Gold Price Forecasting Using ARIMA Model

این مقاله بطورکلی تلاش کرده با استفاده از مدل آرما داده های قیمت طلا را پیش بینی کند. با توجه به اینکه داده ها بصورت time series هستند مدل آریما را انتخاب کرده ایم.حال باید بهترین آریمای موردنظر را پیدا کنیم؛با توجه به ACF وPACF که رسم شده فرض اولیه ی ما بدین سمت میرود که آریما قسمت AR ما باید یک باشد.وقتی تست دیکیفولررا در کد ها گرفتیم منوجه شدیم که داده stationary نیست و حتی داده ها بصورت trend stationary هم نبودند پس first diff گرفتیم و داده ها بصورت stationary شدند.از اینجا متوجه شدیم که قسمت inter great ما برابر یک میباشد.با توجه به تست BIC و MIC نتایجی بدست آمده که BIC بدین فرم بود، کم ترین مقدار را همانطور که حدس میزدیم مدل (۰و۱و۰) و بعد از آن مدل (۰و۱و۱) و مدل (۱و۱و۰) و در نهایت مدل (۱و۱و۱) کم ترین مقادیر را داشتند؛ اما با توجه جدولی که در قسمت پایانی کشیده شده است و میزان ME، BIC، RMSE ، MAPE و R-squared به این نتیجه دست یافتیم که آریما (۱و۱و۱) از همه بهتر است.

البته هر شش مدل داخل مقاله ترسیم شده و شش دوره ی پایانی دیتای ما با استفاده از هر شش دوره ی داخل مقاله پیش بینی شده و همچنان همانطور که مشهود است بهترین پیش بینی مدل (۱و۱و۱) بوده که بیشترین نزدیکی را با داده های اصلی دارد(figure4) در ادامه با HSTEP=۶ و مدل (۱و۱و۱) دیتای مان راپیش بینی کردیم.(figure5) در نهایت باید اشاره کرد که مدل آریما قادر به پیش بینی شوک های شدید نمیباشد.مدل آریما (۱و۱و۱) تنها مدلی بود که اگراستاندارد ارور را دوبرابر میکردیم تمامی قسمت AR وMA آن کوچکتر از قدر مطلق مقدار AR و MA بودند، در بقیه ی موارد گاها یکی از پارامتر ها یا تمامی پارامتر ها بدین فرم نبودند.

***Abstract*—This study gives an inside view of the application of ARIMA time series model to forecast the future Gold price in Indian browser based on past data from November 2003 to January 2014 to mitigate the risk in purchases of gold. Hence, to give guideline for the investor when to buy or sell the yellow metal. This financial instrument has gained a lot of momentum in recent past as Indian economy is curbed with factors like changing political scenario, global clues & high inflation etc, so researcher, investors and speculators are in search of different financial instrument to minimize their risk by portfolio diversification. Gold earlier was only purchased at the time of marriage or other rituals in India but now it has gained importance in the eyes of investors also, so it has become necessary to predict the price of Gold with suitable method.**

***Index Terms*—gold price, ARIMA, forecasting**

INTRODUCTION

"All that glitters is not gold" is a proverb use to depict that not everything that looks attractive is not so, in reality. This yellow metal has grab lot of attention for every class of people as investment purpose.

People investing in gold have mainly two primary objectives, one being it is a hedge against inflation as over a period of time, the return on gold investment is in line with the rate of inflation, next to mix your investment basket and hence diversify the risk and will help you reduce the overall volatility of your portfolio.

Investing in gold have evolved over a period of time for traditional ways by buying jewelries or by modern way as purchasing gold coins and bars (which is available in scheduled banks nowadays) or by investing in Gold Exchange traded fund (Gold ETF).Gold ETF is in financial instrument of mutual fund in nature which in turn invests in gold and these are listed in a stock index. Gold Fund of Funds and Equity based Gold Funds are other instrument where investor can choose to invest in Gold having some variation like Gold Fund of Funds is an investment made on behalf of the investor without holding a Demat account and Equity based Gold Funds are investment which are not made directly in Gold, but investing in the companies, which are related to the mining, extracting and marketing of the Gold.

Importance of the yellow metal has changed over a period of time. In India few thousands of years ago, countless Kings & Emperor, the then rulers of land in different parts of the country having different monetary system, but only Gold was treated as common exchange commodity.

