DYNAMIC PRICE INTEGRATION IN GLOBAL MARKET OF PRECIOUS METALS IN THE PRESENCE OF STRUCTURAL BREAK

Rakesh Shahani
Associate Professor, Dept. of Business Economics
Dr. Bhim Rao Ambedkar College
University of Delhi, Delhi
E-mail: rakesh.shahani@gmail.com

Ansh Yadav
Student Researcher, Dept. of Business Economics
Dr. Bhim Rao Ambedkar College
University of Delhi, Delhi
E-mail: anshyadavv08@gmail.com

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ABSTRACT

The paper analysed co-integration dynamics amongst the three precious metals viz. gold, silver and platinum by taking their daily closing future prices for the sampled period; 31st Dec, 2015-31st Dec, 2020. The aim was to ascertain whether long run cointegration was maintained amongst the precious metals when the study period included a structural break in time series. The need for this research assumed importance as a general feeling exists amongst the investing class that precious metals tend to move in tandem in all times and therefore keeping any one of these assets was sufficient to achieve asset allocation and diversification. The study employed ARDL linear Co-integration Model after confirming for model linearity. The results showed no co-integration between gold, silver and platinum, however strong short run bidirectional causality between silver and platinum was visible from results. Further two of the three metal series showed presence of a structural break. The study therefore recommends that two prominent precious metals; gold and silver could be safely considered as two separate asset classes as two were not co-integrated and a fund manager may hold silver as well as gold in his/her portfolio as a part of asset allocation strategy.

Keywords: ARDL Model, Serial Correlation, Causality, COVID 19 pandemic

INTRODUCTION

The precious metals space in the commodities market is primarily cornered by three metals viz. gold, silver and platinum. Out of the three, gold is the leader of the pack and is held by the investors as a “safe haven” due to its ability to maintain its value during adverse conditions while rest of the assets including equities witness a correction or fall in their values. However in terms of economic value and industrial usage, gold fairs poorly and gives way to another precious metal , silver or the ‘white metal’. Silver’s industrial usage includes industries like batteries, switches and coating material. Gold and other precious metals are also extensively used especially in Asian countries for ornamental purposes which also keeps the demand for these two metals high in these countries.

The third precious metal considered is Platinum which has been traditionally priced higher than gold, however there is a question mark on its price discovery as trading in this metal is extremely thin.

Further, it has been seen that when most assets including stocks, bonds and real estate have the tendency of moving in tandem and invariably follow a downward journey during uncertain times say during a crisis period , gold & silver have been found to maintain its value (Chua, 1990).

On the other hand, even though gold and silver have been instruments of monetary value for centuries, empirical research studies on these precious metals are fairly of recent origin and one reason for same could be that these metals are considered both a commodity and a financial asset (Shahani, *et al*., 2022).From an investment point of view, many fund managers usually keep any one of these two assets, with preference being gold in their portfolio as they are of the opinion that keeping both gold and silver in their portfolio offers very little advantages as two are closely related in their movement. Research has however revealed the contrary i.e. the relation between the two metals is neither stable nor constant and therefore there can be certain times when keeping both of these metals together in their portfolio becomes sensible and highly desirable (Lucey & Tully 2006). One of the probable reasons why the movement of the two metals need not necessarily be in same direction is their differences in commercial applicability. On the other hand, those who argue against this opinion feel that both assets have traditionally performed similar roles which makes them close substitutes and hence must be classified into a single asset class (Pradhan et.al 2020).

Going forward, the study makes an attempt to understand through empirical analysis whether the two assets need to be considered as a single asset class or be separated from one another. Past studies which have tested this hypothesis have mainly employed time series techniques of co-integration and causality to get an idea of their co-movement. The findings of majority of the research papers reveal that although there is a long term relation between gold and silver, but this relation gets weakened whenever there is a change in economic conditions or during adverse situations say during a financial crisis while the same is known to become stronger after the crisis especially when normality returns (Baur, et.al 2014, Lucey & Tully 2006). Similar result was obtained by Pradhan et al. (2020) where they too failed to arrive at any consensus opinion regarding cause-effect relation amongst the returns of gold and silver, thereby revealing that causality was based on the frequencies of different lengths. Mishra, et al. (2019) revealed that the relation amongst precious metals was only short run with uni-directional causality moving from gold to silver indicating that investors in gold market could predict returns on silver markets.

