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Modeling Energy and Steel Price Volatility and Experimental Test of Inter-Market Volatility Spillover: A Multivariate Study Using VECM and GARCH Models

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ABSTRACT

The spread of volatility between financial indices indicates the process of information transfer between markets. Despite the relationship between financial markets, the information created in one market can affect other markets as well. Therefore, the main purpose of this study is to investigate the volatility of energy and steel prices and the experimental test of inter-market volatility spillover. To do this, the monthly data of steel and energy price (oil and gas) during 2009 to 2019 were collected from valid databank using VECM and GARCH Family and VAR model and ICSS algorithm were analyzed by considering and without considering structural failure. Then, the causal relationship between them is examined through Granger causality test. The results show that there is volatility in the energy market (oil and gas) as well as the steel market during the studied time period. Results also show that the price of steel as well as its return and index are changed significantly by energy price effect. However, there is a causal link between energy prices and steel products and these results are consistent with the theoretical basics of the study and review of literature.

1 Introduction

The expansion of the globalization process has made the financial markets of different countries more and more affected by each other. However, increasing the dynamics of communication between financial markets can be seen as a volatility factor in each market, because volatility in one market can spread to other financial markets. For example, the 2008 financial crisis, which began in the US mortgage market, spread to most of the world's financial markets and caused a deep recession in many countries [41]. Therefore, due to the importance of this issue, many researchers have studied the relationship between financial markets ((Hosseini and Ebrahimi [3], Fallahi et al 3 and Moghaddam and Sezavar [45]). When there is a shock in a financial market, fluctuations in the market cause investors to revise and change their portfolio, which causes market turmoil and the transfer of fluctuations and shocks to another market. Understanding the chronological relationship between markets is very important for stakeholders and policymakers. Volatility in markets affects the behavior of stakeholders and directly

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affects the performance of the overall economy. Gaining sufficient knowledge of market behavior and fluctuations and their volatilities and the causes and factors causing volatility and inter-market fluctuations' spillovers can, in addition to developing the range of relevant theories, lead to the presentation of practical results for actors in these markets. For this purpose, the present study was conducted with the aim of providing a model of the relationship between energy and steel markets and analysis of fluctuations in these markets. In the following, after examining the research literature and background, the research importance and necessity are examined. Then, the research objectives and questions are stated and research hypotheses are expressed. Research method, data collection and analysis tools, the scope and statistical population of the research are also addressed in separate paragraphs.

2 Theoretical Basics and Review of Research

Financial markets are strongly influenced by environmental factors, and policymakers seek to create a relatively stable market so that investors are not incurred losses or their confidence in the market is not reduced by sudden and drastic changes. With a stable financial system, markets are functioning properly, key institutions are operating smoothly, and asset prices are not significantly different from their core value. Such a situation is vital for an economy that wants to achieve the goals of sustainable growth and low inflation. Thus, a sustainable system is flexible and able to withstand normal fluctuations in asset prices due to dynamic supply and demand conditions and increased uncertainty [28]. Financial instability can lead to financial stress. Financial distress is a condition that leads to the inability of financial institutions to meet their obligations and the loss of the ability to allocate financial resources [8]. Given that the spread of financial stress is typically through increasing financial imbalances due to economic turmoil [6], if they become too long, it will become difficult for the economy and financial markets to return to normal conditions [25]. Recent global financial crises indicate numerous weaknesses in financial systems. One of the most important lessons of these crises is that financial system monitors and decision makers do not have the tools to identify the process of stress increase and measure it in a timely manner. Another problem is that even when they are aware of the formation process, they do not have the tools to allow them to intervene quickly [23].

Thus, the main concern about financial stress is how it affects economic activities and how policymakers can mitigate the economic consequences and prevent similar events in the future [8]. Every shock experienced in one market affects other markets as well. This has focused researchers on understanding how shocks and fluctuation spillovers are transferred from one market to another [2]. In recent years, various studies have addressed the issue of the spread of fluctuations in financial markets, but there are a limited number of studies related to the study area, some of which are mentioned [32]. Have examined the spillover of fluctuations between oil prices, exchange rates, gold prices and the stock market at intervals and structural failure using the GARCH (BEKK) model and the ICSS algorithm. The results of their research showed that if the calculation of structural failure in the equations is omitted, exchange rate changes have no effect on oil prices, but have a significant effect on gold prices and stock indices. On the other hand, changes in the price of gold can affect the stock index and stock changes can also affect the exchange rate. But when structural failure is used in the equations, the results will be different. Examined the relationship between oil prices, gold prices, exchange rates and stock returns and showed that gold prices are not affected by oil prices, exchange rates and stock markets, while the opposite is true [40]. Used univariate and bivariate GARCH models to investigate the instability of structural failures in future oil and gold prices. Their results showed that there is a significant transfer of volatility between gold and oil returns [17]. They (ibid.) used generalized conditional bivariate heteroscedasticity model to examine price fluctuations in future gold and oil markets for structural failures. They showed that the direct transfer of fluctuations between gold and oil returns is when considering structural failures in variance.