India is known to demand of gold mainly for jewelry fabrication where it makes in the top list of imports of gold as the production of gold in India for mining activities is very limited, but in our country the demand for the yellow metal is seasonal and are high during wedding season, Post harvest season and festival season and demand are down during monsoon season. As of today the exchange (National Stock Exchange & Bombay Stock Exchange) has introduced different instrument linked with Gold investment to simplify to purchase of gold from exchange without forgoing with different charges associated with purchase of jewelries which ultimately reduces the return of investors while investment in yellow metal, so it is important for investors to be well informed about fluctuation in the price so that he can take wise decision in investing in Gold. Hence this paper gives an insight of forecasting of Gold price through time-series ARIMA model.

LITERATURE REVIEW

Ref. [1] Banerjee, D., (2014) in her paper "Forecasting of Indian Stock Market using Time-series ARIMA Model" has applied ARIMA model based on which she predict the future stock indices which have a strong influence on the performance of the Indian economy. In her paper she first determined the ARIMA model then she forecasted the sensex through model validation and at the end the recurrence validation was done.

Ref. [2] Abdullah Lazim (2012) in his paper has addressed the forecasting of gold bullion coin prices through ARIMA model and had concluded by suggesting that the gold bullion coin selling prices are in upward trends and could be considered as a worthy investment. Wouter Theloosen in his research paper "A review on the determinants of the price of gold" has cited the different factors associated with the gold price fluctuation.

Ref. [3] Baber. P., Baber. R, Thomas. G in their study "Factors affecting Gold prices: a case study of India" list different factors affecting the gold price in India and gives special emphasis on rise in gold price in the decade from 2002 to 2012.

Ref. [4] Mohamad As'ad (2012) has modeled the peak daily electricity demand using half hourly demand date. He coined for ARIMA Models based past three, six, nine and twelve months of data and suggested that the ARIMA model build based on past three months data is the best model in terms of forecasting two to seven days ahead

and ARIMA model based on the past six months data is the best model to forecast one day ahead.

Ref. [5] Aidan Meyler, Geo Kenny and Terry Quinn (1998) had forecasted Irish inflation though ARIMA model. This research paper gives an insight of ARIMA Modeling by step by step approach for forecasting using ARIMA Model.

Deepika M G, Gautam Nambiar & Rajkumar M (2012) has tried to study the forecasting of gold price through ARIMA model & Regression but their finding suggests that suitable model was not identified to forecast Gold price through ARIMA Model hence Regression analysis was carried out in the later part of their study.

OBJECTIVE OF STUDY

To forecast the price of Gold using time-series ARIMA Model.

DATA & METHODOLOGY

Our study is based on secondary monthly data for Gold price which is collected from Multi Commodity Exchange of India Ltd (MCX) ranging from November 2003 to January 2014. MCX is a commodity future exchange based in India which started its operations from November 2003.

MCX has different commodities product list for trading in varied commodity futures contracts across segments which includes bullion, ferrous and non-ferrous metals, energy, Agri-based and agricultural commodities.

Gold is segmented as bullions in MCX, its other future contracts in this category are Gold Guinea, Gold M, Gold Petal, Gold Petal(New Delhi), Platinum, Silver, Silver M, Silver Micro, Silver 1000.

Data of total Quantity in terms of 1000 grams and Value in Rs. Lakhs was taken for a particular month from MCX website and the price of Gold per 10 grams was found out tabulated in Table VI inserted in Appendix A.

SPSS 15 evaluation version was used for computation & graphical plotting of data.

After collecting data it was tested for its suitability for time series analysis. For this purpose Durbin-Watson Test was carried out to understand the nature of data. According to James Durbin and Geoffrey Watson test statistics was developed to detect the presence of autocorrelation for its suitability for regression analysis. Autocorrelation is interrelated between the values with suitable time lag.

Durbin-Watson (DW) $\approx 2[1-\rho(1)]$, where $\rho(1)$ is the 1st order auto-correlation.

Ref. [1] If DW value lies between 0 to 1.5 or between 2.5 to 4 then the data is longitudinal i.e. dependent on time, so time-series analysis can be done, but if DW value is between 1.5 to 2.5 then it is cross-sectional data i.e. independent of time hence regression analysis should be carried out on the collected data.

As test statistics indicate the suitability of time-series analysis, we can move further in our finding to fulfill our objective of forecasting using ARIMA Model. The first steps involved in finding out autocorrelation and partial auto-correlation between the values of the data.

