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IDENTIFYING THE INTER-DYNAMICS BETWEEN GOLD PRICES OF TURKEY AND KEY ECONOMIC INDICATORS: AN APPLICATION OF THREE DIFFERENT MODELS

Abstract. *In this study, we examine the comparison of three models (ARIMAX, GARCH, and NARX) based on their forecasts and find out the factors affecting the gold prices in the case of Turkey. For this, the monthly data from January 1997 to December 2021 have been used. This study provides evidence that NARX is the best model and ARIMAX is a better model for forecasting. This study also points out that the prices of other precious metals, i.e., platinum and silver, have a significantly positive relationship with the gold prices irrespective of the model. Moreover, on the basis of ARIMAX, Turkey's XU (100) Stock Exchange closing price and Crude oil Brent Prices have a significant negative relationship with the gold prices.*

Keywords*: Neural Network, Gold Price, ARIMAX, GARCH, and NARX*

JEL Classification: C32, C45, E37, G17

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1. Introduction

Oil is an important indicator of the price level of many commodities as the most frequent input for the production process followed by copper, platinum, and palladium. On the other hand, during periods of increased economic and political uncertainty metals like gold, silver, copper, etc. serve as a means of store of value. Due to economic fluctuations and to combat inflation, these metals are considered investment vehicles, and are considered safe investments. The markets for such commodities are expected to be tied and the investment demand is increasing due to financialization of commodities and their diversified industrial use. In this regard many studies such as (Pindyck and Rotemberg, 1990; Baffes, 2007; Le and Zhang, 2015; Lutz and Park, 2009; Lescaroux, 2009; Zhang and Wei, 2010; Turhan et al., 2014; Bildirici and Turkmen, 2015) show a strong association between oil prices and metal prices.

Models using linear or non - linear regression have been used by many researchers, but the opinions still vary. If (Zhang and Wei, 2010) claim a linear relationship between oil prices and metals, (Bildirici & Turkmen, 2015) argue a non-linear relationship between commodity variables. (Lau et al., 2017; Turhan et al., 2014) showed that the relationship between prices of oil and precious metal is also found to be different and shows that the regime-dependent model can capture the relationship between oil and precious metal prices better than regime-independent models. Also (Bhar and Hammoudeh, 2011; Balcilar et al., 2015) argue that due to high-volatility regime the impact of oil prices shock on precious metal prices is much higher, but in the same researcher paper Balcilar found that the changes are more frequent due to financial crisis.

In the past, many researchers used methodologies to analyse the correlation between oil and precious metals, but they were not conclusive enough. In the last years, this subject started to spark the interest and Alana and Tripathy (2014) showed that increasing speculative activities in emerging economies lead to more uncertainty and volatility in the commodity markets. The volatility can affect the economic growth pattern of nations. As a result, the correct modelling of volatility in metal markets is a crucial issue, which on one side increases the ability to generate more accurate out-of-sample forecasting of prices for policymakers, and on another side facilitates value-at-risk management strategies for financial traders (Behmiri and Manera, 2015).

2. Literature review

The literature highlights three major transmissions of the association between oil and metal prices: First, the oil-metal prices correlational association (Baffes, 2007), second, the long-term causal association of oil-metal prices (Zhang and Wei, 2010; Sari et al., 2010), and third, the impact of oil price shocks on metal prices(Hammoudeh & Yuan, 2008; Pindyck and Rotemberg, 1990; Baffes, 2007), find a direct correlation between oil prices and commodity prices and this relationship can be found stable even if the frequencies of data were daily, weekly, monthly or annually. (Baffes, 2007; Lescaroux, 2009) explained that the shock in oil prices is instrumental to bring major shocks in metal prices.