2.1 Transmission of Financial Indices' Volatility

Financial time series and volatility of returns in financial markets have prominent features. For example, the distribution of returns in them has a fat tail, cluster volatility, asymmetry, mean reversion and volatile movement between assets and financial markets. Due to the fact that time series volatility has a complex structure, different estimates vary based on the current volatility rate, volatile structure (stability, mean reversion, etc.), and the forecast time horizon [33]. Shocks may have an asymmetric effect on volatility. Conditional volatility models usually assume that assets are affected by both positive and negative shocks. As for stock returns, the impact of negative and positive shocks on volatility may be different. It has often been observed that negative price shocks have a greater effect on volatility than similar but positive shocks [14]. Volatility can also be affected by exogenous variables. Most volatility assessment models assume that turbulence depends only on information contained in previous values of the time series of its return. However, other variables may have information for the volatility of a return. Various studies have been conducted to find other factors that can affect volatility. These factors can include corporate news, macroeconomic news, or calendar effects [14].

2.2 Review of Research Background

Yoon et al. [41] used the analysis of variance to measure the dynamics of relationships in different markets such as crude oil, stocks, gold, currency and bonds between December 1999 and June 2016. The results showed that in the financial crisis of 2008, the dynamics of market communication reached its highest level. Also, gold can be selected as a good option to cover the risk of investment portfolios due to its low connection with other markets. Finally, they showed that the US stock market is the most important sender of shock to the markets. Al-Yahyaee et al. [1] analyzed the dynamic returns and risk spillovers between commodity futures (energy and precious metals) and the GCC stock markets from 2005 to 2016. Using dynamic correlation models and analysis of variance, they realized the existence of significant spillovers of returns and risk between commodities and the GCC, especially at the beginning of the global financial crisis 2008-2009. In addition, silver, platinum and energy futures transfer returns to the stock market. Precious metals (except silver) and WTI are the net transmitter of risk to the GCC markets. Moreover, portfolio management analysis shows that the combination of commodities and GCC stocks provides diversification opportunities for different periods of crisis. Finally, precious metals markets in all GCC markets have a high protection effect on energy markets. Fasanya and Akinbowale [19] examined the dynamics of volatilities and communication return between the crude oil market and agricultural commodities in Nigeria using the variance decomposition approach from 1997 to 2017. They showed that there is a two-way relationship between these markets.

Husain et al. [24] used the Dibold and Ilmaz model to examine the dynamics of crude oil prices and the stock index and metal prices for the US economy from 1990 to 2017. Research has shown that palladium, gold, platinum and silver cause shock, while crude oil, titanium and steel are shock absorbers. These connections have been measured in the context of economic crises, including the global financial market 2008-2009 and the European crisis period 2010-2012, and in these periods the level of communication has reached the highest value. Ono [31] examined revenues from oil exports versus revenues from non-oil exports. The result of this study showed that countries that have bettered liberalization of their oil sectors in growing their current account balances have been more successful. A stronger current account indicates a stronger ability of the currency for the country concerned. Excessive reliance on oil also exacerbates macroeconomic fluctuations, and for OPEC countries such as Gabon, Ecuador, and Libya, which have the lowest oil export revenues and are, of course, subject to OPEC quotas, do not have much influence on OPEC decisions. Due to the wide gap in the capacity of oil revenues, Saudi Arabia needs to cover individual economies from the impact of oil price instability by creating a suitable basis for economic diversification. Lack of diversification of the economy away from oil is risky, given that oil, in addition to being a worn-out resource, also has an unstable price pattern.

Lee et al. [30] examined the relationship between oil price shocks and country risk using the SVAR approach on industrialized countries (G-7) from January 1994 to December 2014. The results of the study indicated that national risk is significantly affected by fluctuations in oil price shocks. Accordingly, an unforeseen positive oil price shock reduces the country's risk index in Group Y countries. Chen et al. [9] have studied the effects of OPEC policy on global crude oil prices that have caused widespread concern and the analysis of its effects is very important in investment decisions and risk aversion in crude oil markets. The results of their study showed that the political risk of OPEC countries had a positive and significant effect on crude oil prices during the period from January 1998 to September 2014. Dasgupta and Roy [10] studied the energy industry in India by expanding the model of Roy et al. [34] and concluded that these industries experienced technical progress between 1973 and 2012 with a reduction in the share of energy costs (energy savings). Rising energy prices lead to reduced energy demand and accumulated technical advances in most industries. Energy and raw materials are substitutes. Energy efficiency growth is driven by energy prices as well as technical advances. In a study, Giuliodori and Rodriguez [13] examined and analyzed the stainless steel market in the EU, China and the United States using the Co-Integration and VECM models. This analysis seeks to determine two aspects related to pricing in the stainless steel market. First, it seeks to determine whether China is currently the world's largest producer of stainless steel in terms of price. Given the first question, they secondly wanted to understand whether the European market is simply a component of the global stainless steel market, and without significant pricing power, this study mainly concludes that European stainless steelmakers follow prices and the volume of imports to Europe is affected by long-term relative price relations. Ewing and Malik [17] used the generalized conditional bivariate heteroscedasticity model to examine price fluctuations in gold and oil futures considering structural failures. They found that there is a direct transfer of fluctuations between gold and oil revenues when considering structural failures in variance [37]. Jointly concluded that there is a significant long-run relationship between capital market indices and oil prices [35]. rejected the claim that oil price shocks have a significant effect on market returns.

