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Investigating the Impact of Oil Price and Exchange Rate Uncertainty on Stock Return using Whitening Linear Transformation and Vector Autoregressive Model

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This study aims at investigating the impact of oil price and exchange rate uncertainty on stock returns in Tehran Securities Exchange (TSE). To this end, "oil price uncertainty" and "exchange rate uncertainty" are considered as independent variables and "return on stocks" as the dependent variable. Daily data on the price of heavy oil, official exchange rate and Tehran Exchange Price Index (TEPIX) are used from 1 January 2002 to 31 December 2012. To evaluate the impact of oil price and exchange rate uncertainty on stock returns, the uncertainty is measured using Whitening Linear Transformation method and is estimated using the Vector Auto Regressive model. Results of the estimations of the model show that there is a significant relation between the uncertainty of oil price and stock returns and another between the uncertainty of exchange rate and stock returns. Thus, the hypothesis of this study are confirmed by the error level of 0/05.

Keywords: *Uncertainty, Stock Return, Whitening Linear Transformation, Vector Autoregressive Model*

JEL classification: E31, E44, G11

Introduction

In the traditional investment theories, it is assumed that investment decisions are made in a safe environment. But recently the investment literature has introduced uncertainty in models of investment, as well. In the previous theories two features of investment spending as irreversibility and waiting for new information are not considered. However, the two features mentioned make private investors more sensitive to uncertainties in macroeconomic variables and the uncertainty is of high degrees in developing countries like Iran (Kazerouni & Dowlati, 2001).

The fluctuation in oil price is one the things which has always been in the spotlight in oil importing and exporting countries. Rehman (2018) believes oil price shocks to any economy requires appropriate and timely response by the policy makers and this is because these shocks have the power to change relative prices, distribution of income, expectations about real interest and inflation rates and economic policy uncertainty. Moreover, current literature reports significant oil price effects on inflation and industrial production. The increase of the oil price in exporting countries leads to the increase of government revenue and ultimately helps the industry and manufacturing sector.

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On the other hand, the increase of oil price in importing countries leads to the increase of costs which is followed by increased costs of associated activities. In oil-depending economies, changes in oil price and volatility can be expected to influence also their equity markets (Dutta, Nikkinen & Rothovius, 2017), therefore is very necessary for portfolio managers, investors and policy makers to understand factors which affect the macroeconomic variables.

In addition to the oil price, fluctuations of exchange rate is another important factor which influence the volume of production in manufacturing companies and the income in trading and service companies, as supplying the locally produced goods and services in foreign markets are done using known currencies. Whereas, the more a country's exchange rate system tends to lean on floating exchange rate systems, the more the exchange rate volatility will be. Reducing exchange rate uncertainty may decrease the real devaluation required to improve the current account balance while avoiding a recession. According to Caballero & Corbo (1989), increases as small as 5 percentage points in the annual standard deviation of the real exchange rates can lead to a short-run decline in exports of 2.5 (Colombia) to 30 percent (Thailand and Turkey). These effects are substantially magnified in the long run.

Also, the performance of the capital market as one of the main economic hubs in any country is largely influenced by the oil price and exchange rate fluctuations by which many listed companies in the stock exchange will be strongly affected due to reasons such as supplying their required raw materials from other countries and offering their goods and services to foreign markets. Investors rebalance portfolios from stock to bonds in times of increased stock market uncertainty (Lin, Yang, Marsh & Chen, 2017). Chiang, Li and Yang (2015) further specify that the financial market uncertainty attributes to the bond market uncertainty as well as the stock market uncertainty. According to Mollick & Sakaki (2018), when global stock market returns increase, the currency with higher interest rate should appreciate against the currency with lower interest rate. As investors experience positive equity returns they borrow from low yield countries and invest in high yield countries, which leads to higher demand of the high yield currency. The currency with higher interest rate will thus appreciate.

In this paper, we are investigating the impact of oil price and exchange rate uncertainty on stock returns which would be very helpful to portfolio managers and investors for more exact predictions especially in oil-depended economies and emerging markets where volatilities in exchange rates is quite high. Results confirm the impact of uncertainties in oil price and exchange rate on stock returns. In the next section, theoretical literature is reviewed and is followed by research methodology presentation. Subsequently, research findings are presented and, finally, the conclusion of the study is drawn.

