The Empirical Test of Steel Price Volatility and Volatility Spillover between Energy (Oil & Gas) and Steel Markets

S. A. Bahreini [1], H. Badie *[2], F. Ahmadi [3], J. Asadnia [4]

[1, 3, 4] *Department of Accounting, Qeshm Branch, Islamic Azad University, Qeshm, Iran Tehran, Iran*
[2] *Department of Accounting, Faculty of Economic Science and Accounting, Tehran South Branch, Islamic Azad University, Tehran, Iran*

Abstract

Interdependence of markets may cause fluctuations in one market to positively or negatively affect another market. Therefore, investigating the behavior of fluctuations in financial markets and their causes in financial asset pricing processes, implementation of global risk hedging strategies and asset portfolio preference decision-making is of great importance. Given the importance of this issue, the current research aims to model energy and steel price volatility and experimentally test the spillover of fluctuations between markets using the GARCH BEKK model, during a 10-year period of 2013-2022. The data of the current research were extracted from daily data from the World Data Bank, Coin and Currency Information Site, and Economic and Financial Data Banks; then, using the Dickey-Fuller and Phillips-Perron tests, the significance of the data was evaluated. After that, the spillover effect of fluctuations between the markets was tested using the univariate GARCH and GARCH BEKK tests. The results of the research showed that the steel and energy markets have significant volatility in the studied period. Also, the fluctuations in the oil and gas market are significantly transferred to the global steel price.

Keywords: Volatility Spillover, Oil Price, Gas Price, Steel Price.

1. Introduction

Market volatilities are one of the important and discussed topics in the macroeconomics and capital market field, and researchers in the financial and economic fields have made extensive efforts to study this issue and have conducted numerous studies in this area. These studies often include identifying factors creating fluctuations and the impact of fluctuations and turmoil on different sectors of the market and the economy. Limited research has also been done in the area of intra-market fluctuation spillover in stock markets. The term fluctuation (volatility) in the market refers to extensive and almost unpredictable changes that occur in market indicators for various reasons. The increase in oil prices leads to an increase in production costs and ultimately affects the final price [19]. In addition, the financialization of commodity markets is an important factor that helps the interdependence of various commodities such as metals and energy (such as oil and gas)[48]. Individual and institutional investors may prefer multiple investment instruments to benefit from the return on different investment instruments. Shareholders, when choosing investment instruments to hold in their portfolios, not only consider the return on

**Corresponding author*
Email: badiei@iau.ac.ir
Address: Department of Accounting, Faculty of Economic Science and Accounting, Tehran South Branch, Islamic Azad University, Tehran, Iran
1. Ph.D. Student
2. Assistant professor
3. Assistant professor
4. Ph.D.

one asset against another, but also consider the risk of each asset and its ability to protect against risk factors. The prices of goods and the relationships between product prices may affect production, consumption, investment, and savings decisions in economies, the reason for which is the fluctuations in prices, the increase in regions of use of goods, and the observed coordination in price changes. Oil and precious metals are among the most strategic commodities subject to production, consumption, investment, savings, and trade in global markets. Expensive metals such as gold, silver, platinum, and palladium, which have high economic value and have been as important as money throughout history, are now mostly used for industrial purposes or investment. Recently, many shareholders have paid attention to investing in metals due to their sensitivity to oil prices as an economic tool [46].