Gholami et al. [21] designed a network to measure the dynamics of the relationship between oil volatilities and financial markets. In this study, financial information from 2007 to 2019 in the form of networks with different time horizons with weekly frequency has been used. The results show that in all time horizons of variance, the prediction error of most markets is due to the shocks of those markets. The Saudi Stock Exchange has the most impact on other Middle Eastern stock exchanges. The dynamics of oil market relations with each other is significant. However, with increasing time horizon, the relations between these two markets decrease and are affected by other markets, especially the Middle East stock exchanges except Iran. The dynamics of gold market relations with other markets are not significant. Therefore, it can be used as a tool to cover risk. Heidari et al. [22] investigated the effect of oil price fluctuations on the country risk index in OPEC member countries in different economic regimes using monthly data for the period 2002-2015. The results of this study show that oil price fluctuations have different effects on the country risk index of OPEC members in different regimes, so that oil price fluctuations have a positive effect on the country risk index of the UAE and Kuwait, a negative impact on Qatar, Nigeria, Libya and Algeria, and asymmetric effects on Angola, Iraq, Saudi Arabia and Venezuela. In addition, the results of the study show that among OPEC member countries, oil price fluctuations had the most positive effect in the UAE, Iraq, Ecuador, Saudi Arabia and Angola, respectively, and the least positive effect of oil price fluctuations was observed in Kuwait and Venezuela, respectively. Also, the least negative impact of oil price fluctuations on the country risk index was observed in Iran and Iraq and the most negative impact was for Qatar. Therefore, it is recommended that planners, investors and other institutions pay attention to the country risk of OPEC member countries and the impact of oil price fluctuations before investing.

Botshekan et al. [7] investigated the dynamic conditional correlation and fluctuation spillover between the gold, oil and housing markets on the stock exchange using four multivariate GARCH models in a twelve-year period (from the 2005 to 2016). The results of this study confirmed the spillover of fluctuations between the stock exchange with the foreign exchange market, gold market and oil market. However, the spillover of fluctuations between the stock exchange and the housing market is not confirmed. In addition, the positive correlation between the return of the stock market index and the return of the dollar exchange rate and the rate of return on housing is confirmed in a positive way. Bordbar and Heidari [5] conducted an experimental study of the relationship between oil price fluctuations and stock returns of basic metals industries, petroleum and chemical products using vector Auto regression (VAR) models and multivariate conditional heteroscedasticity (MGARCH) over April 2004 to March 2014. The results show that there are average effects between the oil market and the stock market of basic metals and petroleum products, but these effects do not apply to the stock market of the chemical industry. There is no effect of fluctuations between the two world prices of oil and chemical industries and basic metals. There is a significant negative relationship between fluctuations in the oil market and fluctuations in the return on stocks of petroleum products. As a result, investors should reduce the dependence of their portfolio on oil prices as much as possible. Mamipour and Feli [27] investigated the effects of spillover of oil price fluctuations on the return of stocks of selected industries (37 industries) in the Tehran Stock Exchange during the period December 2008 to April 2016 with a weekly frequency using the analysis of variance presented by [11]. In the framework of the generalized vector Auto regression model. In this study, first the periods of recession and boom with different fluctuations in the oil market were separated using the Markov switching model and then the effects of spillover of market fluctuations for periods of high and low volatilities in the stock market. The results of estimation obtained from the analysis of variance model showed that more than 90% of the variance of the forecasting error of both markets (oil and stocks) in both low volatility regimes (regime zero) and high volatility (regime one) is due to market shocks and there is no spillover effect among markets. The results show that in general, the effects of volatility spillover from the oil market to the stock market in the low volatile regime compared to the high volatile regime are less in most industries and fluctuations spillover in the high volatile regime occur at a wider level. The results also show that the highest amount of spillover belongs to volatility spillover from the oil market to the index of basic metals industry and chemical industries, publications and printing, cement, non-metallic minerals, communication equipment and rubber in regime zero and metal, technical and mineral industries, engineering, paper products, petroleum products, other mines and mining are in the next order in regime one, respectively. Sefidbakht and Ranjbar [32] studied fluctuations' spillover between oil prices, exchange rates, gold prices and the stock market under time intervals and structural failure using the GARCH model (BEKK) and ICSS algorithm. They found that if structural failure is ignored, exchange rate changes have no effect on oil prices but have a significant effect on gold prices and stock index. On the other hand, changes in the price of gold can affect the stock index, and changes in stocks can also affect the exchange rate. But when structural failure is used in equations, the results will be different.

Fetri and Hoshidari [20] examined the relationship between the fluctuations of crude oil price returns and the fluctuations of stock market index returns using a multivariate GARCH model and monthly data during the period May 2001 to March 2016 and BEKK model. It was found that there is a negative and significant relationship between these variables. Lee et al. [30] in a study investigated the relationship between oil price shocks and national risk using the SVAR approach on industrialized countries (G-7) from January 1994 to December 2014. The results of their research showed that national risk is significantly affected by fluctuations in oil price shocks. Accordingly, an unforeseen positive oil price shock reduces the country's risk index in other countries. Giuliodori, Rodriguez [13] in a study examined and analyzed the stainless steel market in Europe, China and the United States. The results show that European stainless steel producers follow prices and the imports volume to Europe is affected by long-term relative price relations. Other studies on the relationship between energy and steel prices include research by Hussein et al [24] and Ewing and Malik [17]. Also, Luo and Shengquan [42] used the MHAR-DCC model to investigate the frequent volatilities spillover in stock returns in international stock markets.

3 Research Hypotheses

Based on the theoretical foundations and research backgrounds, the energy market (oil and gas) in the world has experienced many fluctuations affected by political factors and economic shocks. Also, world steel price is also volatile by exchange rate fluctuations, gold and oil prices, and other factor. The transfer of shocks and fluctuations from one market to other markets and the volatilities spillover between markets has been observed frequently. Based on this issue, the hypotheses of this research are formulated as follows:

Hypothesis 1: The energy market is volatile during the study period.

Hypothesis 2: Steel prices fluctuate during the period under study.