Literature Review

The relation between macroeconomic variables' uncertainty (such as oil price, exchange rate, inflation, etc.) and stock return has received increasing attention over the past years. Taking Golob's view (1994) into account, the uncertainty caused by the variables' fluctuations has two economic effects: first it makes economic agents including enterprises and consumers make economic decisions different from what they expected. Analysts refer to these effects as "ex-ante" because in these decisions the predicted variable value is considered. The second category of effects are found after the decision making and are called "ex-post" effects. This happens when the actual value is different from what was predicted.

Human beings are unwilling to take any risks facing the distributions of unknown possibilities. Generally, people are hesitant in ambiguous situations and they exhibit a tendency which is called "Ambiguity Aversion Bias". The individual investors' behavior represents Ambiguity Aversion Bias. Investors' uncertainty about the distribution of returns of financial instruments, is the most obvious situation. Pascal Maenhout (1999) showed that if investors are uncertain about the return of a share,

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they demand more risk premium to compensate for the ambiguity in the probable distribution which they have imagined (as cited in Pompian, 2006).

Growford and Kasnovic (1996) and Gierre and Perre (1998) believe that uncertainty is the opposite choice of the risky event that a particular possibility can be attributed to an incident. If future changes in economic variables consist of the total anticipated and unanticipated changes, uncertainty is an economic variable that includes its unpredictable part (as cited in Heidari & Bashiri, 2011). Dreze (1999) states that uncertainty refers to a situation in which the probability of future incidents cannot be determined. Emami and Salmanpour (2006) define uncertainty as unpredictable changes (as cited in Arshadi, 2011). Heidari and Bashiri (2011) believe that uncertainty is a situation in which decision-makers and economic agents are not sure about variables' amount and direction of change. The uncertainty caused by various sources leads to changes in procedures and decisions of economic agents which ultimately influences their actual activities. Grigoli, Herman, Swiston & Dibella (2015) have expressed that uncertainty makes us face some problems in determining an appropriate policy and proposing a proper definition of economics.

The benefit and profit of investment are called 'return'. An investment return is achieved through price changes, dividend per share, benefits of the right of priority purchase of shares and benefits from share or bonus share profits. The return of investment includes the quantitative return (accounting earnings such as EPS and capital gain) and qualitative return (company's credibility, social benefits and the potential impact on socio-economic trends). On the other hand, return can also be divided into two categories of 'past returns' and 'future returns' in terms of time.

The exchange rate literature points out that the out-of-sample predictive power of the empirical exchange rate models is erratic (Byrne, Korobilis & Ribeiro, 2018). Rogoff and Stavrakeva (2008) and Rossi (2013) believe models that forecast well for certain currencies and periods often fail when applied to other exchange rates and samples.

Kouchakzadeh and Jalaei (2014) investigated the effects of exchange rate uncertainty on the growth of Iranian economic sectors and concluded that the influence of exchange rate uncertainty on the growth of the industrial sector was more than the others (agricultural and service).

Heidari and Bashiri (2012) studied the relation between the uncertainty of the real exchange rate and the uncertainty of stock price with the real exchange rate and the stock price index in the bivariate GARCH model using monthly data from 1999 to 2011. The results of this study showed no significant correlation between the stock price index and the real exchange rate uncertainties.

Ebrahimi (2011) investigated the effect of oil price shocks and exchange rate fluctuations and uncertainties resulting from them on the economic growth of MENA countries. This article shows that there is a long-term relation between the oil price, exchange rate and production in the four countries studied (Algeria, Iran, Saudi Arabia and Venezuela). In these countries, there is a positive long-term relation between the oil price and the production growth and a negative long-term relation between the exchange rate and production growth.

Researchers have recently found a strong link between crude oil and stock markets which is very crucial to investment diversification and risk management (Fang, Chen, Yu, Xiong, 2018). Dutta et al. (2017) show that the oil market uncertainty has substantial effects on the realized volatility of most of the markets under study. Findings also reveal that, even after controlling for the effect of the implied volatility index of S&P 500 (VIX), the impact of the oil volatility index on the Middle East and African equity markets still holds for almost half of the markets considered.

