



## Futures Leads the Spot but Why not so When Market in Shocks? A Time-Varying Price Discovery of Indian Precious Metals

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### Abstract

The study empirically measures the average and time-varying contribution of the spot and futures market to the price discovery of benchmark Indian precious metals from June 2005 to March 2023. The two most popular precious metals in India, i.e., Gold and Silver, were selected for the study. The average contribution is measured through VECM (Vector Error Correction Model) and CFW (common factor weights). Additionally, for getting time-varying contribution, VECM is reformulated into state space form and Kalman filter and smoothening are applied for computing time-varying CFW. Findings reveal that price discovery depicts time-varying behaviour during the study period. While most of the time, futures lead the spot, in case of any shocking news, the spot market dominates the futures as noise trading happens in the futures market for both precious metals, i.e., Gold and Silver. Furthermore, futures market volume, volatility, and COVID-19 negatively affect the price discovery in both precious metals.

**Keywords:** Time-Varying Price Discovery, Indian Precious Metal Market, State Space Model, Kalman Filter and Smoothening

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## **Introduction**

In an efficient market, all the price-sensitive information is reflected in the prices of two related assets simultaneously (the price of spot and futures). However, when one market updates the price relative to another market, the earlier is considered the leading market in terms of price formation. Price discovery refers to how fast information is capitalised into the prices of financial assets. The price discovery mechanism is significant for investors like arbitrageurs, hedgers, and speculators who put their money in both the spot and futures market. After knowing price discovery, they can follow the price-leading market and make their investment strategies. According to a survey of Indian and foreign literature, several studies have been undertaken on the role of futures and spot markets in price discovery for various assets such as stocks, commodities, and currency. On account of low transaction cost, easy execution of the transaction, low margin requirement, and so many advantages of the futures market, many of them support the idea that the futures market leads the spot market (Ilankadhir & Rao, 2018; Karagiannis, 2014; Kharbanda & Singh, 2017; Mallikarjunappa & Afsal, 2010; Raju & Shirodkar, 2020; Ullah, 2013). However, some contrary opinions state that the spot market performs a price discovery role due to the futures market's inefficiency and their investors' unawareness (Phong et al., 2020; Tripathy, 2014).

India is the largest country in gold consumption and derives its demand from jewellery, retail investment, and other sources (Refinitiv, 2019). Gold symbolises purity in India, connected with religion and a passion for people. Silver is the second major attraction for investors in India in the precious metal segment after Gold. Silver is widely used in developing electronic equipment, the healthcare sector, jewellery, purifiers, etc. Besides this, because of its affordability, it also traced its demand among investors after Gold. Much research has been undertaken in India on the role of the precious metal (Gold and Silver) futures and spot markets in price discovery (Gupta et al., 2018; Kumar & Sulphrey, 2015; Kumar & Arora, 2011; Pavabutr & Chaihetphon, 2010; Srinivasan & Ibrahim, 2012). These studies have been made in different time frames and have used a very short period for making conclusions. Moreover, few studies (Yu et al., 2023) look into the impact of futures contract characteristics on the futures price discovery process. In contrast, none of these studies have explored the same in the Indian scenario.

Therefore, we investigate time-varying price discovery in Indian precious metals futures and spot markets by taking a longer period. We also delve into the impact of futures market characteristics on the futures price discovery. It offers insights to

investors and policymakers, empowering them to navigate and regulate the market effectively in the face of evolving conditions. This contributes to maintaining stability and making informed decisions.

The present research article has several contributions. Firstly, it used a longer period to examine the price discovery process compared to earlier studies. Secondly, it measured average as well as time-varying price discovery so that in case of any shocking news, investors can make a decision appropriately. Finally, the study also examined the impact of futures contract characteristics and COVID-19 on the futures price discovery in both precious metals cases.

### **Theoretical Base and Hypotheses**

On the theoretical front and based on the commodity market's structure, two hypotheses describe the supremacy of one market over the other market in information flow. One is the transaction cost hypothesis, and the other is the margin trading hypothesis. According to the transaction cost hypothesis, the market that offers lower transaction costs to investors tends to be superior in information processing (Booth et al., 1999; Chu et al., 1999; Fleming et al., 1996; Min & Najand, 1999; Roope & Zurbruegg, 2002; Saini & Sharma, 2023). In physical form, precious metals attract, making charges about 3% to 25% of the value of precious metals (Tripathi, 2023). On the other hand, initiating a position in precious metals through futures requires costs for opening a Demat Account and lower brokerage charges than making charges. In the view of cost preference, the futures market is expected to lead in terms of price formation over a period of time.