Hypothesis 3: There is a significant relationship between energy prices (oil and gas) and steel prices.

Hypothesis 4: There is a causal relationship between energy prices (oil and gas) and steel prices.

Hypothesis 5: There is a causal relationship between energy prices (oil and gas) and steel index and returns.

Hypothesis 6: Energy market (oil and gas) volatility spreads to steel index and return.

4 Research Methodology

The present study is a descriptive correlational research. It is also considered as applied research due to the possibility of using its results. In this study, monthly data on steel and energy prices (oil and gas) and the index and returns of the steel industry of the Tehran Stock Exchange during the period 2009 to 2019 have been used. The volatility of each of markets and fluctuations' spillover between them were examined using VECM, bivariate GARCH models, the diagonal BEKK model, and Granger causality test. In order to test the research hypotheses, the stationary of data is first examined using Dickey-Fuller and Phillips Peron tests. Then, the structural failure points was determined by ICSS algorithm and, the effect of fluctuation spillovers was examined once without structural failure and again with structural failure using bivariate GARCH test. VAR and Granger causality tests were used to examine the causal relationship between variables. The reason for using the GARCH model is that this model has the ability to model the variability of two variables at the same time and specify the effect that these two variables have on each other. Also, the VAR model is used for determining the responses that each variable may show to the shocks that occur with the change of standard deviation Ranjbar and Sefidbakht[32]. The BEKK-GARCH model is explained as follows:

$$H_{t-1} = \acute{C}C + \acute{B}H_tB + \acute{A}\varepsilon_t\acute{\varepsilon}_tA$$

For this bivariate model, C is a 2 × 2 triangular matrix with three parameters and B is a 2 × 2 square matrix that relates the existing levels of conditional variances to previous conditional variances. A is a 2 × 2 matrix parameter that measures how conditional variances are related to previous square errors. For our bivariate model, the total number of estimated parameters is 13. The development of conditional variance for each equation in the bivariate GHARCH model (1, 1) is as follows:

$$h_{11t+1} = C_{11}^2 + b_{11}^2h_{11t} + 2h_{11}b_{21}h_{12.t} + b_{21}^2h_{22.t} + a_{11}^2\varepsilon_{1.t}^2 + 2a_{11}a_{21}\varepsilon_{1.t}\varepsilon_{2t} + a_{2.1}^2\varepsilon_{2.t}^2$$
$$h_{22t+1} = c_{12}^2 + c_{22}^2 + b_{12}^2h_{1t} + 2b_{12}b_{22}h_{12.t} + b_{22}^2h_{22.t} + a_{12}^2\varepsilon_{1.t}^2 + 2a_{12}a_{22}\varepsilon_{qt}\varepsilon_{2.t} + a_{22}^2\varepsilon_{2.t}^2 \quad (1)$$

These equations show how shocks and volatilities are transmitted in two series over time. We use quasi-maximum estimates with wide standard errors calculated by the method proposed by Bollerslev and Wooldridge [14].

5 Research Model

5.1 Multivariate GARCH Model

In this study, the effect of volatility and fluctuations' spillover of each variable is calculated once without considering the structural failure and again with the involvement of structural failure in the calculations using the multivariate GARCH econometric model. Spillover of fluctuations will also be investigated using Granger causality test and vector autoregressive model (VAR). We also specify how we can determine the structural failure in variance. Each of the proposed models is defined below. Today, with the expansion of information systems and the increasing relationship of financial markets with each other, it has been proven that asset price fluctuations are transmitted to each other and to other financial markets. This has led to the interdependence of different assets and financial markets. This has complicated the forecast in the financial markets. Therefore, in general, M-GARCH models have been developed in recent years to model dynamic performance. To investigate the transfer of shocks and spillover of fluctuations and shocks between different markets, the multivariate generalized autoregressive conditional heteroscedasticity (M-GARCH) should be used [36]. The use of multivariate time series models has two important advantages. Firstly, it is very effective in identifying the relationship between series, and secondly, it will increase the accuracy of prediction. To estimate the volatility propagation between two or more estimation time series through multivariate GARCH models, the variances and Covariance of the series must be estimated simultaneously. Using the maximum likelihood method, the parameters of the M-GARCH model can be estimated. The logarithm of the likelihood function is expressed as follows:

$$L(\theta) = T\log 2\pi - 0.5\sum_{t-1}^{T}\log|H_t(\theta)| - 0.5\sum_{t-1}^{T}\varepsilon_t\,(\acute{\theta})\log H_t^{-1}\,\varepsilon_t(\theta) \tag{2}$$

T is the number of observations and θ is the vector of the parameters to be estimated. The algorithm proposed by [12] is used to estimate the parameters using the maximum likelihood method. The following equations represent the mean equations and conditional variance of the M-GARCH model (p, q), respectively:

$$\begin{aligned} Y_t &= \mu_t + \sigma_t Z_t \qquad\qquad Z_t \sim NID(0.1) \\ \mu_t &= a + \sum_{i=1}^{k} b_i\, X_{it} \\ \sigma_t^2 &= \alpha_0 + \alpha_1\varepsilon_{t-1}^2 + \cdots + \alpha_q\varepsilon_{t-q}^2 + \beta_1\sigma_{t-1}^2 + \beta_p\sigma_{t-p}^2 \qquad \varepsilon_t \sim NID(0H) \\ &= \alpha_0 + \sum_{i=1}^{q}\alpha_i\,\varepsilon_{t-i}^2 + \sum_{i=1}^{p}\beta_i\,\sigma_{t-i}^2 \end{aligned} \tag{3}$$