Again, study by Kucher and McCoskey (2017) showed that long run relation amongst precious metals declined during peak of business cycles but rose during recession period. Further, application of non linear models has gained popularity during recent times and some of the studies to apply these models include Hammoudeh et.al. (2010) where they applied non-linear Threshold Auto Regression (TAR) to ascertain the co-integration between spot and futures of four commodities including gold and silver. Although co-integration was proved but it was also seen that after a negative shock, the speed of adjustment was fast for gold, however after a positive shock the speed of adjustment was rather slow in both metals; gold and silver. Moving with non-linear models, Zhu *et al*., (2016) applied quantile regression approach and it was seen that for any change in price of gold, a contemporaneous change in price of silver was also visible, however long run co-integration amongst two metals was only seen at the tails. Then, Chang, etal., (2013) focusing on five major gold markets found two way causality amongst London & New York gold markets. Further, their results from Asia revealed that out of three Asian Markets, Hong Kong gold market was an important economic hub and was connected with markets of London & New York. On the other hand, Ciner, C. (2001) found the opposite i.e. they reported disappearance of relation between gold and silver during the study period (1992-1998) and concluded that the two markets for gold and silver may now be considered as separate markets.

In light of the above discussion, we have designed our study to explore the cointegrating linkages between three precious metals for the sampled period; 31st Dec, 2015-31st Dec, 2020. We collect daily closing prices for these three precious metals from the website, www.investing.com . The outcome of this paper would add to the existing knowledge in the following three ways; first it empirically examines using high frequency data whether there is any co-movement of the precious metals so as to know whether these can be classified as a single asset class i.e. each of the three constituent assets is a class of asset in itself when the period of study includes at least one period of financial distress (Covid 19 pandemic period in present case), second the incorporation of structural break in our model would tell us whether break in each of the three time series aligns with break period of other markets during Covid 19 pandemic period and third, the study tries to examine short run causality amongst the variables which would help us to understand whether cause-effect lagged relation is actually working on precious metals.

The remainder of the paper has been structured as follows: Section 2 provides information about Statistical Description and Distribution Characteristics of three precious metals. Section 3 brings out the research methodology, model building and pre-requisites, Section 4 provides the study results followed by Section 5giving conclusion and policy recommendations and finally references as Section 6.

Statistical Description and Distribution Characteristics of Data

Statistical Description of returns on three precious metals futures viz. gold, silver and platinum for the study period 31st Dec, 2015- 31st Dec, 2020 is presented in Table I. The closing daily future prices of these variables have been transformed to daily future returns by applying the formula; $\frac{P_t - P_{t-1}}{P_{t-1}}$, P_t and P_{t-1} being the closing price of metal futures at day 't' and day 't-1' respectively.

Table 1 : Statistical Description of Return on Gold, Silver and Platinum for the period (31st Dec, 2015- 31st Dec, 2020)

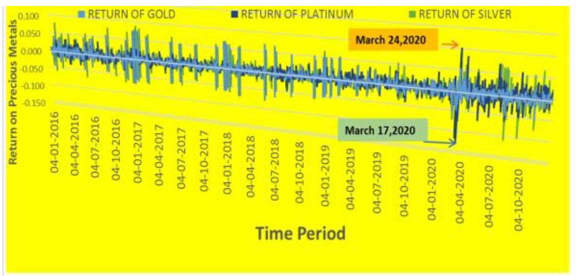
Particulars	Return on Gold	Return on Platinum	Return on Silver
Mean	0.0005	0.00026	0.00064
Std. Dev.	0.01465	0.01574	0.02028
Coeff. of Variation (C.V) = σ / μ	29.3	60.5	31.7
Skewness	0.29589	-0.34653	-0.1154
Kurtosis	12.40723	12.16306	8.28621
Jarque - Bera	4886.54	4644.32	1539.852
Probability	0.0	0.0	0.0
Observation Computation	1320	1320	1320

Source : Author's Own

The analysis shows that mean return on silver futures is highest of the three metals at 0.00064 on daily basis (23.36 % annually), followed by gold and platinum (at 18.25 % and 9.5 % on annual basis respectively). Hence out of the three precious metals, silver futures appears to be the most profitable to invest if we consider the average returns per day. On the other hand, standard deviation, a parameter known as proxy for risk is lowest for gold followed by platinum with silver having the highest Standard Deviation. Thus we find that silver has the highest risk-return profile and is therefore an ideal investment only for a high risk taker but the same may not the case for a risk averse investor for whom Coefficient of Variation (CV) is a better yardstick of measurement . CV which puts both risk and return parameters into a relation is lowest forgold thereby making the yellow metal an ideal investment for an investor who wants to take calculated risk to obtain the desired return.