A. *Autocorrelation*

It is defined by ACF = corr(X_t , X_{t+k}) i.e. relationship between each other. Here X_t is the current observation and X_{t+k} is observation after k period. It ranges from -1 to +1.

B. *Partial Auto-Correlation*

Yet another important characteristic is a partial autocorrelation function (PACF) which is conditional correlation of X_{t+k} with X_t. PACF is defined for positive lag only, their value also lies between -1 and +1. Both the characteristic, ACF & PACF are equally important, but ACF is relatively easier to calculate than PACF.

TABLE I. PROPERTIES OF ACF & PACF FOR AR, MA & ARMA

Properties	AR (p)	MA (q)	ARMA (p, q)
ACF	Decay	Cuts after q lag	Decay
PACF	Cuts after p lag	Decay	Decay

C. *Auto Regressive Integrated Moving Averages*

Ref. [2] ARIMA as it is better known as is a time series forecasting technique for short run, which is widely used in today's world since the evolution of sophisticated statistical software package.

ARIMA has four major steps in model building- Identification, Estimation, Diagnostics & Forecast. With these four steps first tentative model parameters are identified through graphs ACF and PACF then coefficient are determined and find out the likely model, next steps involves is to validate the model and at the end use simple statistics and confidence intervals to determine the validity of the forecast and track model performance.

ARIMA model uses the historic data and decomposes it into Autoregressive (AR) Indicates weighted moving average over past observations, Integrated (I) Indicates linear trends or polynomial trend and Moving Average (MA) Indicates weighted moving average over past errors. Therefore, it has three model parameters AR(p), I(d) and MA(q) all combined to form ARIMA(p, d, q) model where

p = order of autocorrelation
d = order of integration (differencing)
q = order of moving averages

Ref. [1] A non-seasonal stationary time-series can be modeled as a combination of the past values and the errors which can be denoted as ARIMA (p, d, q) or can be expressed as

$$X_t = \theta_0+\varphi_1 X_{t-1}+\varphi_2 X_{t-2}+ +\varphi_p X_{t-p}+ e_t -\theta_1 e_{t-1} - \theta_2 e_{t-2} - \theta_q e_{t-q} \quad (1)$$

Table I gives an idea to assume the initial values of ARIMA (p, d, q) for further computation.

Ref. [5] After estimating the three parameters p, d and q, evaluating the model with fit statistics (goodness of Fit) is required to measure the performance of forecast as shown in Table II with its acceptable limits.

Some of the statistical measures are as follows

TABLE II. FIT STATISTICS

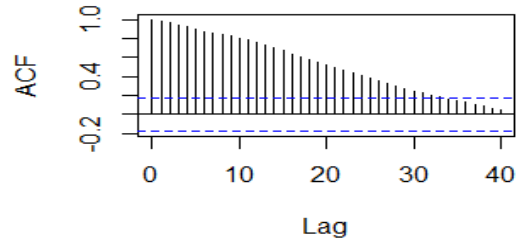
Fit Statistics	Expression	Remark
Root-mean-square error (RMSE)	$\sqrt{\sum_{t=1}^{n}\frac{(x_t-\bar{x_t})^2}{n}}$	Relatively Low
Mean absolute percentage error (MAPE)	$\frac{100\,\%}{n}\sum_{t=1}^{n}\left\|\frac{x_t-\bar{x_t}}{x_t}\right\|$	Minimum
Mean absolute error (MAE)	$\frac{1}{n}\sum_{t=1}^{n}\|x_t-\bar{x_t}\|$	Minimum
Bayesian information criterion (BIC)	$\log\left(\frac{rss}{n}\right)+\frac{k}{n}\log n$	Where rss = residual sum of squares. k = no. of coefficients estimated = 1+p+q+P+Q n= no. of observations.
Lungs Box Q statistics	$n(n+2)\sum_{k=1}^{h}\frac{\bar{\rho}_k^2}{n-k}$	n=the number of residuals h = number of time lags includes in the test ρ^2_k = the residual autocorrelation at lag k