Conventional GARCH models assume that there is no failure in the fluctuation structure, but this is one of the shortcomings of this model. It is while that time series fluctuations are affected by sudden changes and as a result, structural failures in fluctuations are not far from probability and ignoring them may lead to false results on how to transfer information and spillover of fluctuations between financial markets [36]. Lamoureux and Lastrapes [26] documented that GARCH models overestimate the volatility standard when ignoring structural failure, and that these differences must be combined in the GARCH model to obtain accurate parameters [18]. Therefore, after obtaining the structural failure, enter the new variance in the bivariate BEKK model and obtain the new values. For bivariate GARCH, citing the [18], we enter the set of bivariate variables into the BEKK equation as follows:

$$H_{t-1} = \acute{C}C + \acute{B}H_tB + \acute{A}\,\varepsilon_t\,\varepsilon'_tA + \sum_{i=1}^{n} \acute{D}_i\acute{X}_iD_iX_i \quad (4)$$

Di is a 2 × 2 square diameter matrix of parameters, Xi is 2 × 1 row vector of dummy variables, and n is the number of structural failures identified [18]. Thus, when structural failure is considered in the model, real values are obtained.

5.2 Granger Causality Test

Causality is one of the main issues in examining the relationship between economic variables. Determining the direction of causality is used for variables about which there is no explicit theoretical basis. One of the most controversial examples in economics is the relationship between GDP growth (Y) and money growth (X). The question is whether the growth of money causes the growth of GDP or whether the GDP increases first and then the need for money increases and then the central bank increases the money supply? This is a clear example of this concept. The conventional method for examining causality is known as the Granger causality test, in which the following equations are examined [38]:

$$Y_t = \sum_{i=1}^{n} \alpha_i X_{t-i} + \sum_{j=1}^{n} \alpha_j Y_{t-j} + u_t \quad (5)$$

$$X_t = \sum_{i=1}^{n} \alpha_i x_{t-i} + \sum_{j=1}^{n} b_j Y_{t-j} + v_t \quad (6)$$

Based on the above equations, it can be argued that:

A) If $\sum \alpha i \neq 0$ and $\sum bj = 0$ and are statistically significant, then the causality is one-way, according to which X is the cause of Y.

B) If $\sum \alpha i = 0$ and $\sum bj \neq 0$, then the causality is one-way, according to which Y is the cause of X.

C) If $\sum \alpha i \neq 0$ and $\sum bj \neq 0$, then the causality is two-sided.

D) If $\sum \alpha i = 0$ and $\sum Bj = 0$, then these two variables are independent and have no relationship with each other [39].

5.3 VAR Model

Vector autoregressive model (VAR) is a statistical model that expresses the linear dependence between several time series. VAR model is a generalization of the autoregressive model for modeling dependencies between more than one time series. In VAR, the future of a time series is estimated using its past and other series at several time lags. VAR is defined as follows [39]:

$$Y_t = C + \sum_{i=1}^{p} A_i\, Y_{t-1} + \varepsilon_t \quad (7)$$

6 Research Findings

The findings of the present study were considered by researchers in two parts: descriptive and inferential statistics. The results of descriptive statistics are presented in Table 1 and the results of inferential statistics, testing of hypotheses, are presented in Tables 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 and 13.

6.1 Descriptive Statistics

Descriptive statistics related to the variables used in this research are summarized in Table 1. In this table, the values of mean, median, maximum, minimum, standard deviation of data, kurtosis, skewness and Jarque-Bera statistics and probability, respectively. As can be seen in Table 1, the standard deviation specified for the variables indicates that there have been large fluctuations in these markets. Because the amount of skewness is more than 0%, the variables have wide tail distributions and their kurtosis is shorter than normal. Also, Jarque-Bera test statistics reject the normality of research variables at the 0% level, because the p-value is lower.

Table 1: Descriptive Statistics Related to Research Variables

Variable	Symbol	Mean	Median	Max.	Min.	SD	Skewness	Kurtosis
Oil world price	Oil	78.29	74.45	126.65	27.88	25.45	0.152	1.66
Gas world price	GAS	3.40	3.26	6.15	1.64	0.822	0.454	2.75
Steel world price	Steel	1278.23	1535	1609.47	1320.89	5139	-1.49	3.7
Steel industry index	Index	46347	52197	75181	18307	17980	-0.4130	1.650

Reference: research findings

6.2 Examining the Stationary State of Relationships

Before estimating the models, because the type of data used is time series, we must first consider whether time series data are stationary or not. In this study, the unit root tests of Dickey-Fuller and Philips-Perron are used to investigate stationary state of the time series.

Table 2: Dickey-Fuller Unit Root Test Results

Variables	State	y-intercept without trend					y-intercept with trend				
		t-statistics	Critical values			Prob.	t-statistics	Critical values			Prob.
			1%	5%	10%			1%	5%	10%	
GAS	Level	-3.4332	-3.4325	-2.862	-2.567	0.0100	-3.9600	-3.9613	-3.4114	-3.1275	0.0100
	1 time difference	-25.753	-3.4325	-2.8623	-2.5672	0.0000	-23.854	-3.4325	-2.8623	-2.5672	0.0000
Oil	Level	-0.2415	-2.5657	-1.9409	-1.6166	0.5994	-1.6686	-3.4325	-2.8623	-2.5672	0.4472
	1 time difference	-54.663	-2.5657	-1.9409	-1.6166	0.0001	-20.904	-2.5658	-1.9409	-1.6166	0.0000
Steel	Level	-0.9199	-2.5657	-1.9409	-1.6166	0.3180	-1.3355	-3.9613	-3.4114	-3.1275	0.8787
	1 time difference	-52.554	-2.5657	-1.9409	-1.6166	0.0001	-21.945	-2.5658	-1.9409	-1.6166	0.0000
Index	Level	-1.9071	-3.4325	-2.8623	-2.5672	0.3292	-1.8200	-3.9613	-3.4114	-3.1275	0.6950
	1 time difference	-50.188	-3.4325	-2.8623	-2.5672	0.0001	-50.187	-3.9613	-3.4114	-3.1275	0.0000