The other useful information available from Table I is about distribution characteristics of three precious metals. This includes information on Skewness (3rd Moment), Kurtosis(4th Moment) and JB statistics. We shall be commenting on the characteristics of the three metals by comparing with a normal distribution. We begin with skewness and we find that platinum and silver are negatively skewed while gold is positively skewed. However, overall skewness of all the three distributions is quite close to that of a normal distribution which has a '0' skewness. On the other hand, all the three distributions are leptokurtic which reflects longer distribution with fatter tails with a lot of outliers. Further all the three distributions reject the Normality upon applying JB test statistic; $JB = \frac{n}{6}\{S_k^2 + \frac{1}{4}(K_t - 3)^2\}$, where 'n' denotes number of observations,'S_k' the Skewness, 'K_t' the Kurtosis of the distribution.

We next discuss the graphic movement of the daily return on gold, silver and platinum and the same has been shown in Fig 1 below:



Source: Author's Own Computation

Figure 1: Graphic Movement of the Daily Return On Gold, Silver And Platinum

A close look at the Fig 1 reveals the following:- (i) Highest and lowest one day returns are achieved between the dates : March 17, 2020 and March 24, 2020 and both these returns pertain to same metal i.e. Platinum. Incidentally these two dates also coincide with the peak period of COVID 19 Pandemic. (ii) Both Silver and Platinum witness frequent high volatility periods very often during the five year period of study, while volatility in gold has been on the lower side when compared to these two metals (iii) High Volatility without any sign of clustering was seen during the COVID pandemic period again for both metals; silver and platinum.

METHODOLOGY

Building A Co-Integration Model: Model Diagnostics/Pre-requisites

Since the objective is to develop a co-integrating relation amongst precious metals, there is a need to identify the right co-integration model to be applied under the study. The type of co-integration model largely depends upon the nature and behavior of time series of the underlying variables and whether or not they satisfy the underlying assumptions. To this end, researchers usually apply model diagnostics or pre-requisites which we discuss below under the section(s) model specification, variable stationarityand serial correlation.

Model Specification

For Model Specification we apply Ramsey Reset Test where Null Hypothesis is that Model is linear, alternative being a Non Linear Model (e.g. quadratic or cubic model representation) and we apply the eq. (ii) as under

$Y_t = \beta_1 + \beta_2 X_{1,t} + \beta_3 X_{2,t} + \beta_4 X_{3,t} + \ldots + \beta_m (\hat{Y}_t)^2 + e_t$ ….(ii)

A significant $(\hat{Y}_t)^2$ is a proof of non linearity of our model

Stationarity of Variables

Forstationarity, we apply ADF unit root test, (with intercept and trend) with a single breakpoint following Perron's (1997) innovative outlier method and assumes that break exists only at intercept. The three ADF equations, one each for each of our three variables are given as under (eq. iii to v).

$\Delta \text{Gold}_t = \beta_1 + \beta_1^* D_{1t} + (\beta_2 - 1)\text{Gold}_{t-1} + \sum_{i=1}^{m} \beta_{3i} \Delta \text{Gold}_{t-i} + \beta_4 t + u_{1t}$ … eq.(iii)

$\Delta \text{Silver}_t = \alpha_1 + \alpha_1^* D_{2t} \; (\alpha_2 - 1) \text{Silver}_{t-1} + \sum_{i=1}^{m} \alpha_{3i} \Delta \text{Silver}_{t-i} + \alpha_4 t + u_{2t}$ … eq.(iv)

$\Delta \text{Platinum}_t = \lambda_1 + \lambda_1^* D_{3t} + (\lambda_2 - 1)\text{Platinum}_{t-1} + \sum_{i=1}^{m} \lambda_{3i} \Delta \text{Platinum}_{t-i} + \lambda_4 t + u_{3t}$ … eq.(v)

For eq. (iii),ADF equation for Gold, the relevant stationary term being$(\beta_2 - 1)\text{Gold}_{t-1}$, slope coefficient being $(\beta_2 - 1)$. The next term ; $\sum_{i=1}^{m} \beta_{3i} \Delta \text{Gold}_{t-i}$ is the 'augmentation' term and its inclusion aims at removing serial correlation and 'augmented' term sums up 'm' times till serial correlation is removed, we also have time trend variable 't' with coefficient β_4 which takes care of non-stationarity due to underlying time trend (if any).The equation also has an intercept Dummy 'D_{1t}'to identify structural break in time series , 'D_{1t}' takes the value of '1' for observations post break date (break date included) and '0' before break date.The structural break is deemed to exist if the coefficient of Dummy i.e.β_1^* has a significant 'p' value. Finally,the model has a random error term which is given by u_{1t}.