Taking into account these studies, (Turhan et al., 2014) argue that positive and significant correlation between oil and gold tends to increase in the future. With regard to time horizon, mixed results were found for the impact of oil prices on metal both in the short- and long-run. For example, (Soytas et al., 2009; Sari et al., 2010) found a significant influence of oil prices on metals in short-run and long-run. If Soytas notes a momentous influence of oil prices on metals (gold and silver) in the short-run, (Sari et al., 2010; Jain and Ghosh, 2013) found an insignificant association between oil and metal prices in the long-run. On the opposite side (Chang et al., 2013) find no association between oil and metal (gold) prices in short run and long run. What we can say is that the majority of the studies on the oil-metal prices find their cointegration in the short-run, but not in the long-run.

If association between oil and metal prices was found null or unidirectional by some researchers like (Zhang and Wei, 2010; Sari et al., 2010), in other studies a highly insignificant bidirectional association was found whereas (Zhang and Wei, 2010), shows a one-way relationship from oil to metal prices. (Bildirici and Turkmen, 2015) present a quadratic association between oil-metal prices, which denotes a non-linear effect of change in oil prices on metal. All these findings may be due to the heterogeneity in the techniques used.

The above discussed studies investigate the oil-metal prices association by employing “regime independent models”, but (Kim et al., 2008) found that using such data in regime independent models and employing traditional OLS for analysis can give unstable parameters. In this context, according to Lee and Chen (2006), employing the models with “regime switching” may have better performance. On the other hand, (Bhar and Hammoudeh, 2011) stated that employing the VAR model, a significant dependent association between oil and metal prices and a higher impact of oil return on metal’s returns was found in the period of higher volatility regime. Other researchers, e.g., (Ewing & Malik, 2013; Turhan et al., 2014; Balcilar et al., 2015; Lau et al., 2017), using regime-dependent cointegration, found cointegration between oil and metal prices in the presence of peculiar structural breaks.

Reviewing the literature reveals that oil and metal prices can be linked through volatility dependences, economic transmission, market efficiency, and price comovements but it is hard to find any consensus among the studies on this association. Most of the results are of mix nature and in some cases extremely contrary and may be due to the heterogeneity in techniques used for analysis.

3. Research methodology

The data of Gold Prices (GD) for Turkey (our target/dependent variable) has been taken from Istanbul Stock Exchange, Yahoo Finance, and Turkey Capital Market. The factors that can affect this target variables are Inflation in Turkey (IF), Exchange Rate of Turkish Lira to US Dollars (ER), Interest rate in Turkey (IR), Turkey XU (100) Stock Exchange closing price (SE), Crude oil Brent Prices (CO), Platinum Price (PL), Silver Price (SL), and Steel Index with 2010 as base (ST). The data is monthly and ranges from January 1997 to December 2021 giving us a time span of 24 years. In Figure 1 the correlation structure among the variables is presented.

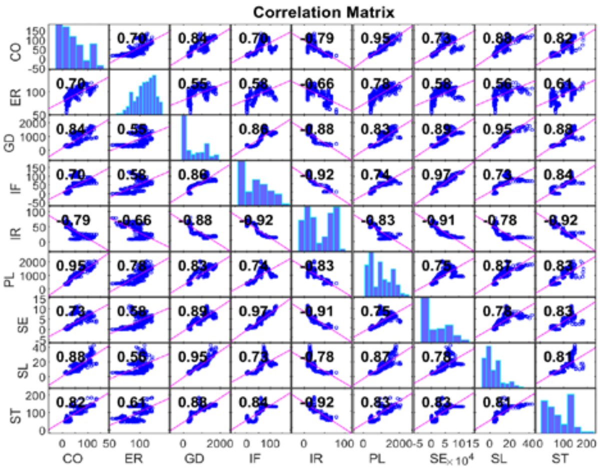

Figure 1. Correlation Matrix – MATLAB

Source: Authors' own processing

From Figure 1, it can be observed that all of the time series involved here are highly correlated with each other having more than 50% correlation. The descriptive statistics of the variables involved are presented in Table 1.