On the other hand, due to economic relationships between countries and the connections between capital markets, the possibility of the spread of fluctuations from one market to another exists. Some studies have focused on how fluctuations and volatilities from one market enter another. This is particularly evident in times of economic and financial crises. A prominent example of the volatility spillover from one market to another can be seen in the 2007-2008 financial crisis. During this period, severe fluctuations occurred in the US capital markets and their immediate effects were observed in many other countries such as Japan and European countries. According to researchers, these relationships between markets were seen as the volatility spillover, so it can be said that the spread of volatility between financial indicators is indicative of the process of information transfer between markets. Since many financial assets are traded based on gold and oil, it is important for financial market participants to understand the mechanism of transferring fluctuations over time and during these periods [13]. Oil and metal resources, which have high trading volumes in the market, have a high cash flow in the world. Today, capital markets encourage investors, especially during financial crises or financial fluctuations and high uncertainty in traditional securities markets, to turn to commodities and metals [24]. Therefore, including important commodity contracts in the portfolio may have a positive impact on improving financial transactions and extensive investments [17]. In other words, optimal asset allocation is done by optimizing the portfolio, reducing the risk of falling below the expected return, and modeling appropriate temporal correlation between risk hedging, commodity, and securities markets. Metals such as steel may provide a natural and effective hedge against inflation [35]. Therefore, combining commodity investments with other assets may provide better diversification compared to a similar portfolio that does not include commodities [31]. As this commodity drives the economy of many countries, a commodity-based risk hedging strategy may provide greater benefits for international diversification [46]. For this reason, in recent years, with the increase in the prices of strategic commodities such as gold, silver, steel, and other expensive metals, the attention of investors has been drawn to them, and the interest in expensive metals has increased. Therefore, fluctuations in the price of metal commodities are very important due to their potential impact on investment decisions [46].

Given that the steel industry is one of the important, strategic, and infrastructural industries and plays a major role in the development of other industrial and economic sectors of a country, it is expected that changes in energy prices can change the total cost and price of steel products. Therefore, the main issue of this research is whether the energy and steel prices have volatility during the study periods. If so, how is the behavior of price volatility between energy and steel markets? With these explanations, the present study examines the volatility of energy and steel prices and experimentally tests the volatility spillover between these markets. It is natural to expect that prices and volatility between energy and steel markets are related. In addition, the asymmetry of good and bad news in these markets suggests that accepting asymmetric news, both good and bad, in one market, such as the oil and gas market, can strengthen and increase the spillover of risk to the metal market, especially steel. Insufficient research in this regard motivates the researcher to cover some of the research gaps by examining the subject and modeling the volatility of energy and steel prices and the volatility spillover between these markets, and also provide accurate information to investors, managers, analysts, and other stakeholders.

2. Theoretical foundations and research backgrounds

The rapid development in commodity markets has led to rapid growth in investment in the past two decades, despite the fact that commodity prices experience significant fluctuations. Worldwide demand growth has been the driving force behind the upward fluctuations observed in commodity prices in recent decades. However, the Global Financial Crisis (GFC) that plunged many world economies into recession also impacted commodity markets significantly. Since investors have to make important choices in the asset allocation process and have increased access to information systems, rapid growth in commodity investment through commodity futures markets has been observed in recent years [5]. Precious metal commodity trading, which is an alternative investment instrument compared to the traditional portfolio containing stocks and bonds, has progressed remarkably in both the cash and derivative markets over the past decade. In this case, the use of commodities like precious metals for diversification in individual investments and hedge funds and other investment funds has increased [17].

Today, energy is one of the major consumptions of households and businesses. Therefore, oil is also considered an important investment instrument for shareholders. Oil price shocks are expected to impact alternative investment instruments and commodity prices due to the relationship between economic growth and financial markets. Economic decision-making units carefully monitor oil prices when deciding to invest. In general, oil price volatility requires close monitoring by market players, as it affects economic activities and stock markets through different channels and can be considered as an alternative investment instrument [46]. Oil is not only an important commodity for all economies but also a determining factor in financial trading. The increase in oil prices directly impacts inflation through increased energy costs. This scenario may limit demand and costs of goods and services, resulting in a decrease in company profits. An increase (decrease) in oil prices leads to a decrease (increase) in demand for oil, which leads to an increase (decrease) in demand for expensive metals and consequently, the price of expensive metals [45]. Therefore, the possibility of using expensive metals as a hedge against inflation increases (Reboredo, 2013). The second factor may be explained by financial investment tendencies and is accompanied by price growth. High oil prices have a negative impact on the economy and hinder growth. As a result, shareholders who are looking for alternative investments tend to choose expensive metals [15]. In this case, the price of oil indirectly affects the price of expensive metals. Oil price shocks (fluctuations) may lead to uncertainty, concerns, and speculative attacks, especially in net oil-importing countries. Therefore, high inflation and inflation expectations increase the tendency to use expensive metals as a hedge, provided that all other goods remain unchanged [39].