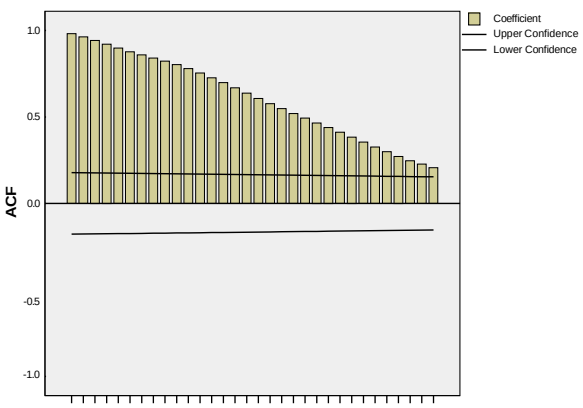
For the model to be adequate the significance level for q statistic should be significant

RESULT & DISCUSSION

The value of Durbin-Watson (DW) was 0.091 for the sample data of the Gold price from November 2003 to January 2014 which indicates that the data is suitable for time-series analysis. As DW ≈ 2[1-ρ(1)] hence ρ(1) = 0.945 which indicates that gold price shows high 1st order auto-correlation.

The ACF and PACF correlogram was plotted to identify the model of ARIMA





to get the model parameters according to model based on parsimony principle of optimality. Comparing six different combinations of p, d, q of ARIMA model given in Table V inserted in Appendix where value of p =1. Fig. 1 shows that ACF correlogram decays hence we are sure about the parameter p of ARIMA which can be assumed as 1 as tabulated in Table I.

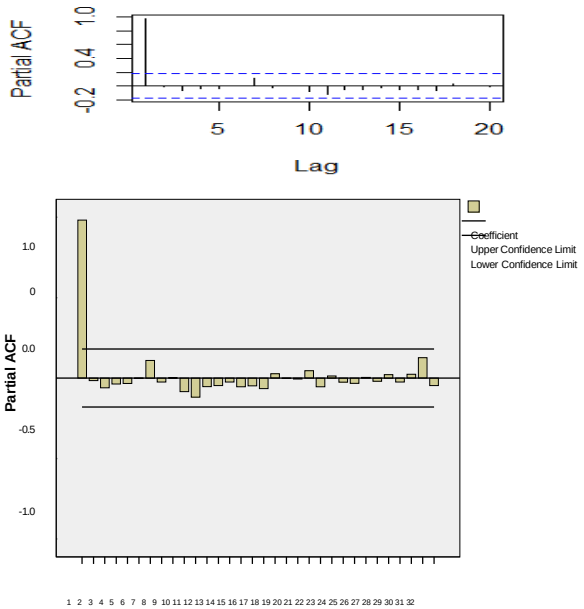


Figure 2. Partial ACF-gold price correlogram

Ref. [1], [5] After comparing the fit statistics as tabulated in Table II, only ARIMA (1, 1, 1) satisfy all the criteria, hence we obtained the model ARIMA (1, 1, 1) which is used to forecast the future gold price.

The generalized ARIMA (1, 1, 1) model is in the form

$$X_t = \mu + X_{t-1} + \varphi\,(X_{t-1} - X_{t-2}) - \theta\, e_{t-1} \qquad (2)$$

where μ = Constant (1- φ)

φ = AR Coefficient

θ = MA Coefficient

The Table III below shows the parameter estimate of ARIMA (1, 1, 1) with respective significance level.

TABLE III. ESTIMATE TABLE-ARIMA(1,1,1)

		Estimate	SE	t	Sig.
Constant		190.708	70.176	2.718	.008
AR	Lag 1	-.734	.170	-4.326	.000
Difference		1			
MA	Lag 1	-.869	.124	-7.011	.000

Thus the model using the above table is X_t=190.708 (1+0.734) + X_{t-1} - 0.734 (X_{t-1} – X_{t-2}) +0.869 e_{t-1}. Here all the significant values are less than 0.05 so ARIMA (1, 1, 1) was taken into consideration

Month	Observed values	Model validation	Recurrent validation	**My result**
Feb-14	29482.91	29386.40	29352.75	29198.29
Mar-14	29670.43	29614.93	29500.68	29299.59
Apr-14	28514.64	29850.13	29913.53	29399.54
May-14	27812.81	30009.72	28477.51	29498.18
June-14	26813.15	30224.71	28067.20	29595.53
July-14	27867.11	30399.11	26753.38	29691.58