Reference: research findings

Figure 2 shows the results of the generalized Dickey-Fuller test, according to which the test results are examined in two ways: y-intercept with trend and y-intercept without trend. The test results show that in both cases the p-values in the level test are greater than 0.05. Therefore, the null hypothesis that the data are stationary is rejected, but with a one-time difference, the p-value is changed and the stationary state is established.

Table 3: Phillips-Perron Unit Root Test Results

Vari-ables	State	Y-intercept without trend					Y-intercept with trend				
		t-statis-tics	Critical values			Prob.	t-statis-tics	Critical values			Prob.
			1%	5%	10%			1%	5%	10%	
GAS	Level	-3.8340	-3.4325	-2.8623	-2.5672	0.0026	-1.587527	-2.565799	-1.940938	-1.616622	0.1059
	1 time difference	-60.378	-3.4325	-2.8623	-2.5672	0.0000	-60.369	-2.5657	-1.9409	-1.6166	0.0001
Oil	Level	-0.7958	-3.4324	-2.8623	-2.5672	0.8197	-2.0787	-3.961242	-3.4113	-3.1275	0.5569
	1 time difference	-55.007	-3.4324	-2.8623	-2.5672	0.0001	-55.055	-3.961243	-3.4113	-3.1275	0.0000
Steel	Level	-0.5646	-3.4324	-2.8623	-2.5672	0.8758	-2883.7	-3.9612	-3.4113	-3.1275	1.0000
	1 time difference	-53.537	-3.4324	-2.8623	-2.5672	0.0001	-53.537	-3.54324	-2.7623	-2.6672	0.0000
Index	Level	-1.9832	-3.4325	-2.8623	-2.5672	0.2944	-1.9379	-3.9613	-3.4114	-3.1275	0.6341
	1 time difference	-50.226	-3.4325	-2.8623	-2.5672	0.0001	-50.2243	-3.9613	-3.4114	-3.1275	0.0000

Reference: research findings

Based on the results obtained in Table 3, the Phillips-Perron's test results were similar to the Dickey-Fuller test. As can be seen in the table above, the data are examined in two ways: y-intercept with trend and y-intercept without trend. The results of Phillips-Perron test also showed that the significance level of most variables in the level test has values greater than 0.05, so the null hypothesis of stationary state is rejected, but with a one-time difference, most of the data become stationary.

6.3 Hypotheses Test Results

Hypothesis 1: The energy market is volatile during the study period.

Univariate GARCH test is used to investigate the transmission of shocks, volatilities and shocks in the energy market (oil and gas) and the steel market [36]. For this purpose, according to the studies conducted in the energy market, the results of the univariate GARCH test are presented in Tables 4 and 5:

Table 4: Gas Market Fluctuations or Volatility Using the Univariate GARCH Model

Description	Variables	Coefficient	Z-statistics	P-Value
GAS	c	6.500105	4.214895	0.0000
	RESID(-1)^2	0.111719	17.70960	0.0000
	GARCH(-1)	0.894483	205.8461	0.0000

Reference: research findings

Table 5: Oil Market Fluctuations or Volatility Using the Univariate GARCH Model

Description	Variables	Coefficient	Z-statistics	P-Value
Oil	c	9.5406	-0.781317	0.4346
	RESID(-1)^2	3.5548	88.19022	0.0000
	GARCH(-1)	0.3115	68.01583	0.0000

Reference: research findings

The results of the energy market volatility test are presented in Tables 4 and 5. In this test, it is assumed that the time series is stationary. Considering the value of Z statistic and its probability in GARCH test, the results indicate that there are volatilities and fluctuations' spillover in the energy market (oil and gas). Therefore, it can be concluded that there is volatility in the energy market (oil and gas) in the period under study.

Hypothesis 2: Steel prices fluctuate during the period under study.

The results of the volatility test in the global steel market based on the univariate GARCH test are presented in Table 6:

Table 6: Fluctuations or Volatility of the Steel Market Using the Univariate GARCH Model

Description	Variables	Coefficient	Z-statistics	P-Value
Steel	c	9.5406	-0.781317	0.4346
	RESID(-1)^2	3.5548	88.19022	0.0000
	GARCH(-1)	0.3115	68.01583	0.0000

Reference: research findings

The results of the steel market volatility test are presented in Table 6. Considering the value of Z statistic and its probability in univariate GARCH test, the results indicate that there are volatilities and fluctuations' spillover in the steel market. Therefore, it can be concluded that there is volatility and fluctuations in the steel market in the period under study. As a result, this research question is also confirmed.

Hypothesis 3: There is a significant relationship between energy prices (oil and gas) and steel prices.