In light of the margin trading hypothesis, the market that provides a higher return on the investment tends to perform better in processing information (Chu et al., 1999; Hseu et al., 2007; Jong & Donders, 1998). Due to the availability of higher leverage in the futures market, investors can get higher returns by paying only the margin amount. The price discovery process is anticipated to be dominated over time by the gold and silver futures markets due to the higher leverage available in these markets. Based on the prepositions, the following hypotheses are framed.

- H<sub>1</sub>: Gold futures prices impact significantly to the price formation process more than spot prices of Gold
- H<sub>2</sub>: Silver futures prices impact significantly to the price formation process more than spot prices of Silver

This research article is divided into five sections. The paper's first section covers the introduction, research problem, theoretical framework, and hypotheses. The

second section includes a brief overview of existing literature on price discovery. The research methodology is discussed in section three, while section four describes the analysis and results. The conclusion, the paper's final section, highlights the study's main findings and discusses their implications for policy framing.

## **Literature Review**

The body of research on how futures and spot markets contribute to price discovery has evolved over time. Four types of studies on price discovery are available in the literature. The first group includes studies that are based on the directional behaviour of spot and futures markets and focused on return spillover (Ilankadhir & Rao, 2018; Kharbanda & Singh, 2017; Phong et al., 2020; Tripathy, 2014; Wahab & Lashgari, 1993). However, the limitation of this approach is that it considers only the return spillover and ignores the second most crucial measure (volatility) of information flow.

The limitations of the price discovery based on return spillover leads to the evolution of the second group of studies that measures the price discovery role based on return and volatility spillover of the spot and futures market (Debasish, 2009; Karmakar, 2009; Magkonis & Tsouknidis, 2017; Malhotra & Sharma, 2016; Mallikarjunappa & Afsal, 2010; R L & Mishra, 2020). However, these studies also have some limitations as they only mention about the direction of information flow and do not quantify the price contribution so that investors can make better decisions regarding their investment.

The limitations of return and volatility spillover measures of the price discovery role of the spot and futures market pave the way for the development of the third measure of price discovery that quantifies the price contribution of each market (Baur & Dimpfl, 2019; Brockman & Tse, 1995; Roope & Zurbruegg, 2002; Tse et al., 2006). However, these are also not free from limitations as these price discovery measures provide information about each market's average contribution over time. The market has witnessed many shocks (arising because of shocking news), which have affected the price discovery process considerably. Consequently, to these shocks, the average contribution of price discovery may provide misleading results.

Limitations of the above three price discovery measures lead to the development of the fourth measure of price discovery that is based on the time-varying behaviour of price discovery of the spot and futures market (Adämmer et al., 2016; Adämmer & Bohl, 2018; Avino et al., 2015; Caporale et al., 2010; Farzanegan, 2022; Li & Xiong, 2021; Narayan & Sharma, 2018; Vollmer et al., 2020; Yu et al., 2023). In the

context of the commodity market, some studies focus on the fourth approach. In a study conducted by Yu et al. (2023), the price discovery process in China's crude oil futures market was examined. The study found that both spot and futures markets contribute to price discovery in a time-varying manner. However, during the COVID-19 pandemic, the pricing efficiency was significantly impacted. Nevertheless, it improved after China's economic recovery from the pandemic shock. Similarly, Vollmer et al. (2020) examined time-varying price discovery in the European wheat market and stated that the futures market performs a price discovery function. However, its efficiency is reduced during periods of high volatility.