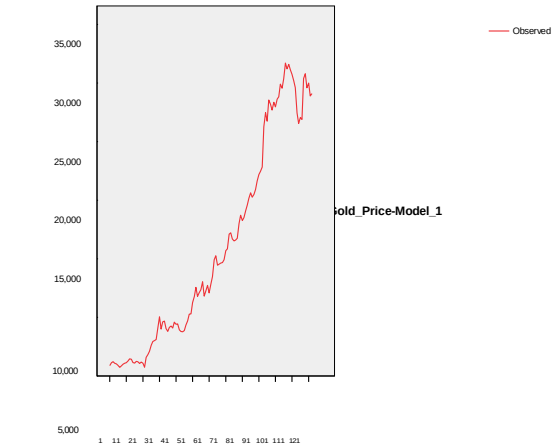


Figure 3. Graph showing gold price-observed value in y-asis vs time in x-asis

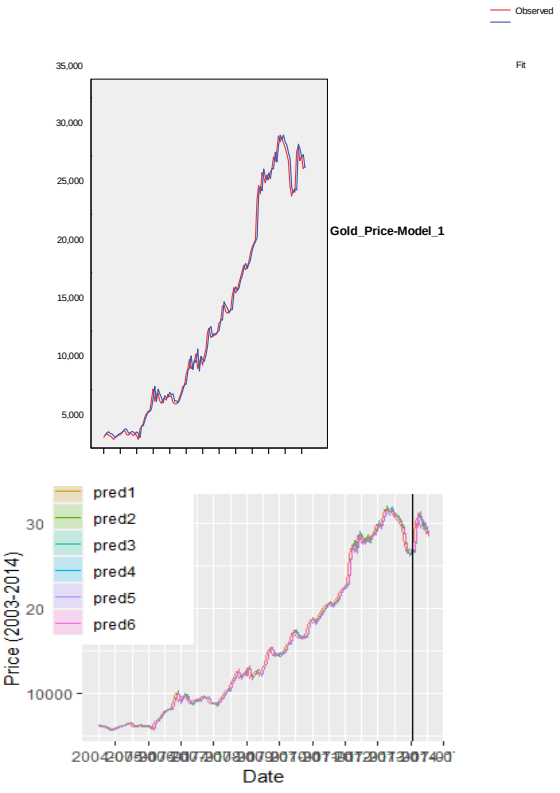


Fig. 4 shows the plotting of gold price and price calculate from model as shown in equation (3) which also tabulated in Table IV. The blue worm in the figure is the model data crawls with the red worm is gold price. As the gap between the blue and red worm is minimum so the model equation can be taken into consideration for forecasting of gold price beyond January 2014.
Fig. 5 shows the plotting of forcasted value with the help of the model values for six months

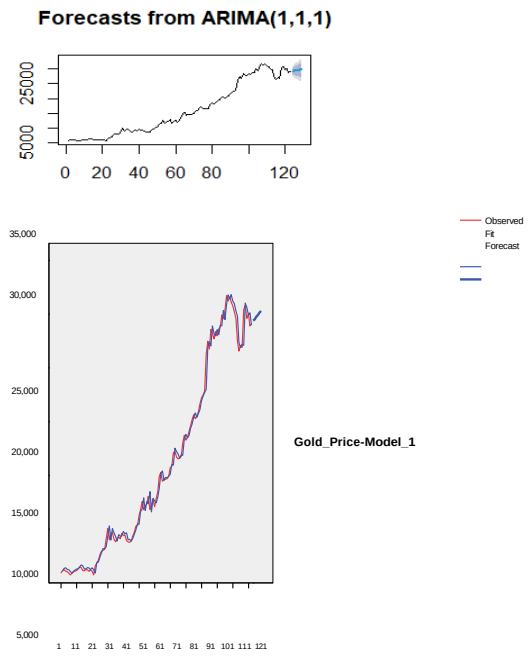


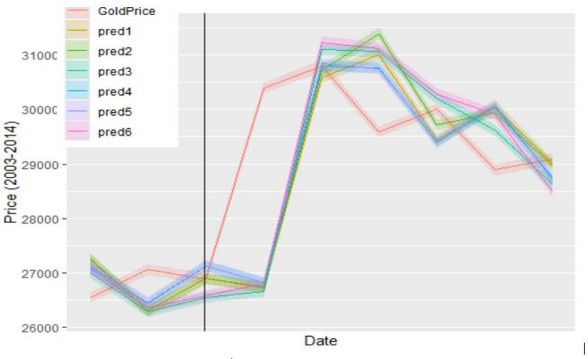
Figure 5. Graph showing gold price-observed value and fit value & forecast value in y-asis vs time in x-asis

CONCLUSION

Analysis of performance of the gold price from preceding 10 years traded value in MCX gives us ARIMA (1, 1, 1) model which helps us in predicting the future values of Gold. ARIMA (1, 1, 1) was chosen from six different model parameters as it provides the best model which satisfies all the criteria of fit statistics while other five failed the fit statistics.