In general, there are many approaches to the relationship between strategic commodities. For example, [19] found that the volatility of oil and silver is negatively affected by past oil price shocks. However, they did not find a significant relationship with copper. Also, they showed that precious metal price volatility increased significantly during the second Persian Gulf War. [37] concluded that precious metal prices are not statistically affected by world oil prices. [49] examined the price discovery process between the oil and gold markets and found a positive correlation between oil and gold prices. The results of the linear Granger causality test indicate the existence of a one-way causality from oil prices to gold prices. On the other hand, the lack of causality is determined based on the results of the nonlinear causality test. [30] examined the relationship between oil prices and precious metal prices using unconditional and conditional value at risk methods for the period 2015 to 2000. They found that big downward and upward movements in oil prices have spillover effects on all metal markets and this effect is valid both before and after the GFC. [34] examined the spillover effects of Bitcoin, gold and oil. Based on the results, Bitcoin and gold are safe havens and provide diversification benefits for oil price changes. [35] also investigated the relationship between oil prices and the prices of five different precious metals using the CoVar approach. The results showed that there is spillover from oil prices to precious metal prices. In addition, [24] found evidence in favor of bi-directional returns and volatility spillovers between oil and precious metal prices. They also showed that the magnitude of volatility spillovers increases significantly during periods of financial turmoil.

As mentioned, commodities are considered as separate assets within all classes of assets. It is envisioned that commodity markets are volatile. Therefore, price volatility leads to demand for risk hedging in the commodity market. Producers and consumers often seek ways to hedge risk and commercial risk. In response to this need, derivative markets emerged for commodity risk trading and their use has grown increasingly widespread. The instruments traded in these markets include financial instruments such as futures contracts, options, swaps and physical instruments such as inventories. Futures contracts are among the most important of these instruments and provide substantial information about cash markets and storage. A futures contract is also an agreement to deliver a specified amount of a commodity at a specified date in the future, at a price (the futures price) to be paid at the time of delivery. Future contracts are usually traded on organized exchanges and have a greater tendency towards liquidity compared to future contracts. Besides this, a futures contract differs from a future contract only in that a future contract is "defined in a specified market", meaning that at the end of each trading day there is settlement and transfer of the related funds. The futures market performs several economic functions including the risk hedging function, the price discovery function, the financing function, the liquidity function and price stabilization [36]. Financial market pricing theory states that the efficiency of the market is a function of the speed and extent of information reflected in prices. The rate at which market information is shown is the price at which this type of information is disseminated to market participants [47]. However, in reality, institutional factors such as liquidity, transaction costs and other market constraints may cause an empirical relationship with a lag between price changes in the two markets. Risk transfer and price discovery are two of the major contributions of futures markets in organizing economic activities [43]. Risk transfer refers to the use of futures contracts to transfer price risk to others. Price discovery refers to the use of futures prices to price spot market transactions or price discovery means that the futures price acts as the market's expectations of the next instantaneous price [16]. In other words, price discovery is a process by which markets combine information to reach equilibrium [42]. In the static concept, price discovery means the existence of an equilibrium price and in the dynamic concept, the process of price discovery describes how information is produced and transmitted in markets. In addition, it also transfers information to all market participants. Price discovery is the primary function of a commodity futures market. Information about price discovery is essential because these markets are widely used by companies that produce, market and process commodities. The nature of the price discovery function of futures markets depends on whether new information is initially reflected in futures prices or reflected in spot prices [20]. Conventionally, it is argued that the futures market is the dominant point of price discovery more than the spot market. Multiple studies show that futures markets play an important role in discovering prices for the essential spot market. This price discovery function indicates that prices in futures and spot markets are systematically related in the short term and/or long term [25]. [33] have studied the spillover of fluctuations between oil price, currency price, gold price and stock market under the influence of gaps and structural failure and using BEKK Garch model and ICSS algorithm and have come to the conclusion that the rate change It is done on it. The price of oil has no effect, but it has a significant effect on the price of gold and the stock index.