Hypothesis for our Variable GOLD(eq. (iii)) is given as

H_{01} : $\beta_2 = 1$ (Variable Gold has a unit root or is not stationary)

H_{a1}: $\beta_2 \neq 1$, (Variable Gold is stationary)

For other two variables Silver and Platinum, we test for stationarity by developing equations using a similar test procedure as given above.

Serial Correlation

We apply BG-LM, a test given by Breusch (1978) & Godfrey (1978) to detects serial correlation. The test establishes an auxiliary equation; equation where residuals(e_i) are regressed against all autoregressive (AR) terms and lags of the residuals (see eq. vi).

$e_t = \lambda_1 + \lambda_2 Y_{i,t-1} + \lambda_3 Y_{i,t-2} + \ldots + \lambda_{p+1} Y_{i,t-p} + \theta_1 e_{i,t-1} + \theta_2 e_{i,t-2} + \theta_3 e_{i,t-3} + \ldots + \theta_q e_{i,t-q} + v_t$ …(vi)

$R^2$from eq. (vi) $\sim\chi^2_q$. and Null Hypothesis being (H_0): $\text{Cov.}(e_t, e_{t-1}) = 0$ i.e. $\theta_1 = \theta_2 = \theta_3 = \theta_m = 0$ (No Serial Corr.), Null stands rejected if R^2 (s-p) $> \chi^2_q$.

Model Representation and Construction

The diagnostic results of the Ramsey Reset test inform us that the model is linear, ADF stationary results indicate that the model must include a mix ofI(0) and I (1) variables while serial correlation is not seen. Based upon these diagnostic results it was decided to set up an Auto Regressive Distributed Lag (ARDL)Co-integration Model.

ARDL is a popular dynamic single equation co-integration regression and is commonly used when some variables are non-stationary at level. The non stationarity of the variables is taken care of by establishing an error correction along with co-integration model. Thus by differencing and combining all the variables into linear format, all the variables be stationary or non-stationary are transformed to an error correction model with all the variables as stationary (see: Hassler and Wolters, 2006).

In this paper, we would be presenting our ARDL Model in three parts; first part being ARDL representative model equation, a single equation which includes both short and long run variables, second part gives the Partial 'F' Bounds test and follows critical values as given by Pesaran *et al.*, (2001). and finally the third part which is the error representation or the adjustment mechanism and corrects for short run disequilibrium. The error representation also determines the speed of correction of short run deviation towards achieving long run equilibrium. Our ARDL Model also includes single structural break for which the methodology applied is Perron (1997) criteria

ARDL Model Representation Equation

The ARDL Model equations for each of the three variables are given as eq. (vii) to eq. (ix)

$$\Delta Gold_t=\beta_1+\beta_1^{\#}D_{1,t}+\beta_2 Gold_{t-1}+\beta_3 Silver_{t-1}+\beta_4 Platinum_{t-1}+\sum_{i=1}^{n}(\beta_{5,i}\Delta Gold_{t-i})+\sum_{i=0}^{n}(\beta_{6i,}\Delta\ Silver_{t-i})+\sum_{i=0}^{n}(\beta_{7,i}\Delta Platinum_{t-i})+u_t \quad \text{…(vii)}$$

$$\Delta\ Silver_t=\alpha_1+\alpha_1^{\#}D_{2,t}+\alpha_2 Gold_{t-1}+\alpha_3 Silver_{t-1}+\alpha_4 Platinum_{t-1}+\sum_{i=1}^{n}(\alpha_{5,i}\Delta Gold_{t-i})+\sum_{i=0}^{n}(\alpha_{6i,}\Delta\ Silver_{t-i})+\sum_{i=0}^{n}(\alpha_{7,i}\Delta Platinum_{t-i})+v_t \quad \text{….(viii)}$$

$$\Delta\ Platinum_t=\delta_1+\delta_1^{\#}D_{3,t}+\delta_2\ Gold_{t-1}+\delta_3 Silver_{t-1}+\delta_4 Platinum_{t-1}+\sum_{i=1}^{n}(\delta_{5,i}\Delta Gold_{t-i})+\sum_{i=0}^{n}(\delta_{6i,}\Delta\ Silver_{t-i})+\sum_{i=0}^{n}(\delta_{7,i}\Delta Platinum_{t-i})+e_t \quad \text{….(ix)}$$