LIMITATION

There are certain limitations in forecasting a data with ARIMA modeling. This technique is used for short run only, to detect small variation in the data. In case of sudden change, in the data set (when the variation is large) in case of change in government policies or economic instability (structural break) etc. it becomes difficult to capture the exact change, hence this model becomes difficult to capture the exact change, hence this model becomes ineffective to forecast in this scenario more over the forecasting with this method is based on assumption of linear historic data but there is no evidence that the gold price is linear in nature



Pred1 از همه نزدیک تر به داده های اصلی است و در واقع همان آریما مدل (۱و۱و۱) است.

Pred1 = arima(1,1,1)
Pred2=arima(1,1,2)
Pred3=arima(1,1,3)
Pred4=arima(1,0,1)
Pred5=arima(1,0,2)
Pred6=arima(1,0,3)

APPENDIX A TABLES

TABLE V. ARIMA MODEL SUMMARY

ARIMA (p, d, q)	R-squared	RMSE	MAPE	MAE	Normalized BIC	Lungs Box Q (18) statistics (sig)	p value of				
							Constant	AR (1)	MA		
									lag 1	lag 2	lag 3
ARIMA(1,0,1)	0.978	1300.41	4.846	595.112	14.458	1	0.366	0	0.266	-	-
ARIMA(1,0,2)	0.978	1295.70	4.829	594.480	14.490	1	0.340	0	0.304	0.854	-
ARIMA(1,0,3)	0.979	1274.90	4.707	570.170	14.497	1	0.231	0	0.05	0.888	0.008
ARIMA(1,1,1)	0.993	719.18	3.245	477.330	13.274	0.646	0.008	0	0	-	-
ARIMA(1,1,2)	0.993	720.74	3.261	474.840	13.318	0.63	0.005	0.004	0.002	0.575	-
ARIMA(1,1,3)	0.993	716.35	3.135	463.150	13.345	0.841	0.019	0.106	0.047	0.738	0.067

ARIMA (p, d, q)	R-squared	RMSE	MAPE	MAE	BIC	BOX	Standard Error			
							AR(1)	MA		
								lag1	lag2	lag3
ARIMA(1,0,1)	0.04271989	744.8516	3.343961	506.8395	13.34374	0.3891	0.0036	0.0913		
ARIMA(1,0,2)	0.0431175	745.1223	3.340425	505.8701	13.34639	0.3816	0.0036	0.1002	0.1191	
ARIMA(1,0,3)	0.02606739	722.7037	3.21563	483.8737	13.38545	0.8058	0.0035	0.0949	0.1092	0.0933
ARIMA(1,1,1)	0.00915252	729.0256	3.172568	486.9052	13.26166	0.4156	0.0292	0.0573		
ARIMA(1,1,2)	0.0093334	728.4074	3.161767	486.0023	13.299	0.4004	0.0287	0.0994	0.0962	
ARIMA(1,1,3)	0.03197269	713.6466	3.11975	468.3821	13.3015	0.9545	0.2069	0.1996	0.1139	0.0941