On the other hand, Farzanegan (2022) inspected time-varying price discovery in the Bahar-e-Azadi Gold coin spot and futures market in Iran. They found spot market dominates the price discovery process due to the illiquidity of the futures market. Likewise, Li and Xiong (2021) look into the dynamic price discovery of 14 agricultural products in China. They found that price discovery is affected by trading volume in China. Narayan and Sharma (2018) examined the price discovery of 15 commodities, namely Canola, Cocoa, Coffee, Copper, Corn, Crude Oil, Gold, Palladium, Platinum, Silver, Soybean Meal, Soybean Oil, Soybean Yellow, Sugar, and Wheat with a rolling window by using monthly data during 1977 to 2012 from Commodity Research Bureau (CRB). They found time-varying nature of price discovery in 14 commodities, including Gold and Silver. They also found that in the case of only six, commodity price discovery is dominated by the futures market. While, in the case of the rest of the commodity price discovery (including Gold and Silver), it is dominated by the spot market. They also revealed that different events related to particular commodities affect the price discovery process. Time-varying behaviour-based measures of price contribution are appropriate for investors as they assist in decision-making in case of shocks and normal situations. From this approach, the investor could make a better decision regarding investment based on in-depth details of price contribution over a period of time. The present study adopts this method for a better description of price discovery.

Numerous studies have been conducted in respect of the precious metal market based on the first three approaches (Figuerola-Ferretti & Gonzalo, 2010; Garbade & Silber, 1983; Hauptfleisch et al., 2016; Kumar & Sulphrey, 2015; Kumar & Arora, 2011; Singh & Singh, 2018; Srinivasan & Ibrahim, 2012). However, there is a dearth of literature (Narayan & Sharma, 2018) based on the fourth approach, specifically for an emerging economy like India. Therefore, the present study fills this gap and finds the average as well as the time-varying contribution of the price of precious metal (Gold and Silver) futures and the spot market.

## Data and Methods

### Collection of Data

The study is based on secondary data. The spot and futures prices for Gold and Silver, along with their futures contract trading, are retrieved from MCX (Multi Commodity Exchange), India's largest commodity exchange. MCX comprises about 75% of commodity futures trading in India. The sample data for Gold and Silver are collected from June 06, 2005, and June 01, 2005, respectively and data is collected up to March 31, 2023, subject to availability of spot market data at MCX. The sample unit of single gold and silver futures contracts is 10 grams and 1 kilogram, respectively. MCX provides six types of futures contracts for Gold, which mature in February, April, June, August, October, and December. On the other hand, it provides five types of futures contracts for silver with maturity in March, May, July, September, and December, from which the nearest month contracts' futures prices are considered for the study. Due to the maturity effect, concerned futures series are rolled over to the next contract seven days before expiration. The study used the closing price series of the futures contract. MCX provides spot prices for both Gold and Silver, prevailing in Ahmedabad for morning and evening session data, namely session-1 and session-2. The study considers session-2 data for the spot price series as we use futures closing prices. If any missing values are related to spot and futures prices, then the corresponding prices are also deleted. After filtering data for the selected period, the researchers got 4801 daily price observations for Gold and 4829 observations for silver. The log-transformed price series of spot and futures prices has been used for the whole analysis.

**Table 1: Descriptive Statistics**

	Gold		Silver	
	InSPOT	InFUTURES	InSPOT	InFUTURES
Mean	10.04371	10.04596	10.47821	10.48810
Median	10.23182	10.23294	10.57021	10.58461
Maximum	10.99474	11.00035	11.20850	11.23917
Minimum	8.702012	8.701679	9.235033	9.226607
Std. Dev.	0.573071	0.573844	0.476274	0.477752
Skewness	-0.547204	-0.542234	-0.646279	-0.653048
Kurtosis	2.343606	2.344735	2.549306	2.560037
Jarque-Bera	325.7841	321.1558	377.0300	382.1856
Probability	0.000000	0.000000	0.000000	0.000000
Observations	4801	4801	4829	4829

Table 1 provides the descriptive statistics of data. The descriptive statistics of Gold and Silver's log futures and log spot prices show that Silver and Gold have similar results. However, futures prices are slightly higher than the spot prices, and volatility is also higher in the case of futures prices compared to spot prices. As far as the Jarque-Bera test is concerned, none of the series is normally distributed, indicating fat tails. Another important observation is that Gold prices volatility is higher than Silver prices, which indicates that investment in Gold is riskier than silver.

### **Methods**

The study aims to examine both constant and time-varying price discovery. For this purpose, firstly, VECM is estimated and then to find out constant price discovery, common factor weights (Gonzalo & Granger, 1995; Schwarz & Szakmary, 1994) are calculated. Finally, for time-varying estimates of price discovery, VECM is reformulated into state space form, and Kalman filtering and smoothing are applied to get time-varying parameters of price discovery.