Consider eq.(vii) which is our first ARDL single equation representation where variable Gold is taken as a function of Silver& Platinum, the equation incorporates both type of variables ;short and long run. In the equation , $\Delta\ Gold_{,t}$ reflects Change in Gold in period 't' , 'β_1'is the intercept while '$\beta_1^{\#}$' is the slope coefficient of Dummy (D_1) reflecting structural break at the intercept level obtained using Perron (1997) criteria. The variable, $Gold_{t-1}$has a slope coefficient as'β_2' while 'β_3' and 'β_4'are the slope coefficients of first lag of independent variables; Silver & Platinum. The long run relation as established when all the three beta coefficients (β_2 , β_3 , β_4) are taken together. The next term, $\sum_{i=1}^{n}(\beta_{5,i}\Delta Gold_{t-i})$ is a short term regressor with $\beta_{5,}$ as its coefficient, 'n' denotes the number of lags determined independently by AIC lag selection criteria, all the lag coefficients are added up till optimal number of lags 'n' is reached. Similarly,$\sum_{i=0}^{n}(\Delta\ Silver_{t-i})$ and $\sum_{i=0}^{n}(\Delta Platinum_{t-i})$ reflect the change in the other two variables and follow the same process as for variable Gold stated above. All the three terms; $\sum\Delta Gold_{t-i}$,$\sum\Delta Silver_{t-i}$ and$\sum\Delta Platinum_{t-i}$collectively make up the short run relation. Finally, u_t is the stochastic error term. Similar methodology has been followed to develop our other two ARDL equations i.e. eq.(viii) & (ix) for our two variables Silver and Platinum respectively.

Partial 'F' Bounds Long term Co-integration Test

The long term co-integration amongst the variables under ARDL Model is tested by applying Partial 'F' Bounds test, developed by Pesaran, Shin and Smith (2001). Under the Partial 'F' Bound test, 'F' value as obtained from the model is compared with the upper and lower bound critical values as given by Pesaran *et al.*, (2001). The decision of existence of co-integration is validated if obtained 'F' Statistics exceeds the upper bound critical. These critical values along with 'F' Computed values are given in Table 2.1.

Error Correction Representation

The third part of the ARDL Model Specification shows the mechanism of error correction which corrects for any disequilibrium in the short run by bringing the long and short run into steady state. We begin with our equation (vii) and replace the long run terms by the first lag residual error term which has been arrived by running an OLS equation on contemporaneous (but stationary) variables. The short run variables of the ARDL equation (vii) however remain unchanged and the new equation developed is called error correction (see eq. x below). The coefficient of the lagged residual term(if significant and negative) provide information about adjustment mechanism from the short run to long run, however the term has meaning only when co-integration has been proved amongst the variables. Using the same process, we build up our error correction equations for the remaining two variables (see eq.(xi),(xii)). We use the same notations for the parameters of the ECM Models as used for ARDL Representative Model except these are with sign '/'.

$$\Delta \text{ Gold}_t = \beta_1^{/} + \beta_1^{/,\#} D_{1,t} + \beta_2^{/} ECM_{1,t-1} + \sum_{i=1}^{n} \left(\beta_{3,i}^{/} \Delta \text{Gold}_{t-i}\right) + \sum_{i=0}^{n} \left(\beta_{4,i}^{/} \Delta \text{ Silver}_{t-i}\right) + \sum_{i=0}^{n} \left(\beta_{5,i}^{/} \Delta \text{Platinum}_{t-i}\right) + u_t \quad \text{....(x)}$$

$$\Delta \text{ Silver}_t = \alpha_1^{/} + \alpha_1^{/,\#} D_{2,t} + \alpha_2^{/} ECM_{2,t-1} + \sum_{i=1}^{n} \left(\alpha_{3,i}^{/} \Delta \text{Gold}_{t-i}\right) + \sum_{i=0}^{n} \left(\alpha_{4,i}^{/} \Delta \text{ Silver}_{t-i}\right) + \sum_{i=0}^{n} \left(\alpha_{5,i}^{/} \Delta \text{Platinum}_{t-i}\right) + v_t \quad \text{....(xi)}$$

$$\Delta \text{ Platinum}_t = \delta_1^{/} + \delta_1^{/,\#} D_{3,t} + \delta_2^{/} ECM_{3,t-1} + \sum_{i=1}^{n} \left(\delta_{3,i}^{/} \Delta \text{Gold}_{t-i}\right) + \sum_{i=0}^{n} \left(\delta_{4,i}^{/} \Delta \text{ Silver}_{t-i}\right) + \sum_{i=0}^{n} \left(\delta_{5,i}^{/} \Delta \text{Platinum}_{t-i}\right) + e_t \quad \text{....(xii)}$$