Results related to the effect of spillover of energy price fluctuations (oil and gas) on world steel prices using GARCH, diagonal BEKK model:

Due to the structural failure in the global oil and gas market and in order to investigate the effect of energy price spillovers on fluctuations in steel products, the GARCH-BEKK model has been used. The results obtained from the output of bivariate BEKK for each of the markets are as follows:

Table 7: The Effect of Gas Price Fluctuations on World Steel Prices Using Diagonal BEKK Model

Description	Variables	Coefficient	Z-statistics	P-Value
GAS	M(1,1)	1.053205	5.692242	0.0000
	M(1,2)	7.633210	5.316506	0.0000
	M(2,2)	3.991209	3.031205	0.0000

The results of the test for the effect of changes in gas prices on world steel prices by the BEKK GARCH model are shown in Table 7. In this test, if the value of the significance level for each of the variables is less than 0.05 and the test statistic is outside the values of ±1.96, it can be claimed that changes in gas prices have a significant effect on the price of steel. The corresponding values in line M (1, 2) for the test results show the effect of gas price changes on steel prices. As can be seen, the significance level of the test for the global gas price is 0.0000 and the value of the test statistic is Z = 5.3165, so it can be claimed that gas price fluctuations have a significant effect on the cost of steel products.

Table 8: The Effect of Oil Price Fluctuations on World Steel Prices Using Diagonal BEKK Model

Description	Variables	Coefficient	Z-statistics	P-Value
Oil	M(1,1)	1.663794	6.038197	0.0000
	M(1,2)	-193.6023	-6.038197	0.0000
	M(2,2)	4.390408	5.191337	0.0000

The results of the test for the effect of changes in oil prices on world steel prices by the BEKK GARCH model are shown in Table 8. In this test, if the value of the significance level for each of the variables is less than 0.05 and the test statistic is outside the values of ±1.96, it can be claimed that changes in oil prices have a significant effect on the price of steel. The corresponding values in line M (1, 2) for the test results show the effect of oil price changes on steel prices. As can be seen, the significance level of the test for the global oil price is 0.0000 and the value of the test statistic is Z = -5.0381, so it can be claimed that world oil price fluctuations have a significant effect on the world steel price.

Therefore, according to the results of Tables 7 and 8, there is a significant relationship between energy prices and global steel prices using the diagonal BEKK GARCH model.

Hypothesis 4: There is a causal relationship between energy prices (oil and gas) and steel prices.

Granger causality test was used to test the causal relationship between energy prices (oil and gas) and world prices of steel products. Granger causality test can show the causal and two-way relationship between two variables. The purpose of this test is to determine whether changes in oil and gas prices have caused fluctuations in steel product prices and vice versa. The results of this test are shown in Table 9.

Table 9: The Causal Relationship Between Energy Variables (Oil and Gas) and World Steel Prices

Index/Lag	2	3	4	5	6	7	8	9
Steel price <- gas price	0.1757	0.7833	0.0005	0.0001	0.0002	0.0005	0.0011	0.0014
Gas price <- steel price	0.7625	0.9111	0.5839	0.5659	0.6986	0.7732	0.7960	0.8643
Steel price <- oil price	0.3899	0.7796	0.0413	0.0767	0.1078	0.1606	0.2080	0.2824
Oil price <- steel price	0.5930	0.5606	0.7081	0.8243	0.8918	0.9329	0.9592	0.9710

According to the results presented in this table 9, which is the result of Granger causality test, it can be claimed that there is no causal relationship between gas price and steel price in the short term. In the long run, there is a causal relationship from gas price to steel price, or in other words, gas price is the main cause of fluctuations in steel prices in the long run. Also, regarding causality between oil prices and steel prices, there is only a short-term and one-way causal relationship from oil prices to steel prices (in lag 4), but this relationship was not observed in the long run. The results of this test also showed that there is no causal relationship from steel prices to energy prices (oil and gas) in the short and long term, indicating that the price of steel products is not the main cause of energy prices (oil and gas). Therefore, at the 95% confidence level, the causal relationship between energy prices and steel prices is rejected.

Hypothesis 5: There is a causal relationship between energy prices (oil and gas) and steel index and returns.

Table 10: Causal Relationship Between Energy Variables (Oil and Gas) and Steel Index

Index/Lag	2	3	4	5	6	7	8	9
Oil price <- steel index	0.9875	0.9976	0.9344	0.9728	0.9892	0.9751	0.9137	0.8689
steel index <- oil price	0.2874	0.1201	0.1953	0.2873	0.3978	0.4739	0.5511	0.6569
Gas price <- steel index	0.0478	0.1153	0.1910	0.2249	0.4085	0.5307	0.5458	0.6306
steel index <- gas price	0.4008	0.4100	0.2183	0.3183	0.4270	0.4151	0.2418	0.3099

According to the results presented in the table above, which is the result of Granger causality test, it can be claimed that there is no causal relationship between oil price and steel index and return in short and long term periods. In other words, oil price is not the main cause of fluctuations of the steel industry index. Also, regarding the causality between gas price and steel industry index, there is only a short-term and one-way causal relationship from the steel index in lag (2) to the gas price, but this relationship was not observed in the long run.

Hypothesis 6: Energy market (oil and gas) volatility spreads to steel index and return.

Table 11: Spread of Oil Price Volatility on the Steel Index Using the GARCH Model

Description	Variables	Coefficient	Z-statistics	P-Value
OIL	C(4)	7.134288	55.97355	0.0000
	C(5)	2.496522	117.6583	0.0000
	C(6)	1.747643	66.29632	0.0000

The results of the test for the effect of oil price volatilities on steel index by the GARCH model are shown in Table 11. In this test, if the value of the significance level for each of the variables is less than 0.05 and the test statistic is outside the values of ±1.96, it can be claimed that oil price volatilities have a significant effect on steel index. The corresponding values in line C (5) for the test results show the effect of oil price changes on steel index. As can be seen, the significance level of the test for the global oil price is 0.0000 and the value of the test statistic is Z = 117.6583, so it can be claimed that oil price fluctuations have a significant effect on the steel index.