[48] investigated the predictability of precious metal price volatility with global economic policy uncertainty in the pre-pandemic period and during the COVID era. The results show that there is a significant relationship between global economic policy and precious metal price volatility. It can be inferred that any uncertainty recorded in global economic policy intensifies the volatility of gold, palladium, platinum, and silver prices. [11] examined the contagion of dynamic volatility spillovers between iron ore prices and crude oil prices during the COVID period. Empirical results indicate that: First, the dependence between the Baltic dry index, iron ore prices, and Brent crude oil prices is time-varying and lagged. Second, dynamic dependencies and volatility spillovers between the Baltic dry index, iron ore prices, and Brent crude oil prices have been significantly strengthened during the COVID period, indicating that the impact of market turmoil has strengthened the linkage between markets.[3] studied discernible trends in international metal prices in the presence of unstable volatility. Findings generally show that unpredictable changes in demand, extraction costs, and reserve discoveries affect the slope estimate of this fundamental trend. In addition, low demand and supply elasticities cause high price volatility, making trend estimation difficult. [44] tested oil resource price volatility in identifying barriers to economic recovery. Based on the Granger causality test, impulse response functions and variance decomposition, economic recovery and investment have been significantly impacted by oil price volatility from Q1 2000 to Q4 2020. Based on this research, commercial investment and oil price have demonstrated high power throughout the international economic crisis. Given the recent spread of COVID-19, volatility in economic activities and oil prices is expected during this crisis. In addition, during the GFC and the COVID-19 crisis, oil prices and economic growth are highly correlated. [18] examined the predictability of oil price volatility based on global economic conditions. [40] examined oil price shocks and return and volatility spillovers between base and precious metals. The findings show that demand shocks and risk-receiving (sending) shocks are the dominant shocks from (to) metal returns. Net return directionality and volatility comovement indicate that some metals like tin, gold and even nickel, lead, and aluminum appear as net senders at least over some intervals of the sample period under analysis.

[14] investigated the transmission of fluctuations among precious metals, energy, and stocks during the COVID-19 pandemic. The main findings show a significant impact of the pandemic on the links between market fluctuations, as the correlation between different asset fluctuations reached its peak during the outbreak. [46] tested the time-varying fluctuations between the prices of oil and precious metals. The empirical results indicate a causal relationship between the average of the oil return series and the precious metal return series. The causality test of average indicates that the oil price is the Granger cause of all precious metals. [13] examined the commodity markets of energy and non-energy based on the spillovers of fluctuations and the effectiveness of risk hedging. The results showed that the oil market transmits fluctuations to the metal and overall non-energy markets.[12] studied the asymmetric relationship between the price of oil and the COVID-19 pandemic with the value of trading on the stock exchange. The results showed that in the long run, the increase in oil prices has a significant asymmetric effect on the value of trading on the stock exchange. On the other hand, in the short term, the number of COVID-19 patients has a positive but insignificant relationship, while the coronavirus media index has a negative and significant relationship with the value of trading on the stock exchange. [32] investigated the role of fundamental factors in the global oil price. The results showed that in the estimation pattern, world GDP has the most significant impact with a demand elasticity of 0.6039, while world military and security tensions have the least impact with a demand elasticity of 0.0110. [5] examined the impact of the coronavirus on the global oil and gas market and its prospects for the future. The results of this study suggest reduction of OPEC production and prevention of price collapse, which weaken the global economy, or maintenance of stable production and acceptance of the risk of price collapse.