TABLE VI. MONTHLY GOLD PRICE IN RS/10GRAMS FROM NOVEMBER 2003 TO JANUARY 2014

Month	Gold Price	Month	Gold Price	Month	Gold Price	Month	Gold Price	Month	Gold Price
Nov-03	5884.183	Dec-05	7624.102	Jan-08	11263.45	Feb-10	16516.16	Mar-12	27961.04
Dec-03	6132.507	Jan-06	7941.226	Feb-08	11774.79	Mar-10	16602.01	Apr-12	28622.32
Jan-04	6223.322	Feb-06	8018.163	Mar-08	12554.32	Apr-10	16748.32	May-12	28823.41
Feb-04	6081.285	Mar-06	8112.945	Apr-08	11789.38	May-10	17984.35	Jun-12	29912.06
Mar-04	6032.368	Apr-06	9055.945	May-08	12116.98	Jun-10	18722.85	Jul-12	29554.97
Apr-04	5902.734	May-06	10048.49	Jun-08	12350.31	Jul-10	18265.4	Aug-12	30366.65
May-04	5732.307	Jun-06	8993.265	Jul-08	13037.99	Aug-10	18509.24	Sep-12	31706.28
Jun-04	5855.261	Jul-06	9611.196	Aug-08	11805.17	Sep-10	19103.68	Oct-12	31208.85
Jul-04	6001.504	Aug-06	9683.527	Sep-08	12273.34	Oct-10	19583.55	Nov-12	31592.91
Aug-04	6086.221	Sep-06	9046.995	Oct-08	12736.15	Nov-10	20162.13	Dec-12	31130.5
Sep-04	6132.289	Oct-06	8809.648	Nov-08	12084.21	Dec-10	20628.66	Jan-13	30754.81
Oct-04	6272.087	Nov-06	9150.099	Dec-08	12837.27	Jan-11	20253.88	Feb-13	30205.77
Nov-04	6463.56	Dec-06	9256.871	Jan-09	13474.71	Feb-11	20495.05	Mar-13	29599.85
Dec-04	6423.59	Jan-07	9090.71	Feb-09	14912.04	Mar-11	20919.54	Apr-13	27449.18
Jan-05	6133.366	Feb-07	9589.743	Mar-09	15256.39	Apr-11	21635.71	May-13	26551.51
Feb-05	6099.13	Mar-07	9403.5	Apr-09	14450.24	May-11	22189.03	Jun-13	27066.7
Mar-05	6237.06	Apr-07	9442.006	May-09	14543.05	Jun-11	22465.34	Jul-13	26893.88
Apr-05	6202.608	May-07	8923.453	Jun-09	14631.97	Jul-11	22824.97	Aug-13	30386.25
May-05	6056.98	Jun-07	8796.646	Jul-09	14682.79	Aug-11	26268.63	Sep-13	30798.54
Jun-05	6181.291	Jul-07	8763.533	Aug-09	14922	Sep-11	27471.55	Oct-13	29590.1
Jul-05	6087.641	Aug-07	8867.74	Sep-09	15690.97	Oct-11	26742.87	Nov-13	30000.51
Aug-05	5738.967	Sep-07	9340.204	Oct-09	15855.3	Nov-11	28560.84	Dec-13	28891.53
Sep-05	6583.637	Oct-07	9699.008	Nov-09	17101.92	Dec-11	28188.29	Jan-14	29095.65
Oct-05	6821.654	Nov-07	10273.67	Dec-09	17222.07	Jan-12	27692.52		
Nov-05	7107.171	Dec-07	10297.75	Jan-10	16696.9	Feb-12	28357.57		

Thanks for your attention

Bic result arima (j,0,i)
bic.results[i+1,j+1]

	[,1]	[,2]	[,3]	[,4]
[1,]	18.17929	13.31568	13.34338	13.38052
[2,]	16.91102	13.34374	13.34639	13.38545
[3,]	16.02272	13.38359	13.38533	13.39525
[4,]	15.41315	13.36162	13.38236	13.41662

bic.results intigrate1 c(j,1,i)
bic.results[i+1,j+1]
(0,1,0) then (1,1,0) then(0,1,1) then(1,1,1)

	[,1]	[,2]	[,3]	[,4]
[1,]	13.22981	13.25773	13.29511	13.29940
[2,]	13.25829	13.26166	13.29900	13.30150
[3,]	13.29727	13.29909	13.30023	13.34058
[4,]	13.28146	13.29727	13.33143	13.36838

		Point Forecast	Lo 80	Hi 80	Lo 95	Hi 95
124	Feb-14	29198.29	28260.19	30136.40	27763.59	30633.00
125	Mar-14	29299.59	27952.97	30646.20	27240.12	31359.05
126	Apr-14	29399.54	27725.98	31073.10	26840.05	31959.03
127	may	29498.18	27537.79	31458.58	26500.02	32496.35
128	jun	29595.53	27372.66	31818.39	26195.95	32995.10
129	july	29691.58	27222.70	32160.47	25915.75	33467.42

ARIMA(1,1,1) **(figure5)**
Coefficients:

ar1	ma1
0.9868	-0.9570
s.e. 0.0292	0.0573

sigma^2 = 544765: log likelihood = -977.97
AIC=1961.93 AICc=1962.14 BIC=1970.35
> accuracy(modele11)