For applying VECM (Vector Error Correction Model), the spot and futures prices must share information in the long run, meaning there must be a long-run association between Gold spot and futures prices. Therefore, for testing the long-run relationship between spot and futures prices the Johansen Co-integration test (Johansen, 1988) has been used. The cointegrating relationship between spot and futures is written as

$$F_t = c + S_t + t + e_t \quad (1)$$

Here  $F_t$ ,  $S_t$ ,  $c$ ,  $t$  and  $e_t$  is the log futures price, log spot price, constant, trend and error correction term, respectively.

The pre-condition for applying the Johansen Co-integration test is that both spot and futures prices should be integrated at 1<sup>st</sup> order, which means there should be a unit root at their level form, but at the first difference, they should be stationary. So before applying the Johansen Co-integration test, two tests, namely the Augmented Dicky Fuller (ADF) test and the Philip-Perron (PP) test (which is the non-parametric counterpart of ADF) have been applied for testing stationarity.

If the two series are Cointegrated, the following VECM is obtained in reduced form (Engle & Granger, 1987).

$$\Delta x_t = m + \sum_{i=1}^p \Gamma_i \Delta x_{t-1} + \Pi x_{t-1} + \varepsilon_t \quad (2)$$

Here,  $x_t$  is the  $(2 \times 1)$  vector  $(S_t, F_t)$  of log spot and log futures,  $\varepsilon_t$  is the  $(2 \times 1)$  vector of the error term  $(\varepsilon_{s,t}, \varepsilon_{f,t})$  that follows as yet-unspecified conditional distribution with mean 0 and time-varying co-variance matrix,  $\Delta$  represents the difference operator, where  $\Gamma$  measures the short-term link between two variables and  $\Pi$  measures the long-term association between two variables.

The VECM specification in Equation (2) is expressed as follows.

$$\Delta F_t = \sum_{i=1}^p \alpha_{f,i} \Delta S_{t-i} + \sum_{i=1}^q \beta_{f,i} \Delta F_{t-i} + \rho_f z_{t-1} + \varepsilon_{ft} \quad (3)$$

$$\Delta S_t = \sum_{i=1}^p \alpha_{s,i} \Delta S_{t-i} + \sum_{i=1}^q \beta_{s,i} \Delta F_{t-i} + \rho_s z_{t-1} + \varepsilon_{st} \quad (4)$$

where  $\alpha_{s,i}$ ,  $\alpha_{f,i}$ ,  $\beta_{s,i}$ , and  $\beta_{f,i}$  are the short-run coefficients,  $\rho_s$  and  $\rho_f$  are the error correction term coefficients, and  $\varepsilon_{st}$  and  $\varepsilon_{ft}$  are the error terms.

The contribution of futures and spot markets is measured by common factor weight, which is the portion of the adjustment coefficient of one market relative to total adjustment. The magnitude of common factor weight for futures ( $CFS_f$ ) and spot ( $CFS_s$ ) is equal to,

$$CFS_f = \frac{|\rho_s|}{|\rho_s| + |\rho_f|} \quad (5)$$

$$CFS_s = \frac{|\rho_f|}{|\rho_s| + |\rho_f|} \quad (6)$$

where, values of  $CFS_f$  and  $CFS_s$  are limited between 0 and 1. If  $CFS_f$  is 0, It suggests that price discovery is completely dominated by the spot market. Where's,  $CFS_f = 1$  implies that price discovery is entirely determined by the futures market. Similarly, if  $CFS_s = 0$  suggests that the futures market completely determines price discovery, whereas  $CFS_s = 1$  indicates that the spot market has complete supremacy in price discovery.

### ***Time-varying Price Discovery***

The common factor weight computes the price discovery on average. However, price discovery in the Indian precious market may vary as it improved over a period. Hence, for checking the dynamic contribution of the market, VECM is reformulated into state space form following (Li & Xiong, 2021; Silv erio & Szklo, 2012)

$$\rho_{ft} = \rho_{ft-1} + \eta_1 \quad (7)$$

$$\rho_{st} = \rho_{st-1} + \eta_2 \quad (8)$$



$$\Delta F_t = \sum_{i=1}^p \alpha_{f,i} \Delta S_{t-i} + \sum_{i=1}^q \beta_{f,i} \Delta F_{t-i} + \rho_{ft} z_{t-1} + \varepsilon_{ft} \quad (9)$$

$$\Delta S_t = \sum_{i=1}^p \alpha_{s,i} \Delta S_{t-i} + \sum_{i=1}^q \beta_{s,i} \Delta F_{t-i} + \rho_{st} z_{t-1} + \varepsilon_{st} \quad (10)$$