[41] investigated the decomposition of crude oil prices and its impact on the return of selected stock price indices using the VECM method. The results of this study showed that positive price fluctuations affect the return of stock indices of all three groups, and have the greatest impact in order on the return of stock indices of the petroleum coke and nuclear fuel products group, oil and gas extraction and ancillary services excluding exploration group, and rubber and plastics group; while negative price fluctuations only affect the return of stock index of the oil and gas extraction and ancillary services excluding exploration group. With regard to the test of instantaneous response of all three groups of stock index returns to the positive shock in the model, the result showed that there is a dynamic response in all three groups of stock index returns to the positive shock of the two variables of positive and negative fluctuations in oil prices, so that it has a positive effect on the return of the stock index of the petroleum coke and nuclear fuel products group; but in the other two stock index return groups, a negative effect is observed. In a study by [4], the regional gas prices were examined in relation to crude oil prices in the global market. The findings showed a high level of susceptibility of regional gas and oil prices to market fluctuations in Asia and Europe due to their interdependence. However, in the American market, particularly in the shale oil sector, this relationship was not observed due to excess energy supply. In another study by [27], the response of natural gas prices to changes in crude oil prices in the European and Asian regional gas markets was investigated. The results showed that the crude oil price had a direct or inverse effect on the natural gas price in different regimes. In Europe, the first crude oil price interruption had an inverse effect for one month and a direct effect for 18 months and the second crude oil price interruption had a direct effect on natural gas prices in both regimes. In Asia, the effect of crude oil prices on natural gas prices was direct in both regimes, with prices of 28 months in regime one and 26 months in regime two. [27] conducted a study to examine the response of natural gas prices to changes in crude oil prices in regional gas markets in Europe and America. The results show that the oil price directly affects gas prices in some regimes and has an inverse effect in other regimes. In Europe, oil price shocks have had a reverse effect for one month and a direct effect for 16 months on gas prices. In this region, the second oil price shock has had a direct impact on gas prices in both regimes. In America, the first oil price shocks for 2 months and the second oil price shocks for 18 months have had a direct impact on gas prices. Furthermore, the Granger causality test shows the causality is from oil price to gas price. [33] investigated the volatility of oil, currency, gold and stock markets using BEKK bivariate GARCH model and Granger causality test. The results of their research showed that the fluctuations in the oil market can spread to the stock market of the supplying countries. Also, exchange rate fluctuations have a significant effect on the price of gold and the stock index of the studied countries. In another study by [8], the relationship between natural gas prices and crude oil prices in the global gas markets was examined. The results showed that although the long-term relationship between gas and oil prices in the American market has been separated, it still exists in the UK, Europe, and Asia, and a high percentage of gas price fluctuations are explained by oil price shocks.

3. Research Method

The present study is applied in terms of its objectives, and descriptive and exploratory in terms of its methodology. In this research, a library method was used to investigate the theoretical literature and collect the statistical data. It should be noted that the statistical information related to daily data during the 10-year period of 2013-2022 was extracted from the World Bank database[1], the Economic and Financial Database[2] , and the Coin and Currency Information website[3] , which includes daily energy prices (oil and gas) and the performance of steel companies in the Tehran Stock Exchange. The spillover effect of fluctuations between these markets was tested using the bivariate GARCH models and the diagonal BEKK model. The statistical population of this study includes oil and gas prices and the performance of steel industries. Accordingly, the information related to the 10-year period was selected in the relevant sections and examined and tested as the sample of the study.

BEKK Model

Another type of multivariate GARCH model called "Diagonal BEKK" has been proposed as an extension of the MGARCH model. Its most important feature is its generality, and one of its other features is that its conditional variances and covariances of this time series affect each other and it estimates fewer parameters than other methods. This method allows for the examination of the impact of shocks and disturbances in one series on the disturbances of another series. This effect can be symmetric or asymmetric.