Cause – Effect Relation

Cointegration relation also paves the way for causality which can be either unidirectional or bidirectional. Since only one of the ARDL equations with Platinum as dependent revealed long run co-integration, the long run causality would be restricted to the same metal. Further instead of using the usual Granger Causality (Granger, 1969), we would be following the ECM route for the same and for long run causality to exist, ECM term should be negative and significant. On the other hand, existence of short run causality shall be validated when lagged value of the short run independent variables are in the expected direction (+ or -) and also significant. If these are so then we may perform a Wald 'F' test to confirm short run causality moving from independent to dependent variable. Wald 'F' would test for the equality of the short runlagged coefficients to ensure that these are jointly significantly different from zero or note. g. consider eq.(x) where we have a case for causality moving from silver to gold, we define Null (for No Causality) as $\beta_{4,1}^{/} = \beta_{4,2}^{/} = \beta_{4,3}^{/} = 0$ (Optimal Lag Determination '3' by AIC). In case the Null Hypothesis is rejected, we have causality moving from Silver to Gold. Further, we repeat the test for lagged values of dependent variable i.e.$\beta_{3,1}^{/} = \beta_{3,2}^{/} = \beta_{3,3}^{/} = 0$ in the model (i.e. eq.x) and if proved then we have a case of bidirectional causality between silver and gold.

EMPIRICAL RESULTS OF THE STUDY

The section discusses the empirical results which are spread over Tables 2-4.Table 2with sub tables (Table 2.1-2.4)discusses the results of Co-integration between Gold, Silver and Platinum and also the results pertaining to error correction model. Table 3gives the short run causality results followed by Table 4 (Sub Tables: 4.1,4.2 & 4.3) giving the results of ARDL diagnostics pertaining to stationarity, serial correlation and model linearity.

To begin with, we discuss the ARDL Partial 'F' Bounds test results for our three variables namely Gold, Silver and Platinum. Table 2.1provides these results for the optimal model chosen as per AIC criteria. The results reveal that long run co-integration is established in case of only one out of three metals i.e. for Platinum as its computed value of 'F' under Partial 'F' Bounds test ; 4.89 is higher than upper bound (I(1)) critical value as given by Pesaran *et al*., (2001)tables at 5 % level and these have been provided as a footnote to the table. For the other two metals viz. Gold and Silver, co-integration in the long run is not established as both have 'F' bound computed values as lower than critical values.

Table 2.1: ARDL Partial 'F' Bounds Test Results for Gold, Silver and Platinum

	'F' Bounds Computed	*Inference*
F_{Gold}(Gold / Silver, Platinum)	1.96	Co-int not estd. even at 10 % levels
F_{Silver}(Silver / Gold, Platinum)	1.85	Co-int. not estd. even at 10 % levels
$F_{Platinum}$ (Platinum / Gold, Silver)	4.89	Co-integration established

Critical Table for 'F' Bounds test ('n' =1000)

	5 %Critical	**10 % Critical**
Lower Bound I(0)	3.1	2.63
Upper Bound I(1)	3.87	3.35

Source : Author's own computation

The next three tables (Table 2.2, 2.3 and 2.4) give the results of ARDL Error Correction Model for the three metals. Each of these three tables has all the short run variables, a dummy variable representing break and lagged error correction term (ECM(-1) . The interpretation ECM(-1) would depend upon whether the variables are found to be long run co-integrated or not.In case, co-integration is proved amongst the variables, we would be interpreting the ECM(-1) term and also determining the adjustment speed from short run disequilibrium towards equilibrium. On the other hand, in absence of long run co-integration,the term is actually meaningless and table interpretation would be restricted to short run causality only.

We begin with the results of Table 2.2 which gives the results of ARDL Error Correction Regression for our variable gold. Since long run cointegration could not be proved in case of gold (Table 2.1), we would be focussing our attention only towards short run causal relationship amongst the variables. Table 2.2 shows that lagged short run coefficients of both independent variables i.e. Silver and Platinum are highly significant indicating the presence of causality from Silver to Gold and again from Platinum to Gold, however we need to perform a formal 'F' Wald test to confirm the same. The table also provides results for the Dummy variable for gold which is significant and confirms break in time series of gold on 19th Jan 2026. An important consideration here is that this break falls outside the Covid 19 period.