Arshadi (2011) concludes that there can be observed a conditional variance structure in oil price changes in Iran. In addition, while measuring the uncertainty index in terms of conditional variance obtained, it can be seen that the fluctuations of this variable is mainly in the range of 0 to 3 percent.

Kang, Ratti & Yoon (2015) examined the effect of structural oil price shocks on stock market returns covariance and the volatility of stock market in the USA, concluded that there is a relation between positive shocks in aggregate and oil market-specific demands and the covariance of returns and volatilities.

In another research Kang and Ratti (2013) said that the oil market-specific demand shocks are in charge of 30 percent of economic policy uncertainties after 24 month and this amount increases to 58 percent in longer periods of time. The uncertainty of economic policies is responsible for 19 percent of long-term changes in the real stock returns and oil price shocks for 32 percent of them.

Although the link between oil price and exchange rate has been widely investigated, the results are mixed. Reboredo (2012) in "the analysis of the correlation between oil price and exchange rate changes" concludes that there is a poor relation between the increase of oil price and the devaluation of the USD and vice versa. Of course, the intensity of this movement differs for different currencies. Mollick & Sakaki (2018) point out that some empirical evidence contains evidence of cointegration between exchange rate and oil prices with causality running in both directions. Some studies show that an increase in oil price leads to U.S. dollar appreciation while others find, however, that increases in oil price cause U.S. dollar depreciation against other currencies.

Research Methods

In the theoretical literature and literature review of this study, the data collection is done using library research method. In addition to referring to sources like books, articles and published materials on scientific websites, we use information available in the databases of Central Bank of the Islamic Republic of Iran, the Ministry of Petroleum, the security and exchange organization (SEO) of Tehran, Shaygan Energy Consultants and Economics and the Rahavard Novin data bank. Daily data on the price of heavy oil, official exchange rate and Tehran Exchange Price Index (TEPIX) are used from 2002:1 to 2012:12. The data analysis is done through descriptive and inferential statistical techniques.

First, we have used whitening linear transformations to determine the uncertainty of the exchange rate and oil price. These transformations transform a set of time series vectors to uncorrelated white noise vectors with the variance of 1 and an average of 0. Hence, in order to control the autocorrelation of the components of time series and equalizing its variances, these transformations appear in ARIMA form. The output of this process, is a vector of the main variable value which is acceptable as white noise. The transformed time series values achieved by this method will be tested to control the variance consistency and stability. If the consistency and stability of variance is approved, they will be used as an index for uncertainty. Otherwise, other transformations will be done on the data.

Then, we have used Dicky-Fuller test to measure the stability of variables and the results of Johansen Juselius test to determine the number of co-integration vectors. In case of variables having the same degree of stability, we have used the estimations of VECM model to measure short-term relations between the variables. This model, which was introduced by Christopher A. Sims (1980), is widely used as a linear model in multivariate linear models. This can be considered as an extension of a single variable autoregressive model.

Generally it can be said that in Sims's method, the distinction between endogenous and exogenous variables is not taken into account. Each equation in this method has the same set of regressors which lead into the formulation of the general pattern of autoregressive vectors which you can see below:

$$Y_t = \sum_{i=1}^{p} A_i Y_{t-1} + \varepsilon_t \qquad (1)$$

Y_t is a column vector of observations at time t than all model variables. Y_t is a column vector of stochastic disturbances values which can be correlated simultaneously. A_i is the parameters matrix and is nonzero. In practice, expressions including intercept, seasonal virtual variables and temporal trends can be added to the general autoregressive vector pattern.

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Table 1. Determining the optimal lags of the model

Optimal Lag	HQ	BIC	AIC	FPE
1	29.76392	29.77051	29.76001	1.69E+09
2	29.70856*	29.73493*	29.69292	1.58E+09
3	29.71790	29.76404	29.69053	1.57E+09
4	29.71916	29.78508	29.68007	1.56E+09