The BEKK specification is as follows:

$$H_t = \acute{C}C + A\varepsilon'_{t-1}\varepsilon_{t-1}A + \acute{B}H_{t-1}B \qquad \text{Eq. (1)}$$

Base on [33], Parameter estimation for the multivariate Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model can be performed using the maximum likelihood estimation method. The logarithm of the likelihood function is expressed

1. https://data.worldbank.org/
2. https://databank.mefa.ir/
3. https://www.tgju.org/

as follows:

Eq. (2)

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

Where, T is the number of observations and θ is the vector of parameters to be estimated. The maximum likelihood estimation algorithm proposed by [10] is used to estimate the parameters. As previously mentioned, the drawback of conventional multivariate GARCH models is that they assume no structural breaks in the volatility process, but financial time series are subject to sudden changes and thus, structural breaks in volatility are likely to occur. Ignoring these breaks may lead to false results regarding the transmission of information and spillover of fluctuations between financial markets.

3.1. Research Model

In this study, the first and second hypotheses are examined using univariate GARCH, and the following model is used to test the third hypothesis. It should be noted that the following model is also applicable to the first and second hypotheses, but oil and gas prices are separated for analysis.

Eq. (3)

$$Steel_{it} = \alpha_0 + \beta_1 Oil_{it} + \beta_2 Gas_{it} + \varepsilon_{i,t}$$

3.2. Research Variables

The research variables include global energy prices, which consist of daily global oil and gas prices (independent variable).

Global oil prices (Oil): which are extracted daily from the World Bank database and global economic and financial databases, and their logarithm is taken. Each barrel is calculated in US dollars.

Global gas prices (Gas): are extracted daily from the Coin and Currency Information website and global databases, and their logarithm is taken and calculated in US dollars.

The dependent variable is global steel prices.

Global steel prices (Steel): which are extracted daily from the Coin and Currency Information website and global databases, and its logarithm is taken. It should be noted that each ton of steel is calculated in US dollars.

3.3. Research Hypotheses

H1: The energy market experiences volatility during the study period.

H2: The steel price experiences volatility during the study period.

H3: There is a spillover effect of fluctuations from oil and gas prices to steel prices.

3.4. Descriptive Statistics

Descriptive statistics for the variables used in this study are summarized in Table 1. The table shows the mean, median, maximum, minimum, standard deviation, kurtosis, skewness, and Jarque-Bera statistic and probability, respectively. As seen in Table 1, the standard deviation specified for the variables indicates that there has been high volatility in these markets. Since the kurtosis is greater than 0.05, the variables have platykurtic distributions, and their skewness is also shorter than the normal limit. Furthermore, the Jarque-Bera test statistics reject the normality assumption of the research variables at a 95% significance level, as the p-value is less than 0.05.

As seen in the above table, the average price of oil during the study period was \$68.28, which has experienced one of the highest price trends. The price of oil during this period increased to over \$104.83 and experienced a minimum price on the border of \$44.49. Therefore, it can be concluded that we have witnessed significant changes and volatility in its price during the study period. Additionally, the results of examining gas prices during the study period show that it was equal to 3.405, with the maximum value being 6.149 and the minimum value being 1.639 units. As observed, the average global steel price during the study period was 14.06 units, with the maximum and minimum values being 14.34 units and 11.79 units, respectively.

3.5. Data Stationarity Analysis

In time series data, it is essential to examine whether the data is stationary. Therefore, before estimating and predicting research models, data stationarity should be investigated.

Table 1. descriptive statistics.

Variable	Mean	Median	Max.	Min.	SD	Kurtosis	Skewness
Oil	68.28	65.76	104.83	44.49	20.97	0.1524	1.6648
Gas	3.4058	3.2630	6.1490	1.6390	0.8222	0.4541	2.7514
Steel	14.06	14.24	14.34	11.79	13.14	1.4890-	3.7424

Table 2. Stationarity of Variables - Dickey-Fuller.

