e.*, -0.194) indicates that the transmissibility is not so strong. Regarding the fluctuation transfer, the GARCH (1,2) rendered insignificant. Indeed, shock transfer from the Brent oil to TEPIX was evidently significant but the obtained value of ARCH (1,3) (*i.e.*, -0.112) implied that the transfer was not strong. Previous shocks in the gold price were found to affect its current fluctuations (ARCH (2,2)). On the other hand, stationarity of fluctuations is evident in this market, as GARCH (2,2) was larger than ARCH (2,2). Previous shocks in the TEPIX were found to affect its current fluctuations (ARCH (3,3)). On the other hand, stationarity of fluctuations is evident in this market, as GARCH (3,3) was larger than ARCH (3,3). The shock transfer across the markets was found to be one-way in nature, *i.e.*, from the Brent oil toward the gold ounce and TEPIX. The opposite was found when it came to fluctuations. Indeed, the transmission of fluctuations from the gold ounce to the Brent oil (GARCH (2,1)) was evident at 0.022, which is albeit not remarkable. Transmission of fluctuations from the gold ounce to TEPIX (GARCH (2,3)) was significant at -0.31, which is again negligible or delayed due to the small transmissibility ratio. Similar findings were obtained for transmission of fluctuations from TEPIX to the Brent oil and gold ounce, although the transmission from the TEPIX exhibited a higher correlation coefficient than that

from the gold ounce. We therefore obtained fluctuation overflows across the variables. In conclusion, interactions across the studied markets were either weak or delayed, indicating poor correlations in between them. Finally, one can formulate proper policies for financial markets and investment activities based on the findings of this research.
Acknowledging the findings of this research, the followings are recommended:

1) The presence of securities exchange markets (SEMs) is a crucial necessity for successful economic activities in different countries. By accumulating available capitals and optimizing their allocation, a SEM can increase production and contribute to realization of socioeconomic development objectives. Accordingly, indices of the SEM in an economy reflect the economic performance of the country. Therefore, strengthening the SEM and expanding the culture of investing on intangible assets through mid-term and long-term profitability, one can attract and guide otherwise unleashed capitals. This can provide the required foundations for economic growth by attenuating the motivations toward agiotage and investment in non-productive sectors.
2) Acknowledging the inflation-dominated environment of Iran, on one hand, and the economic depression occurred in the recent past, on the other hand, the Central Bank of Iran (CBI) is recommended to set policies to lower the money stock by issuing bonds, selling gold coins and houses through preorders, etc.
3) Guiding the money stock toward productive firms by motivating people toward investing in the capital market. The government can adopt proper planning and introduce promising potentials and opportunities in the capital market to guide the available money stock toward the TSE.
4) It is recommended to keep the oil revenues out of the annual budget and economy of the country as a whole. In this way, fluctuations in the oil prices can no longer hit essential markets, like housing, strongly. With the oil being a non-renewable resource, strong dependence of national economy on the temporary oil revenues may end up with irrecoverable damages to the national economy, especially the capital market, should this fossil resource come to an end someday.
5) In order to explain the behavior and fluctuations of different assets, one should consider not only economic factors, but also political factors such as economic sanctions.
6) Building on the public trust in capital market by, for example, reducing governmental interventions into the TSE, monitoring the transactions (especially those committed by legal persons) by the TSE regulator to ensure the ruling out of fake transactions, implementation of modern up-to-date regulations involving, for example, increased leverage ratios, harmony in policy-setting and avoiding contradictory policies, and guaranteeing the profitability of IPOs of public companies for 6 – 9 months at a minimum interest rate of 18%.
7) It is recommended to keep the oil revenues out of the annual budget and economy of the country as a whole. In this way, fluctuations in the oil prices can no longer hit essential markets, like housing, strongly. With the oil being a non-renewable resource, strong dependence of national economy on the temporary oil revenues may end up with irrecoverable damages to the national economy, especially the capital market, should this fossil resource come to an end someday.
8) In order to control the gold market and encourage people to invest in the capital market, it is recommended to adopt proper solutions to increase the investment security in production sectors and TSE.

Researchers are recommended to do studies on the following topics:

1) Considering developing and developed countries separately and comparing their results to one another and to the Iranian economy as well.
2) Investigation of other important markets like the housing market, cryptocurrency market, and automotive market.
3) Application of novel Bayesian methods and artificial intelligence to forecast the returns in different markets.

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