Here Equations (7) and (8) are the state equations. On the other hand, Equations (9) and (10) are the measurement equations that are similar to Equations (3) and (4). Where,  $\rho_{ft}$  and  $\rho_{st}$  are state vectors equal to the error correction term in Equations (3) and (4).  $\eta_1$  and  $\eta_2$  are uncorrelated error terms. From the above model, getting time-varying parameters of error correction terms is possible. For that, the Kalman Filter and smoothing are applied (Hamilton, 1994). The Huber-White method (White, 1980) is adopted to estimate time-varying parameters for dealing with heteroscedasticity in error terms. After getting the time-varying parameter of ECT terms, common factor weights for futures and spot markets are computed as per Equations (11) and (12), which measure time-varying price discovery.

$$CFS_{ft} = \frac{|\rho_{st}|}{|\rho_{st}| + |\rho_{ft}|} \quad (11)$$

$$CFS_{st} = \frac{|\rho_{ft}|}{|\rho_{st}| + |\rho_{ft}|} \quad (12)$$

## Empirical Results and Discussion

The first part of the analysis measures the average price discovery of precious metals in the spot and futures market. We have checked the spot and futures market graphs in their level and first differenced forms. Figure 1 indicates that both Gold and Silver's log spot and log futures series are non-stationary in their level form, and comovement is also observed in their graph. Moreover, the First difference series of Gold and Silver's log spot and log futures seems stationary, Demonstrating the possibility of a long-run association between log futures and log spot series.

To confirm this relationship, firstly, we have checked their stationarity at the level and at first differenced form. Table 2 presents the result of the augmented dicky fuller (ADF) and Phillip Perron (PP) result that indicates the case of both precious metal counterpart (spot and Futures) accepting the unit root at level but rejecting at the first difference form. So, it indicates their order of integration is one, that is, the pre-condition for applying the Johansen co-integration test.

Figure 1: Spot and Future Prices of Gold in Log Natural Form at Level and 1<sup>st</sup> Differenced