Variables	Status	Interception without trend					Interception with trend				
		T-statistics	Critical values			Prob.	T-statistics	Critical values			Prob.
			1%	5%	10%			1%	5%	10%	
Gas	Level	-3.4332	-3.4325	-2.8623	-2.5672	0.0100	-3.9600	-3.9613	-3.4114	-3.1275	0.0100
	1st order differential	-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
	1st order differential	-54.663	-2.5657	-2.1501	-1.9820	0.0001	-20.904	-2.5658	-1.9409	-1.6166	0.0000
Steel	Level	-0.9199	-2.5657	-1.9409	-1.7246	0.3180	-1.3355	-3.9613	-3.4114	-3.1275	0.8787
	1st order differential	-52.554	-2.5657	-1.9409	-1.7246	0.0001	-21.945	-2.5658	-1.9409	-1.6166	0.0000

Table 3. Stationarity of Variables - Phillips-Perron test.

Variables	Status	Interception without trend					Interception with trend				
		T-statistics	Critical values			Prob.	T-statistics	Critical values			Prob.
			1%	5%	10%			1%	5%	10%	
Gas	Level	-3.8340	-3.4325	-2.8623	-2.5672	0.0026	-1.58752	-2.56579	-1.94093	-1.61662	0.1059
	1st order differential	-60.378	-3.4325	-2.8623	-2.5672	0.0000	-60.369	-2.56579	-1.94093	-1.61662	0.0001
Oil	Level	-07958	-3.4324	-2.8623	-2.5672	0.8197	-2.0787	-3.96124	-3.4113	-3.1275	0.5569
	1st order differential	-55.007	-3.4324	-2.8623	-2.5672	0.0001	-55.055	-3.96124	-3.4113	-3.1275	0.0000
Steel	Level	-0.5646	-3.4324	-2.8623	-2.5672	0.8758	-2.8837	-3.96124	-3.4113	-3.1275	0.2901
	1st order differential	-53.537	-3.4324	-2.8623	-2.5672	0.0001	-53.537	-3.96124	-2.7623	-2.6672	0.0000

The results of the Dickey-Fuller and Phillips-Perron tests show that in both cases, the level of significance (probability) in the level test had values greater than 0.05. Therefore, the null hypothesis of data stationarity is rejected, but with one order of differencing, the level of significance changes, and stationarity is established.

Results of H1: The energy market experiences volatility during the study period.

The results of the univariate GARCH test for examining the first hypothesis are presented in tables 4 and 5.

The results of the volatility test in the energy market during the study period are presented in tables 4 and 5. Based on the Z statistic and its probability in the GARCH model, the results indicate that there are fluctuations and volatility spillover in the energy market (oil and gas). Therefore, it can be concluded that there is volatility in the energy market (oil and gas) during the study period.

Results of H2: The steel price experiences volatility during the study period.

The results of the volatility test in the global steel market are presented in table 6. Based on the Z statistic and its probability in the univariate GARCH model, the results indicate that there are fluctuations and volatility spillover in the global steel market. Therefore, it can be concluded that there is volatility and fluctuation in the steel market during the study period, and this hypothesis is confirmed.

Results of H3: There is a spillover effect of fluctuations from oil and gas prices to steel prices.

The results of the spillover effect of energy prices (oil and gas) on global steel prices using the diagonal BEKK GARCH model are presented in tables 7 and 8.

The results of the spillover effect of gas prices on global steel prices using the diagonal BEKK GARCH model are presented in table 7. In this test, if the level of significance for each variable is less than 0.05 and the test statistic is outside the range of ±1.96, it can be claimed that the changes in gas prices have a significant effect on steel prices. The corresponding values in row M (1,2) show the results of the spillover effect test of gas on global steel prices. As seen, the significance level of the test for gas prices on global steel prices is 0.0000, and the test statistic is Z=5.3165. Therefore, it can be claimed that spillover effects of gas prices on global steel prices exist.

Table 4. Gas market fluctuations using the univariate GARCH model.

Description	Variables	Coefficient	Z-statistics	Sig. level
Global Gas Prices	c	1.500105	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 using the univariate GARCH model.

Description	Variables	Coefficient	Z-statistics	Sig. level
Global Oil Prices	c	0.5406	2.781317	0.4346
	RESID(-1)^2	3.5548	88.1902	0.0000
	GARCH(-1)	0.3115	68.0158	0.0000

Reference: research findings

Table 6. Steel market fluctuations using the univariate GARCH model.