Coming over to Table 2.3which gives ARDL results for Silver ; here too co-integration is not established. Further Silver Dummy reveals break is significant only at 10 % level. However ,all the short run lagged coefficients of both Platinum and Silver arestatistically significant but same is not with gold, thereby making a strong case for bidirectional causality between Silver and Platinum.

Coming toTable 2.4 which gives results of ARDL Error Regression Model for Platinum and has been constructed for the metal as co-integration was proved when 'F' as 4.89 was found to be higher than table critical at 5 %. This ECM(-1) term has a value of - 0.0023 which is negative and statistically significant reflecting the movement towards equilibrium is stable, however speed is slow and the correction takes place at 0.23 % in a day. Further all the lagged coefficients of independent variables (except gold) are statistically significant, short run causality again does appear to move bi-directionally; between Silver and Platinum. Further, the existence of long run causality also gets proved in case of Platinum as ECM(-1) term is both negative and significant.

Table 2.2: ARDL Error Correction Regression : ***Dep Variable :*** **Δ(CL GOLD)**

Independent Variable	Coefficient	Prob.
D[GOLD (-1)]	-0.179269	0.000
D [GOLD (-2)]	-0.094223	0.000
D [GOLD (-3)]	-0.043747	0.066
D [PLATINUM]	-0.087524	0.001
D[SILVER]	43.78848	0.000
D [SILVER -1]	5.824601	0.000
ECM(-1)	-0.0029	0.005
GOLD DUMMY	4.292778	0.003

Source: Author's own computation

Table 2.3: ARDL Error Correction Regression :
***Dep Variable :* Δ(CL Silver)**

Independent Variable	Coefficient	Prob.
D[SILVER (-1)]	-0.172151	0.000
D[PLATINUM]	0.007344	0.000
D [PLATINUM (-1)]	0.002294	0.000
D [GOLD]	0.01343	0.439
D [GOLD (-1)]	0.00213	0.094
SILVER DUMMY	0.026077	0.063
ECM(-1)	-0.00823	0.007

Source : Author's own computation

To confirm short causality amongst the three precious metals we also conducted VAR Block Exogeneity Wald Test(Table 3) Since Causality is strongly influenced by lag length it was decided to go with the consensus of lag length of three criteria viz. FPE, AIC and HQ.

Table 2.4: ARDL Error Correction Regression :
***Dep Variable :* Δ(CL Platinum)**

Independent Variable	Coefficient	Prob.
D[GOLD]	-0.09858	0.366
D[SILVER]	23.64356	0.000
D [SILVER (-1)]	3.33752	0.000
D [SILVER (-2)]	2.782049	0.001
PLATINUM DUMMY	5.883827	0.004
ECM(-1)	-0.0023	0.000

Source : Author's own computation

The causality results revealed bidirectional short run causality between Silver and Platinum and unidirectional from both Silver and Platinum to Gold. These results are in line with short run causality as indicated in Tables 2.2-2.4. On the other hand, metal Gold does not appear to cause short run causality to any other metal, nor other metals tend to cause causality to the yellow metal.

Table 3: VAR Short Run Causality Test Results

Type of Relation tested	Obser.	Observed Chi-Sq. value	Probability 'p' value	Result
Silver → Gold	1313	9.724125	0.0211	Causality
Platinum→ Gold	1313	20.96081	0.0001	Causality
Gold→ Silver	1313	3.173554	0.2046	No Causality
Platinum→ Silver	1313	39.36754	0.0000	Causality
Gold→ Platinum	1313	3.170980	0.3660	No Causality
Silver→ Platinum	1313	7.553051	0.0207	Causality

Source : Author's own computation

Our final set of results pertain to Model Diagnostics(Results of stationarity, serial correlation and linearity tests) and these results are shown in Table 4 (Sub Tables 4.1 to 4.3). Table 4.1 where the stationarity results are displayed shows that two variables namely gold and silver are stationary at level, while Platinum only at 1st difference. Now with two variables having integration atI(0) and one variable at I(1), ARDL method of co-integration became the appropriate choice for our study. Additionally, the table shows the single breakpoint for all the three metals ; breakpoint of metal Silver, falls during the early phase of outbreak of Covid 19 pandemic while for Platinum during the later phase of this pandemic.

Our second table under model diagnostics is Table 4.2 which gives results of BGLM serial correlation test for three variables and as seen in the results, all the variables appear to be accepting the Null Hypothesis (Ho: NoSerial Correlation).The last tableunder Model Diagnostics is Table 4.3 which gives the results of Ramsey Reset Test, (Null Hypothesis being a Linear Model) . The results of the coefficient of Square of Predicted term i.e.($\widehat{Y^2}$) is statistically insignificant for all three metals revealing these variables follow a linear model.