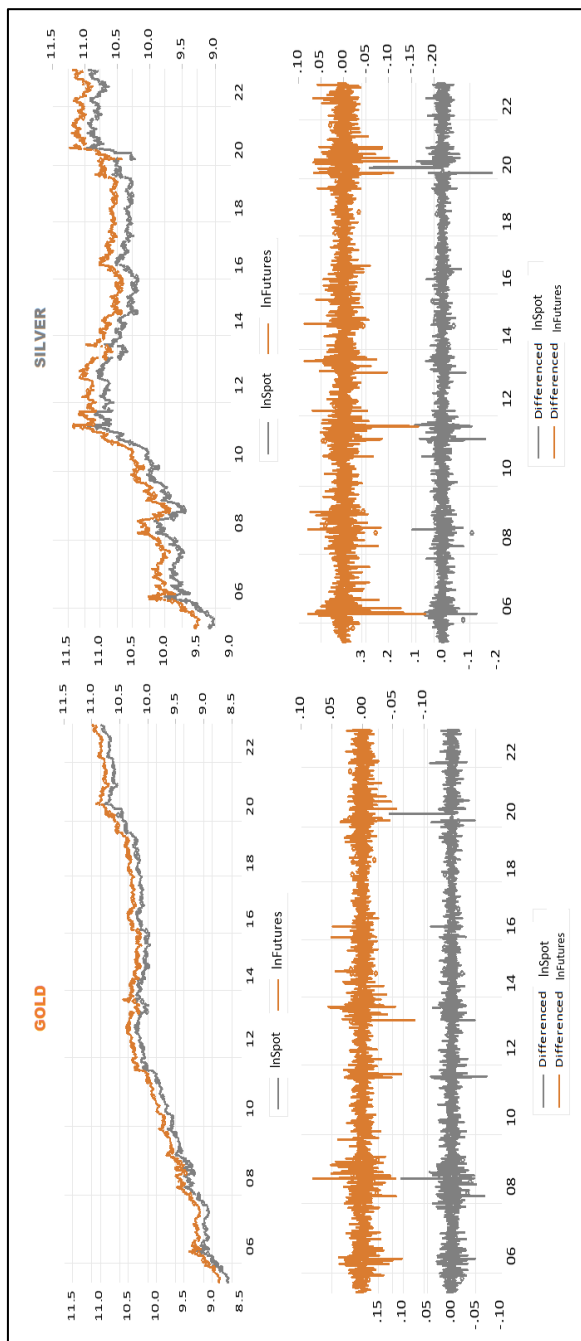


Table 2: Stationarity Results for Gold and Silver (Spot and Futures Logarithm Price Series)

	Gold				Silver			
	InSPOT	FDNLSP	InFUTURES	FDNLFP	InSPOT	FDNLSP	InFUTURES	FDNLFP
ADF	-1.7343 (0.4138)	-68.816 (0.0001)	-1.6823 (0.4403)	-69.928 (0.0001)	-2.0090 (0.2831)	-69.965 (0.0001)	-2.0546 (0.2635)	-70.811 (0.0001)
PP	-1.7075 (0.4274)	-68.899 (0.0001)	-1.6847 (0.4390)	-69.927 (0.0001)	-2.0157 (0.2802)	-69.975 (0.0001)	-2.0566 (0.2627)	70.798 (0.0001)

Note: FDNLSP is First difference of natural logarithm of spot prices and FDNLFP is First difference of natural logarithm of futures prices

Table 3 presents the results of the lag length criteria, which indicates the lag length based on AIC (Akaike Information Criteria), SIC (Schwarz Information Criteria), and HQ (Hannan-Quinn Information Criterion). To ensure parsimony while applying Johansen co-integration, we choose four lags as per SIC. This is because AIC and HQ suggest eight and six lags, respectively. Table 4 presents the Johansen co-integration result, indicating that in the case of both precious metals, their counterparts have a long-run relationship with one cointegrating vector.

**Table 3: VAR Lag Order Selection Criteria**

Lag	Gold			Silver		
	AIC	SIC	HQ	AIC	SIC	HQ
0	-3.831141	-3.828439	-3.83019	-3.31653	-3.31384	-3.31558
1	-13.2595	-13.25139	-13.2567	-11.1501	-11.1421	-11.1473
2	-13.67134	-13.65783	-13.6666	-11.4875	-11.474	-11.4828
3	-13.72193	-13.70302	-13.7153	-11.523	-11.5041	-11.5163
4	-13.73369	-13.70937*	-13.7252	-11.5301	-11.50588*	-11.5216
5	-13.73526	-13.70554	-13.7248	-11.5329	-11.5033	-11.5225
6	-13.73803	-13.70291	-13.72569*	-11.53622*	-11.5013	-11.52394*
7	-13.73707	-13.69655	-13.7228	-11.5348	-11.4944	-11.5206
8	-13.73873*	-13.6928	-13.7226	-11.5351	-11.4894	-11.5191

Note: \*Represent lag order selected by the criteria. The lag length is chosen as per SIC for applying the Johansen co-integration test. As per this criterion, four lag is selected for both Gold and silver for co-integration.

**Table 4: Co-integration Test Result for Gold and Silver**

	Gold		Silver		Decision
	<i>Trace</i>	<i>MAX</i>	<i>TRACE</i>	<i>MAX</i>	
Cointegrating Equation	$\ln FUTURE(-1)$ = $-0.999110 \ln SPOT(-1)$ - $1.16E - 06 @trend$ - $0.008398$		$\ln FUTURE(-1)$ = $-0.998261 \ln SPOT$ - $2.01E - 06 @trend$ - $0.023269$		
<b>Null hypothesis</b>	<b><i>Trace</i></b>	<b><i>MAX</i></b>	<b><i>TRACE</i></b>	<b><i>MAX</i></b>	
r=0	93.600936*** (0.0000)	86.58107*** (0.0000)	152.4004*** (0.0000)	146.0714*** (0.0000)	One cointegrating vector
r=1	7.028296 (0.3416)	7.028296 (0.3416)	6.3290 (0.4197)	6.3290 (0.4197)	

Note: \*\*\* Represents the significance level at 1 cent, and four lags are chosen for Gold and silver as per Schwarz Information Criteria (SIC).