Description	Variables	Coefficient	Z-statistics	Sig. level
Global Steel Prices	c	3.12895	0.781510-	0.2173
	RESID(-1)^2	4.15202	75.1022	0.0000
	GARCH(-1)	0.2415	60.1543	0.0000

Reference: research findings

Table 7. The effect of gas price fluctuations on the global steel price using the diagonal BEKK model.

Description	Variables	Coefficient	Z-statistics	Sig. level
Global Gas Prices	M(1,1)	1.053205	5.692242	0.0000
	M(1,2)	2.633210	5.316506	0.0000

Reference: research findings

Table 8. The effect of oil price fluctuations on the global steel price using the diagonal BEKK model.

Description	Variables	Coefficient	Z-statistics	Sig. level
Global Oil Prices	M(1,1)	1.663794	6.038197	0.0000
	M(1,2)	0.936023	4.22156	0.0000

Reference: research findings

The results of the spillover effect of oil prices on global steel prices using the diagonal BEKK GARCH model are presented in table 8. In this test, if the level of significance for each variable is less than 0.05 and the test statistic is outside the range of ±1.96, it can be claimed that the changes in oil prices have a significant effect on steel prices. The corresponding values in row M (1,2) show the results of the spillover effect test of oil on global steel prices. As seen, the significance level of the test for oil prices on global steel prices is 0.0000, and the test statistic is Z=4.2215. Therefore, it can be claimed that spillover effects of oil prices on global steel prices exist. Thus, according to the results of the tables, a significant relationship can be observed between the energy price and the global steel price using the diagonal BEKK GARCH model.

4. Conclusions

The steel industry is considered one of the most important foundational and primary industries in the world, providing the basis for the creation and development of many other industries and activities. Today, over 1 billion tons of steel are produced annually worldwide, with the majority being produced in China and some other Asian countries. Steel industry products have a wide range of applications in various industries and sectors, and any changes in their supply and demand, quality, and price quickly affect other industrial and economic activities. On the other hand, energy (especially gas and oil) is a very important and influential factor in the production process and the final cost of these products. The energy required for different sectors and processes of production, transportation, and conversion of steel products is supplied from fossil fuels, especially gas and oil, and due to the huge energy consumption in these products, the possibility of replacing or using other energy sources has not yet been possible. The energy market, especially oil and gas, is constantly changing under the influence of global economic conditions and sometimes experiences turbulence in prices and, as a result, changes in supply and demand. The spread of volatility between financial indicators indicates the process of transferring information between markets. Despite the relationship between financial markets, information created in one market can also affect other markets. In this research, the daily data related to the price of energy (oil and gas) and the global price of steel in the 10-year period ending at the end of 2022 was collected and analyzed using GARCH and Granger causality models. The research findings indicate that the global price of energy (oil and gas) can have a significant effect on the price of steel in the market. Part of this effect can be related to the role of energy prices in the cost of steel industry products. Therefore, the fluctuation in the energy market, based on this study, spreads to the global steel market. This claim is strengthened based on some past researches. Given the high level of uncertainty and the nature of market fluctuations in today's world, adopting effective risk management strategies and risk hedging opportunities is essential. Risk hedging opportunities provide better conditions for investors to maintain an optimal portfolio, while also reducing portfolio risk. The variable coverage ratios over time show that investors need to constantly adjust their hedging strategies. In terms of policy implications, findings of this study provide valuable insights for investors, policymakers, and portfolio managers. With the increase in integration, regulators need to carefully monitor systemic financial risks and act carefully when observing market movements. Policymakers are recommended to promote financial liberalization reforms in commodity markets to strengthen the transfer of information. Given the evidence of volatility in the energy (oil and gas) and steel markets, analysts in the capital markets, commodity and energy exchanges, and other stakeholders are suggested to monitor periods of volatility in these markets and consider them in their decisions and analyses.

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