Table 1. Descriptive Statistics

	CO	ER	GD	IF	IR	PL	SE
Mean	51.13203	93.89545	738.0078	46.61677	35.59583	910.1961	34869.74
Median	43.83235	96.21756	438.6525	44.80304	28.00000	866.5300	25849.60
Maximum	133.8730	120.0335	1772.140	125.6442	79.00000	2052.450	115333.0
Minimum	9.800000	53.85119	256.0800	0.180468	8.750000	342.6000	43.83010
Std. Dev.	34.19744	14.15229	467.5363	36.81516	21.24739	472.7968	31450.22
Skewness	0.694095	-0.43	0.636311	0.290124	0.155936	0.455078	0.510019
Kurtosis	2.196872	2.470747	1.924524	1.926955	1.507539	2.008302	1.962612
Jarque-Bera	32.15108	12.82946	34.70270	18.60143	29.05878	22.64811	26.45815
Probability	0.000000	0.001637	0.000000	0.000091	0.000000	0.000012	0.000002

Source: Authors' own processing

It can be observed from Table 1 that all of the time series involved are Non-Normal according to Jarque-Berra test (Jarque and Bera, 1980). Moreover, all the time series involved here are either positively or negatively skewed, as it can be observed in both the Figure 1 and Table 1. To encounter it, we have taken Natural logarithm of each time series. As it is a one-to-one transformation, it does not affect the inferences.

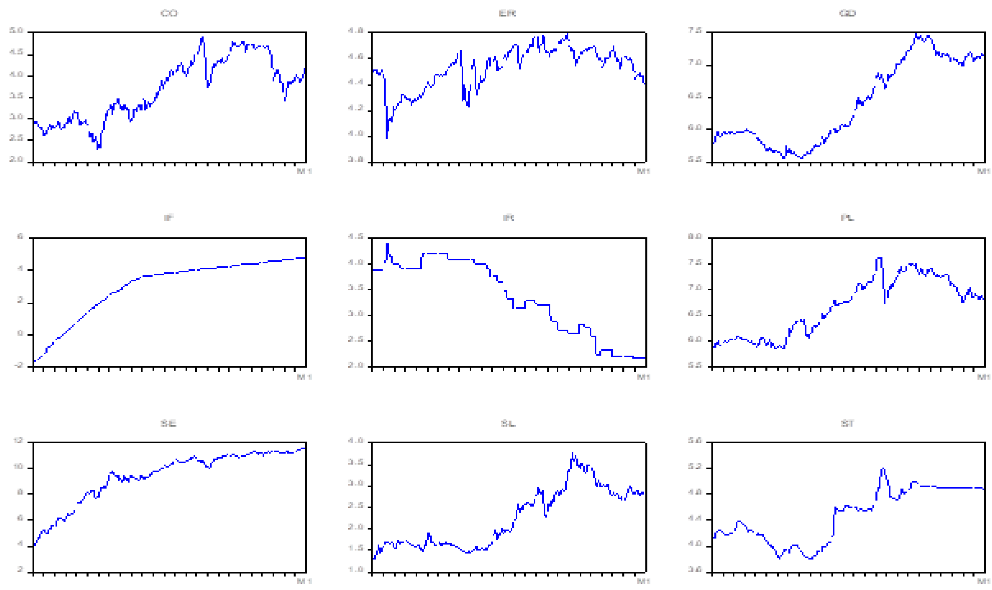

Figure 2. Time Series Graphs
Source: Authors' own processing

The time series graphs are shown in Figure 2. Some of the graphs of time series are showing an overall positive and direct relation with time, as they have an overall increasing pattern with respect to time, and these time series are CO, GD, IF, PL, SE, SL and ST. One time series, i.e. IR is showing a declining pattern with respect to time. Moreover, one time series i.e. ER has a mixed behaviour, firstly it decreased, then it increased, and at the last it is again decreasing.