Table 4.1: ADF (Unit Root) Test of All the Variables Under Study

VARIABLES	Computed 't' *(Level)*	Computed 't' *(1st Difference)*	Break Date *(Inn. Outlier Method)*
Gold	-4.942379 (0.039)	-42.31923 (<0.01)	19-01-2016 (level)
Silver	-5.36988 (<0.01)	-41.72814(<0.01)	16-03-2020 (level)
Platinum	-3.965808 (0.3932)	-36.21485 (<0.01)	16-11-2020(1st diff.)

Note 1Parenthesis show corresponding 'p' values.

2. Critical 5 % level for the Stationarity test is -4.444

3. Relevant break date considered: Which makes the variable stationary

4. Result : Gold and Silver are stationary at level while Platinum at 1st Difference

Source : Author's own computation

Table 4.2: BGLM Test Results for Serial Correlation

Variable	Obs. R Square	Prob. Chi Sq.(2)	Null Hypothesis
Gold	1.0133	0.6017	Accept
Silver	0.9844	0.7021	Accept
Platinum	0.7735	0.8141	Accept

Result : Null Hypothesis of No Serial Correlation is accepted for all three variables

Source : Author's own computation

Table 4.3 : Test Results for Ramsay Reset Test

Variable	Coeff. for Fitted Sq.term ($\widehat{Y^2}$)	'p' value	Null Hypothesis *(Ho)Model is Linear*
Gold	1.042266008	0.070866333	Accept
Silver	-0.45349404	0.068249781	Accept
Platinum	*-0.454533157*	*0.165321045*	Accept

Result : Null is accepted for all the three variables

Source : Author's own computation

CONCLUSION AND POLICY IMPLICATIONS

To conclude, an attempt was made through the present study to analyse the co-integrating relation amongst the three precious metals viz. gold, silver and platinum by considering daily future closing prices for the sampled fiveyear period; 31st Dec 2015-31st Dec 2020. This study also intended to ascertain how the long run cointegration gets impacted amongst the precious metals when the period of study includeda break in time series. The study employed ARDL Co-integration Model after the stationary tests showed some variables asI(0) while others as I(1) integrated. Linear ARDL Model was decided after checking for the linearity using the Ramsey Reset Test. The study results showed no co-integration between gold, silver and platinum except when platinum was taken as dependent variable, however strong short run bidirectional causality was visible between silver and platinum and also unidirectional causality from both silver and platinum to gold. Results of ARDL Error Regression Model for Platinum which revealed a co-integration amongst variables showed a low negative significant value of ECM(-1) term at -0.0023 reflecting extremely slow movement towards equilibrium.Further,two of these metals showed the presence of structural break during the Covid 19 pandemic period reflecting that the pandemic might have impacted the relation amongst the variables.

These results are however somewhatdifferent from some of the earlierworks (Baur,et. al, 2014; Lucey and Tully, 2006)where they could identifya long run relation between two prominent precious metals, which gets weakened during a crisis. Thefindings of our study also represent an argument against the general feeling of the investors that the two precious commodities markets move in tandem and hence becomesa unique contribution of this paper.Furthermore, although it is not uncommon to report findings which are different from existing research studies due to dynamic nature of commodities market, in case of the present study one might argue the time period of five years (31st Dec 2015- 31st Dec 2020) as a limiting factor.Then, not including any control variable in the ARDL model may also be considered as another limitation by some, although there is a strong reason for exclusion of these variables in the current study.

The above results also mean a lot to the portfolio manager and investor. First and direct implication of this would be at least two of three precious metals, gold and silver could be safely considered as separate asset classes and not as a single asset class as these were not found to be co-integrated, this thus becomes a strong case when a fund manager holds silver as well as gold in his/her portfolio as a part of asset allocation strategy. Second, bidirectional cause-effect relation between platinum and silver would imply that lagged information on one of these markets (say price movement) could make a prediction about the price movement of other market. This gives an indication to the fund manager with a short-term viewpoint to avoid including both thesetwo assets together in the portfolio, however things may turn out to be very different in case the same portfolio manager has a long run scenario in his/her mind.

Third, co-integration which was proved only in case of Platinum requires a thorough investigation as to identify the reasons for the same. Then, reason for slow speed of adjustment for Platinum towards long run equilibrium also need to be identified. This thus becomes an important research area for other researchers to explore ; whether the reason for the same isthin trading and low volumes of this precious metal which makes this metal behave differently from its peers or this was due to other unknown reasons.

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