Table 2. The results of the study assumption in the vector autoregressive model

Dependent variable / Independent variable	CUR_UNC	OIL_UNC	ΔR
ΔR (-1)	Beta = 0.006455	Beta = -0.000150	Beta = 0.270877
	Std. = (0.02845)	Std. = (0.00029)	Std. = (0. 02472)
	T-value = [0.22690]	T-value = [-0.51295]	T-value = [10.9600]
OIL_UNC (-1)	Beta = -0.735600	Beta = 0.014153	Beta = 1.938355
	Std. = (2.50635)	Std. = (0.02568)	Std. = (0.57735)
	T-value = [-0.29349]	T-value = [0.55118]	T-value = [3.35733]
CUR_UNC (-1)	Beta = -0.002697	Beta = 2.51E-05	Beta = 0.202303
	Std. = (0.02562)	Std. = (0.00026)	Std. = (0.02226)
	T-value = [-0.10528]	T-value = [0.09548]	T-value = [9.088185]
C	Beta = 0.190961	Beta = 0.007117	Beta = 14.17878
	Std. = (4.23786)	Std. = (0.04342)	Std. = (3.68157)
	T-value = [0.04506]	T-value = [0.16392]	T-value = [3.85128]
Coefficient of determination	0.010290	0.010350	0.574660
Corrected coefficient of determination	0.001877	0.001616	0.572840
F-statistic	0.045806	0.178028	41.014300
Schwarz criterion	13.058060	3.896143	2.177662

Results and Discussions

The summary of descriptive statistics of variables show that the average stock index over the study period was 12970.34 and the average exchange rate was 9384.108. The average heavy crude oil price had been 63.68797 USD. Results show that the average oil price uncertainty was 0.0041 and the average concentration index for the exchange rate uncertainty was 0.2467.

Then, to evaluate the stability of test variables, the Phillips-Perron's test has been used. The test checks the hypothesis of existing a unit root in series values. Results of this study show that the stock index was unstable and in I (0) level and had a significantly lower amount than 0.05 in I (1). However, exchange rate and oil price indices were stable in I (1) level. Hence, it can be concluded that there is a co-integration relation between the stock index and the exchange rate and oil price uncertainties. Thus, Johansen co-integration test has been used to determine the number of co-integration vectors between variables.

According to the findings of this test, it can be seen that based on both trace and maximum eigenvalues tests the number of co-integration vectors among the study variables were estimated up to 2 times.

Determining the Model's Optimal Lag

In order to determine the optimal lags of the vector autoregressive model of the study, it has been invoked to each of the indicators of Final Prediction Error (FPE) including Akaike Information Criterion (AIC), Schwarz Information Criterion (BIC) and Hannan-Quinn Information Criterion (HQ). The findings of this part have been summarized in table 1.

According to each of these indices, it can be seen that the lowest estimate for each of the indicators to determine the optimal lags has been in lag 2. Therefore, the vector autoregressive model with the lag of 2 has been fitted among the study variables.

Estimation of Vector Autoregressive Model

Table 2 summarizes the findings of vector auto regressive model with proper distributed lags according to Schwarz Bayesian Criterion.

Table 3. Estimation of short-term effects of exchange rate and oil price uncertainties on stock returns

Co-integration vector variable	Coefficient	Estimation error	Test statistic	Result
ECM1	0.00049	0.00085	0.57652	-
ECM2	-0.658704	0.25998	-2.53367	-
D(ΔR (-1))	-0.43138	0.0232	-18.5974	significant
D(OIL_UNC (-1))	2.577867	0.76163	3.38467	significant
D(CUR_UNC (-1))	0.015876	0.0252	0.63001	-
Coefficient of determination: 0.585462		Corrected coefficient of determination: 0.583323		
AIC: 1.301178		F-statistic: 86.69304		

Table 4. Normality and serial correlation of error components tests

Test	Test statistic	Significance level
Jarque-Bera (Normality)	9.24328	0.1052
LM (Autocorrelation)	11.2132	0.1187
Kai-square (variance homogeneity)	8.0564	0.6672

According to the goodness of fit indices of the study, we can see that the corrected coefficient of determination of the model with the dependent variable, the stock index is 0.572 which is preferred over other models. In the Schwarz model for determining the optimal model with the variable, the stock index equals to 2.177; it has been less than this amount in other models that this criterion is proved to be preferred over the stock index model. The F statistic values are more than its critical value in direction of the general significance of the study which shows the statistical significance of all models at the error level of 0.05. The estimation of impact coefficients of uncertainty indices in the model with the endogenous variable of stock index shows that the exchange rate uncertainty (T-value=9.088) and oil price uncertainty (T-value=3.357) have a positive relation with the stock index at the error level of 0.05. According to impact coefficients of these two indices on stock index which is positive, we can conclude that there is a direct and significant relation between exchange rate and oil price uncertainties and stock index; with the increase of uncertainty in each of these factors, the stock index will increase. So, the hypotheses of the study were proved at the error level of 0.05.