Methods:

To pursue our objectives, first we have to test each time series for a possible unit root. The Augmented Dicky Fuller (ADF hereafter) test (Dickey & Fuller, 1979) will be used to determine the order of integration of each time series. ADF tests the Null hypothesis of Unit Root against the Alternative hypothesis of Stationarity. After determination of the order of integration, three different Models will be used to capture the interdynamics whose details are:

ARIMAX Model:

The permanent (persistent) model is the simplest estimation method. This method assumes that the wind speeds are same at time t + h and time t.

$$\hat{y}_{t+h} = y_t$$

This technique is based on the high correlation assumption between future and current wind speed values. In fact, this simple model is effective in short-term estimation (minutes to hours). As expected, accuracy decreases rapidly as the estimation time increases.

The p-th order autoregressive and q-th orders moving average ARMA (p, q) model is written as:

$$y_t = \alpha + \sum_{i=1}^{p} \phi_i y_{t-i} + \sum_{j=1}^{p} \theta_j \epsilon_{t-j} + \epsilon_t$$

, wind speed at t, α constant, autoregressive coefficient, θ_j moving average coefficient and residuals of the time series which have mean zero mean and variance σ2. The above ARMA(p,q) model is for the stationary time series i.e. for I(0) and if a time series is non-stationay i.e. either it is I(1) or I(2) or more generally I(d) then the above ARMA transform into an ARIMA(p,d,q) Model written as

$$y_t^d = \alpha + \sum_{i=1}^{p} \phi_i y_{t-i}^d + \sum_{j=1}^{p} \theta_j \epsilon_{t-j} + \epsilon_t$$

Where y_t^d is the I(d) stationary time series after taken “d” successive differences. Another extension of this ARIMA(p,d,q) model is ARIMAX(p,d,q) in which one can use “k” exogenous regressors “X” and it is written as:

$$y_t^d = \alpha + \sum_{i=1}^{p} \phi_i y_{t-i}^d + \sum_{j=1}^{p} \theta_j \epsilon_{t-j} + \beta X + \epsilon_t$$

GARCH Model:

The ARIMAX model assumes that the variance (volatility) is constant over time. However, the GARCH(a,b) model (Bollerslev et al., 1994) takes into account variance and it assumes that the variance is not constant over time, rather it varies with time through an infinite autoregressive process, i.e.

$$\sigma_t^2 = \omega + \sum_{i=1}^{a} \beta_i \sigma_{t-i}^2 + \sum_{j=1}^{b} \alpha_j \epsilon_{t-j}^2 + \epsilon_t$$

$$\epsilon_t = \sigma_t z_t, \qquad z_t \sim N(0,1)$$

Where $\alpha \geq 0, \beta \geq 0$, $\omega > 0$ are constant. This model is conditional Autoregressive Heteroskedasticity with respect to variance σ_t^2 .

ARIMAX-GARCH model combines ARIMAX and GARCH models and can be written as:

$$y_t^d = \alpha + \sum_{i=1}^{p} \phi_i y_{t-i}^d + \sum_{j=1}^{p} \theta_j \epsilon_{t-j} + \beta X + \epsilon_t$$
$$\epsilon_t = \sigma_t z_t, \qquad z_t \sim N(0,1)$$
$$\sigma_t^2 = \omega + \sum_{i=1}^{a} \beta_i \sigma_{t-i}^2 + \sum_{j=1}^{b} \alpha_j \epsilon_{t-j}^2 + \epsilon_t$$

Neural Networks Model:

The Neural Networks s model structure consists of inputs (variables), layers, and outputs. The whole layout of the NARX model is shown in Figure 3.