Finally, after satisfying the pre-condition for applying VECM, the Common factor weights (CFW), a measure of the average contribution of price discovery, are computed. Table 5 reports the results of VECM and common factor weights. According to Pavabutr and Chaihetphon (2010), the Error correction term (ECT) in VECM represents the adjustment coefficient. If the ECT term is positive and significant, then it indicates an increase in the lagged period disequilibrium would lead to an increase in the present price of the response variable. Similarly, if the ECT term is negative, then it indicates an increase in the previous period's disequilibrium, which would lead to a decrease in the current price of the response variable. The value of the ECT Term should lie between 0 and 1, Where 0 indicates no adjustment post divergence and 1 indicates complete adjustment (Prabhdeep, 2018). Table 5 shows that in the case of the Gold spot equation, the error correction term is positive and significant at a 1% level. While the futures equation error correction term is negative and significant at a 5% level, the spot equation error correction magnitude is higher than the futures equation error correction term magnitude. This indicates that in the long run, when futures and spot prices are in disequilibrium, the spot return responds more to the mean reverting process than the futures return.

Moreover,  $CFW_f$  is 72% for futures and 28% for the spot market, indicating that Gold futures prices lead the spot prices. Similarly, in the case of silver, the spot equation error correction term is significant at 1% while the futures equation error correction is significant at a 5% level; this gives the same indication as in the case of Gold. Besides this, futures  $CFW_f$  for the futures market is 80% while spot market  $CFW_s$  is 20%, which indicates that in the case of silver, the futures market has more contribution to price discovery. The results are corroborated by the findings of (Dangi, 2014; Pavabutr & Chaihetphon, 2010).

**Table 5: VECM and CFW for Gold and Spot and Futures Prices**

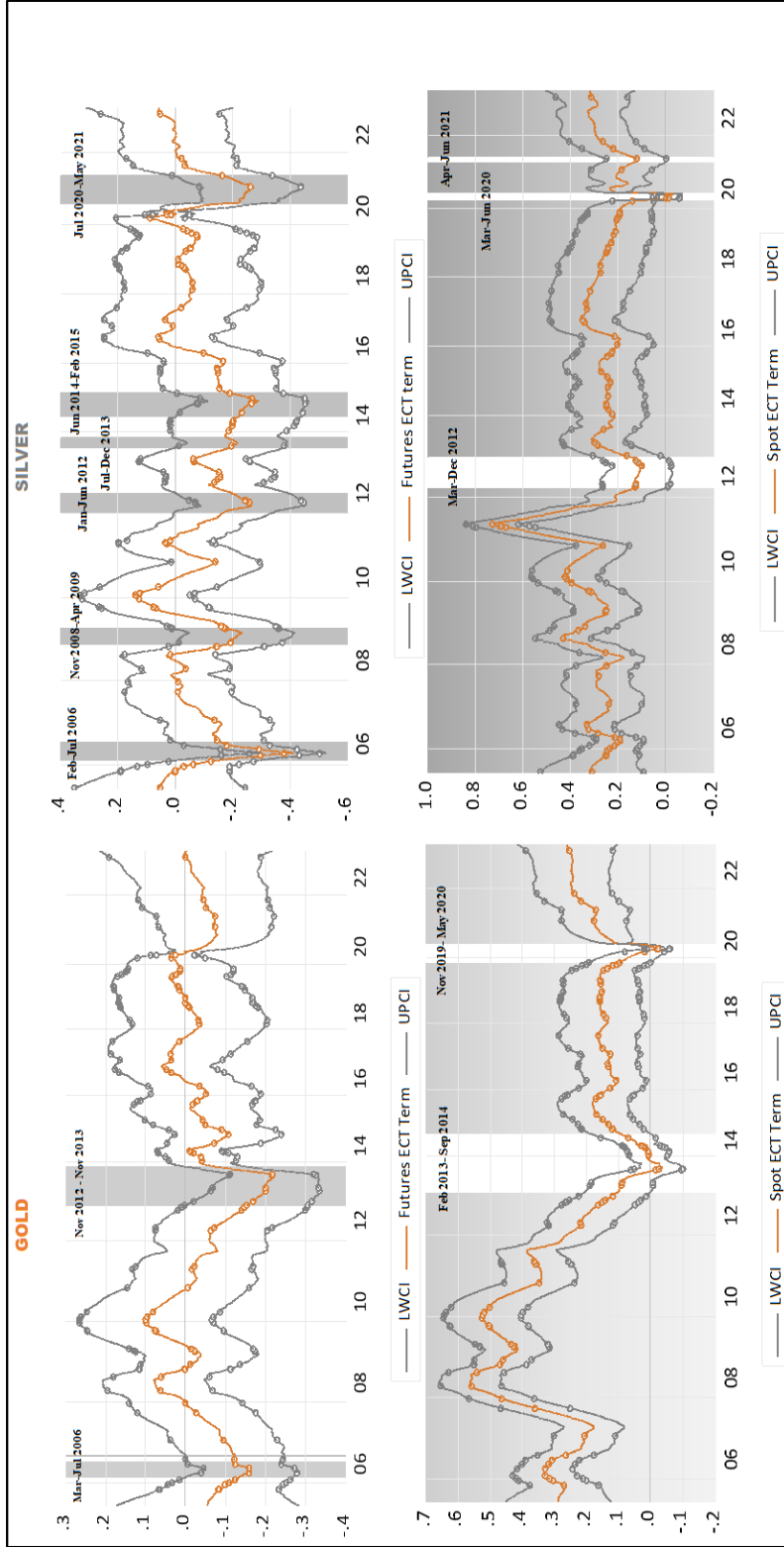
	GOLD		SILVER	
	$\Delta S_t$	$\Delta F_t$	$\Delta S_t$	$\Delta F_t$
	Coefficients	Coefficients	Coefficients	Coefficients
$Z_{t-1}$	0.056346*** [ 7.1018]	-0.021732** [-2.0408]	0.096351*** [10.4812]	-0.024416** [-1.9983]
$\Delta S_{t-1}$	-0.403771*** [-22.9008]	0.043911 [1.8555]	-0.352310*** [-20.6335]	-0.005362 [-0.2362]
$\Delta S_{t-2}$	-0.161274*** [-8.8885]	0.000955 [0.3923]	-0.148908*** [-8.6579]	-0.011707 [-0.5121]
$\Delta S_{t-3}$	-0.055349*** [-4.1685]	0.031467 [1.7657]	-0.059585*** [-4.6795]	0.000665 [0.0393]
$\Delta F_{t-1}$	0.638863*** [44.8160]	-0.014642 [-0.7652]	0.594886*** [40.9917]	-0.002636 [-0.1366]