Estimation of Short-term (VECM) of Vector Autoregressive Model

In order to identify the size of the short-term effect of exchange rate and oil price uncertainties on stock index, we used the VECM model. Table 3 shows the details of the estimations of VECM model.

According to the short-term impact coefficient of exchange rate uncertainty on stock index which is 0.0158 and also statistically significant, it can be concluded that exchange rate uncertainty influences stock index directly. Also, the short-term impact coefficient of oil price uncertainty which is 2.577 and statistically significant shows direct influences of the index on stock index. Based on the findings of feedback coefficient ECM which measures the endogeneity of each of model variables and its long-term causal relation with the dependent variable, exchange rate and oil price uncertainties have endogenous effects on stock index. Therefore, there existed a short-term relation between exchange rate and oil price uncertainties and the stock index according to the findings of vector error correction model. Based on findings of this model, about 65.87% of the imbalance in the short-term relation of variables moves towards a balanced long-term relation in each period of time.

Testing the Remained Effects

After estimating the vector autoregressive equation of the study model, normality and variance homogeneity of error components of the model and also serial autocorrelation of error components were done. Table 4 summarizes the findings of these tests.

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Table 5. The analysis of stock index variance in terms of oil price and exchange rate uncertainties

Period	Standard deviation	Exchange rate uncertainty	Oil price uncertainty	Stock index
1	161.6311	0.004667	0.003023	99.99231
2	186.0486	0.000134	0.006811	99.99305
3	222.3903	0.012565	0.027623	99.95981
4	247.6532	0.012828	0.025133	99.96204
5	272.8527	0.015398	0.026754	99.95785
6	294.9941	0.016242	0.026503	99.95726
7	315.9549	0.01721	0.026823	99.95597
8	335.4589	0.017827	0.026873	99.9553
9	353.9509	0.018368	0.026988	99.95464
10	371.4985	0.018791	0.027052	99.95416

Analysis of Variance and Analysis of Shocks

In this section, the effect of the shock to the special variable on the other ones will be investigated using the impulse response function (IR). The dynamic interactions of the impulses created in the system will be analyzed through the analysis of the variance and response functions. The variance analysis of the variables shows the feasibility of the model's variables over time. Table 5 summarizes the results of the variance analysis test of market index in terms of two variables as exchange rate uncertainty and oil price uncertainty.

According to the analysis of stock index variance, it is clear that in all short-term, medium-term and long-term periods, most of the changes in stock index were justifiable by the index itself and only a small part of the changes were accounted for by the exchange rate and oil price uncertainties. Although the results show that the explanatory role of exchange rate and oil price uncertainties in explaining the changes in stock index was more significant in short-term than in long-term and although the results are explained by the ascending values of variance of exchange rate and oil price uncertainties, more than 99% of stock index changes can be explained by the index itself and exchange rate and oil price uncertainties only controlled 1% of the changes.

Conclusion

In this study, the estimation of vector autoregressive model has been used to measure the effect of exchange rate and oil price uncertainties on stock returns. Results from the model's estimations and uncertainties obtained from whitening linear transformation method showed that there is a significant relation between oil price uncertainty and exchange rate uncertainty and stock returns.

According to the above results and the inconsistency of the findings of different researchers (as discussed in literature review), we can come to the conclusion that uncertainty measurement methods in economic macro indicators are important in determining the overall results. However, it should be noted that the type of relationship between variables is not necessarily linear. It should also be noted that the vector autoregressive models, and many other methods the possible distribution of macro indicators is assumed as a normal one, while the results of recent studies indicate that the economic indicators and particularly the ones in the capital market are skewed. Therefore, assuming a normal behavior of the variables cannot reflect indices' possible behavior and changes

Findings of this study provide interesting implications for investors, portfolio managers and firm managers to better predict fluctuations in stock market return against volatilities in oil price and exchange rate.

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