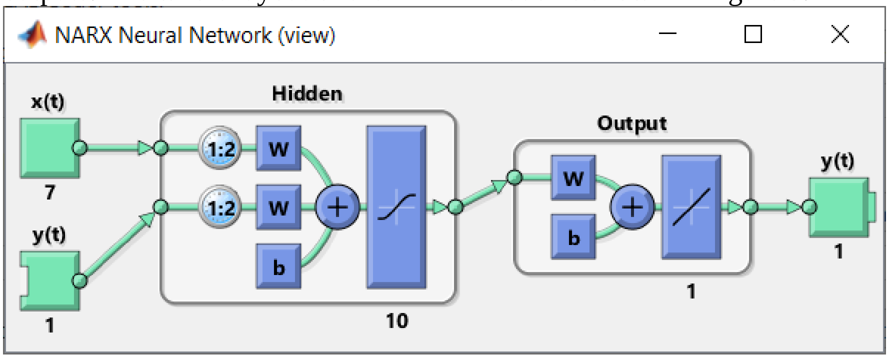

Figure 3. NARX layout

NARX predicts the future values by means of input xt and past obtained yt i.e.

$$\hat{y}_t = f(\hat{y}_{t-1}, \dots, \hat{y}_{t-n_{\hat{y}}}, x_{t-1}, \dots, x_{t-n_x})$$

Where $\hat{y}$ is the predicted value, x the input, $n_{\hat{y}}$ lag of feedback, and n_x the lag of input Each activation function in hidden layer and output layer is a hyperbolic tangent sigmoid transfer function and linear function. In the training network, back propagation is used, and then the weight is determined as minimising Mean Square Error:

$$MSE = \frac{1}{n} \sum_{i=1}^{N} (y_t - \hat{y}_t)^2$$

In a recurrent neural network, the features of each neuron and the training by BP (back propagation) are the same as NARX. The past output of the hidden layer is fed back to the input in RNN while the past output of the estimated value is fed back to the input NARX.

$$\hat{y}_t = f(h_{t-1}, \dots, h_{t-n_h}, x_{t-1}, \dots, x_{t-n_x})$$

Where $\hat{y}_t$ is the output of the hidden layer, and h_{t-i} the lag of feedback of the hidden layer.

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{N}(y_t - \hat{y}_t)^2}$$

$$R^2 = 1 - \frac{\sum_{i=1}^{N}(y_t - \hat{y}_t)^2}{\sum_{i=1}^{N}(y_t - \bar{y}_t)^2}$$

4. Results and Discussions

All time series were investigated on their order of integration using the ADF test and it was found that all time series are I(1). The results are depicted in Table 2.

Table 2. ADF Test Results

Time Series	At Level			At First Difference			Conclusion
	None	Intercept	Trend	None	Intercept	Trend	
GD	2.109	-0.263	-1.229	-15.046 ***	-15.226 ***	-15.206 ***	I(1)
CO	0.405	-1.421	-2.169	-14.059 ***	-14.064 ***	-14.04 ***	I(1)
ER	-0.204	-2.839*	-3.596 **	-12.378 ***	-12.358 ***	-12.341 ***	I(1)
IF	-0.333	-8.430 ***	-4.359 ***	-1.509	-2.082	-3.649 **	I(1)
IR	-1.797*	0.224	-2.635	-17.234 ***	-17.412 ***	-17.474 ***	I(1)
PL	0.623	-1.554	-1.428	-12.897 ***	-12.909 ***	-12.941 ***	I(1)
SE	2.762	-3.818 ***	-2.982	-16.707 ***	-17.356 ***	-17.733 ***	I(1)
SL	0.686	-1.324	-1.713	-14.220 ***	-14.270 ***	-14.262 ***	I(1)
ST	0.675	-1.139	-2.077	-9.726 ***	-9.750 ***	-9.735 ***	I(1)

Note: ***, ** and * indicates the rejection of null hypothesis at 1%, 5% and 10% level of significance respectively.