Table 12: Spread of Gas Price Volatility on the Steel Index Using the GARCH Model

Description	Variables	Coefficient	Z-statistics	P-Value
Gas	C(4)	1.509470	12.23510	0.0000
	C(5)	0.026613	5.369025	0.0021
	C(6)	0.895844	30.01257	0.0000

Reference: research findings

The results of the test for the effect of gas price volatilities on steel index by the GARCH model are shown in Table 12. In this test, if the value of the significance level for each of the variables is less than 0.05 and the test statistic is outside the values of ±1.96, it can be claimed that gas price volatilities have a significant effect on steel index. The corresponding values in line C (5) for the test results show the effect of gas price changes on steel index. As can be seen, the significance level of the test for the global gas price is 0.0000 and the value of the test statistic is Z = 5.3690, so it can be claimed that gas price fluctuations have a significant effect on the steel index. According to the results, it can be said that the spread of energy market volatility (oil and gas) has a significant effect on steel prices and returns. This hypothesis is also tested based on the VECM co-integration test.

6.4 VECM Co-Integration Test

If a time series is differentiated d times to become stationary, that time series has d unit roots and will be an integration of order d or I (d). Now if we have two-time series yt and xt, which are both I(d), normally every linear combination of yt and xt is also I (d). But if there are fixed coefficients such as α and β, the regression error term related to yt and xt, $u_t = y_t - \alpha - \beta x_t$, has an integration order less than d, for example I (d - b) with the assumption that (b> 0). According to [15]. xt and yt are co-integration of order (d, b). Therefore, the two-time series yt and xt are called the co-integration of the order b and d, i.e. CI (db), if the co-integration order of both is equal to I (d) (b> 0). According to the above definition, if yt and xt are both of the integration order of I (1) and I(0)ut ~, then the two time series will be co-integration of the order CI (1.1), and this definition can be extended to more than two time series [15]. It the error term of the regression equation, (0) I, is static, the usual econometric methods can be used to estimate the parameters with the help of time series data and can be used in the inferences of t and F statistics [29]. The co-integration order is estimated using Johansen's method, which derives two probability estimators for CI. The following is the result of the co-integration test:

6.5 Bound Test Approach: Presence or Absence

This relationship can also identify the co-integration between variables, but the result of this approach does not show the direction of causality. In addition, these tests are not valid if there is a co-integration relationship between the variables, but using the error correction model to perform the Granger causality test can eliminate these problems. According to the results of Table 13, the existence of co-integration between the research variables is confirmed.

7 Conclusion

The steel industry is one of the most important infrastructure and strategic industries. Today, a significant part of industrial activities such as automobile manufacturing, shipbuilding, construction, rail transport, military industry and thousands of other industrial activities are associated with this vital and fundamental industry. Changes in the prices of products and its by-products can affect all real sectors of the economy. On the other hand, the cost of products in this industry, besides direct and indirect raw materials, is significantly affected by energy prices. Based on theoretical basics and research background, changes in energy prices, including oil and gas, can also directly and indirectly affect the cost and, ultimately, the products of this industry. Accordingly, and due to the significance of the study, the present study was aimed to examine the fluctuations of energy and steel prices and the experimental test of volatilities spillover between markets. For this purpose, data related to these variables were collected monthly from 2009 to 2019 and analyzed and tested using GARCH models, Granger causality test and VAR model.

Table 13: VECM Co-integration Test

2 Cointegrating Equation(s):		Log likelihood	-58870.70
GAS	OIL	STEEL	INDEX1
1.000000	0.000000	1.480106	0.000107
		(1.20106)	(3.50105)
0.000000	1.000000	8.240105	0.005606
		(8.50005)	(0.00243)
Adjustment coefficients (standard error in parentheses)			
D(GAS)	-0.018613	0.000277	
	(0.00375)	(5.7105)	
D(OIL)	0.174025	-0.002382	
	(0.06179)	(0.00095)	
D(STEEL)	-1264.906	11.57823	
	(989.935)	(15.1494)	
D(INDEX1)	-18.77823	-0.107837	
	(33.0222)	(0.50535)	

The results of testing the first hypothesis of the research indicate the existence of volatility in the energy market (oil and gas). Over one decade of study, this market has experienced various fluctuations. Oil price had fluctuated from $ 27 to $ 127 a barrel, often due to market demand, international political issues and crises, or excess and shortage of supply. Also, based on the obtained results, it can be claimed that for suppliers, energy prices have cycles of prosperity and stagnation, and sometimes the cycles of recession have been for a long period. The results of testing the second hypothesis also show the existence of volatility in the steel market. Steel has also had sharp price fluctuations during the study years. In the middle of the period under study, we have observed a huge recession and a decrease in the price of its products, and in recent years we have witnessed an unprecedented increase in prices. These fluctuations are also often due to changes in demand, raw material and energy prices, and international political conditions. The results of other research hypotheses also show a significant relationship between energy prices and steel prices and the volatilities spillover between these markets during the study period. Therefore, it can be said that energy is the determining factor in the cost price of steel industrial products and, finally, the market price of those products, which can also change the returns of the industry indices in the capital market, but these relations were not observed causally. The results obtained are consistent with some of the researches, including the researches of Fasanya, I., & Akinbowale [46] and are inconsistent with the results of some other researches.

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