	ME	RMSE	MAE	MPE	MAPE	MASE	ACF1
Training set	74.97299	729.0256	486.9052	0.5716242	3.172568	0.9453795	0.02469166

Box-Ljung test
data: modele11$resid
X-squared = 17.582, df = 17, p-value = 0.4156

ARIMA(1,1,2)
Coefficients:

ar1	ma1	ma2
0.9895	-0.9228	-0.0402
s.e. 0.0287	0.0994	0.0962

sigma^2 = 548412: log likelihood = -977.88
AIC=1963.75 AICc=1964.09 BIC=1974.97
> accuracy(modele12)

	ME	RMSE	MAE	MPE	MAPE	MASE	ACF1
Training set	75.71018	728.4074	486.0023	0.5729624	3.161767	0.9436264	-0.0119118

Box-Ljung test
data: modele12$resid
X-squared = 17.818, df = 17, p-value = 0.4004
ARIMA(1,1,3)

```
Coefficients:
         ar1     ma1     ma2     ma3
      -0.4317  0.5839  0.1005  0.2469
s.e.   0.2069  0.1996  0.1139  0.0941
sigma^2 = 530872:  log likelihood = -975.35
AIC=1960.7   AICc=1961.22   BIC=1974.72
                    ME     RMSE      MAE       MPE    MAPE      MASE        ACF1
Training set 140.1277 713.6466 468.3821 0.8988664 3.11975 0.9094149 -0.04586596
Box-Ljung test
data:  modele13$resid
X-squared = 8.5043, df = 17, p-value = 0.9545



ARIMA(1,0,1) with non-zero mean
Coefficients:
         ar1     ma1      mean
      0.9972  0.1033  17063.63
s.e.  0.0036  0.0913  10187.63
sigma^2 = 568674:  log likelihood = -990.65
AIC=1989.3   AICc=1989.64   BIC=2000.55
                    ME     RMSE      MAE      MPE     MAPE      MASE      ACF1
Training set 161.9756 744.8516 506.8395 0.868902 3.343961 0.9840842 -0.051785
Box-Ljung test
data:  modele101$resid
X-squared = 17.996, df = 17, p-value = 0.3891

ARIMA(1,0,2) with non-zero mean
Coefficients:
         ar1     ma1      ma2      mean
      0.9972  0.1154  -0.0202  17273.37
s.e.  0.0036  0.1002   0.1191  10151.43
sigma^2 = 573870:  log likelihood = -990.69
AIC=1991.39   AICc=1991.9   BIC=2005.45
                    ME     RMSE      MAE       MPE    MAPE     MASE      ACF1
Training set 162.7276 745.1223 505.8701 0.8701725 3.340425 0.982202 -0.060668
Box-Ljung test
data:  modele102$resid
X-squared = 18.115, df = 17, p-value = 0.3816

ARIMA(1,0,3) with non-zero mean
Coefficients:
         ar1     ma1     ma2     ma3      mean
      0.9991  0.1782  0.0127  0.2245  20974.92
s.e.  0.0035  0.0949  0.1092  0.0933  28396.46
sigma^2 = 544432:  log likelihood = -987.85
AIC=1987.71   AICc=1988.43   BIC=2004.58
                    ME     RMSE      MAE       MPE    MAPE      MASE        ACF1
Training set 126.527 722.7037 483.8737 0.7465095 3.21563 0.9394935 -0.07629277
Box-Ljung test
data:  modele103$resid
X-squared = 11.905, df = 17, p-value = 0.8058

sum(goldprice-modele101$fitted)^2/sum((goldprice-mean(goldprice))^2)
[1] 0.04271989
> sum(goldprice-modele102$fitted)^2/sum((goldprice-mean(goldprice))^2)
[1] 0.0431175
> sum(goldprice-modele103$fitted)^2/sum((goldprice-mean(goldprice))^2)
[1] 0.02606739
> sum(goldprice-modele11$fitted)^2/sum((goldprice-mean(goldprice))^2)
```

```
[1] 0.00915252
> sum(goldprice-modele12$fitted)^2/sum((goldprice-mean(goldprice))^2)
[1] 0.009333396
> sum(goldprice-modele13$fitted)^2/sum((goldprice-mean(goldprice))^2)
[1] 0.03197269
```