As already discussed in the methods three model have been estimated. The Correlogram of Gold (Figure A-1 in Appendix) suggested p=1 and q=1 for ARIMAX model so ARIMAX(1,1,1) model is estimated (Table A-1 in Appendix is the EVIEWS output). Similarly using the same specification i.e. ARIMAX(1,1,1) a GARCH(1,1) model has been estimated (Table A-2 in Appendix is the EVIEWS output) as suggested by (Bollerslev et al., 1994). Similarly, the NARX model has been estimated and its output regarding the loss function have been detailed out in the Table 3. However, as the NARX cannot provide us with the coefficients of each time series, so they are not given. The results of these three models are depicted in Table 3. Then these models have been used to get the forecasts of Gold Prices (Figure A-2 for ARIMAX forecasts, Figure A-3 for GARCH(1,1) forecasts and Figure A-4 for NARX forecasts in the Appendix). The Root Mean Square Error (RMSE), Mean Absolute Error (MAE) and Mean Absolute Percentage Error (MAPE) from these forecasts have also been put in Table 3 to make the comparison between the three models.

Table 3. Three Models Results

Time Series (X)	ARIMAX(1,1,1)	GARCH(1,1)	NARX
C	0.004676**	0.003322	--------
D(CO)	-0.028692*	-0.026172	--------
D(ER)	-0.012247	0.011229	--------
D(IF)	-0.056987	-0.045401	--------
D(IR)	0.012413	0.011420	--------
D(PL)	0.192742***	0.182736***	--------
D(SE)	-0.032156***	-0.015170	--------
D(SL)	0.325010***	0.326228***	--------
D(ST)	-0.052922	-0.047918	--------
AR(1)	-0.366197	-0.299045	--------
MA(1)	0.540270***	0.536825***	--------
SIG-MASQ	0.000568***	--------	--------
RMSE	0.187231	0.221796	0.105123
MAE	0.147342	0.191545	0.04186
MAPE	2.408595	3.017750	0.003546

Note: ***, ** and * indicates the rejection of null hypothesis at 1%, 5% and 10% level of significance respectively

From Table 3, it is evident that the NARX model is much better at forecasting as compared to ARIMAX and GARCH as it has the least MSE, MAE and MAPE. The second better model at forecasting the gold prices is the ARIMAX model as it has a lesser MSE, MAE and MAPE as compared to GARCH. The results of ARIMAX suggest that PL, SL, and MA have a highly significant and positive impact on GD. Whereas, SE has a highly significant negative impact on GD and CO has significant (at 10% level of significance) negative impact on GD. The rest of the time series are insignificant. The results of the GARCH model support the results of the ARIMAX model in the direction of impact but not in the significance level. The CO and SE have insignificant negative impact on GD, according to GARCH as opposed to ARIMAX where they have a significant impact. The rest of the results are the same.

5. Conclusions

There are so many factors that can affect the gold prices and for the Turkey, this study is intended to find out those factors. Another aim of this study is the comparison of the forecasts of three famous models, i.e., ARIMAX, GARCH, and

NARX. However, the third model NARX is a neural network model, a non-structural one and it cannot tell us what factors are important. It has been concluded that of these three models the NARX is the best forecaster, and ARIMAX is a better one. However, the GARCH model being the poor forecaster from these three is the best in describing the structure and inter-relationship of the time series.

It is also concluded that silver and platinum prices play a very significant role in determining the gold prices and they have a positive relationship. Furthermore, the Turkey's XU (100) stock exchange closing price and crude oil Brent prices also play a role in determining the gold prices, however, their relationship is negative. Therefore, it is recommended for the investors that if they are interested in portfolio diversification, then they may diversify their portfolios by investing in precious metals (Gold, Platinum and Silver) and in Turkey XU (100) Stock Exchange or in Crude oil market. Moreover, to predict the future prices of gold for the planning of investment strategies, they may look at the prices of other precious metals and Turkey XU (100) Stock Exchange closing price (SE) & Crude oil Brent Prices (CO).

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