	GOLD		SILVER	
	$\Delta S_t$	$\Delta F_t$	$\Delta S_t$	$\Delta F_t$
	Coefficients	Coefficients	Coefficients	Coefficients
$\Delta F_{t-2}$	0.253523*** [14.4303]	-0.022165 [-0.9400]	0.223935*** [13.0878]	0.028893 [1.2705]
$\Delta F_{t-3}$	0.098761** [6.1035]	-0.003776 [-0.1738]	0.086418*** [5.4639]	0.043001** [2.0456]
Constant	0.000454** [3.1813]	0.000299** [2.8151]	0.000250 [1.3834]	0.000371 [1.5463]
Adjusted R <sup>2</sup>	0.38	0.003	0.39	0.002
F-statistic	428.17***	2.19**	450.43***	1.96**
CFW	0.28	0.72	0.20	0.80

- Notes: 1. \*\*\* and \*\* indicate  $p < 0.01$  and  $p < 0.05$  respectively  
2. Figure in square brackets [ ] shows the t-statistics.  
3. For dealing with the heteroscedasticity issue, the Huber-white method (White, 1980) is adopted.  
4.  $Zt-1$  represents the lagged error correction term.  
5. In the case of Gold  $ECT = \ln FUTURE_S(-1) - (-0.999110 \ln SPOT(-1) - 1.16E - 06 @ trend - 0.008398)$  while in the case of silver  $ECT = \ln FUTURE_S(-1) - (-0.998261 \ln SPOT - 2.01E - 06 @ trend - 0.023269)$ .  
6. For determining appropriate lag length, firstly VAR model has been specified in that four lags are appropriate according to Schwarz information criteria (SIC). For selecting the appropriate lag length for VECM, these lags are reduced to three due to the differenced operator in VAR (see (Lütkepohl, 2005)).

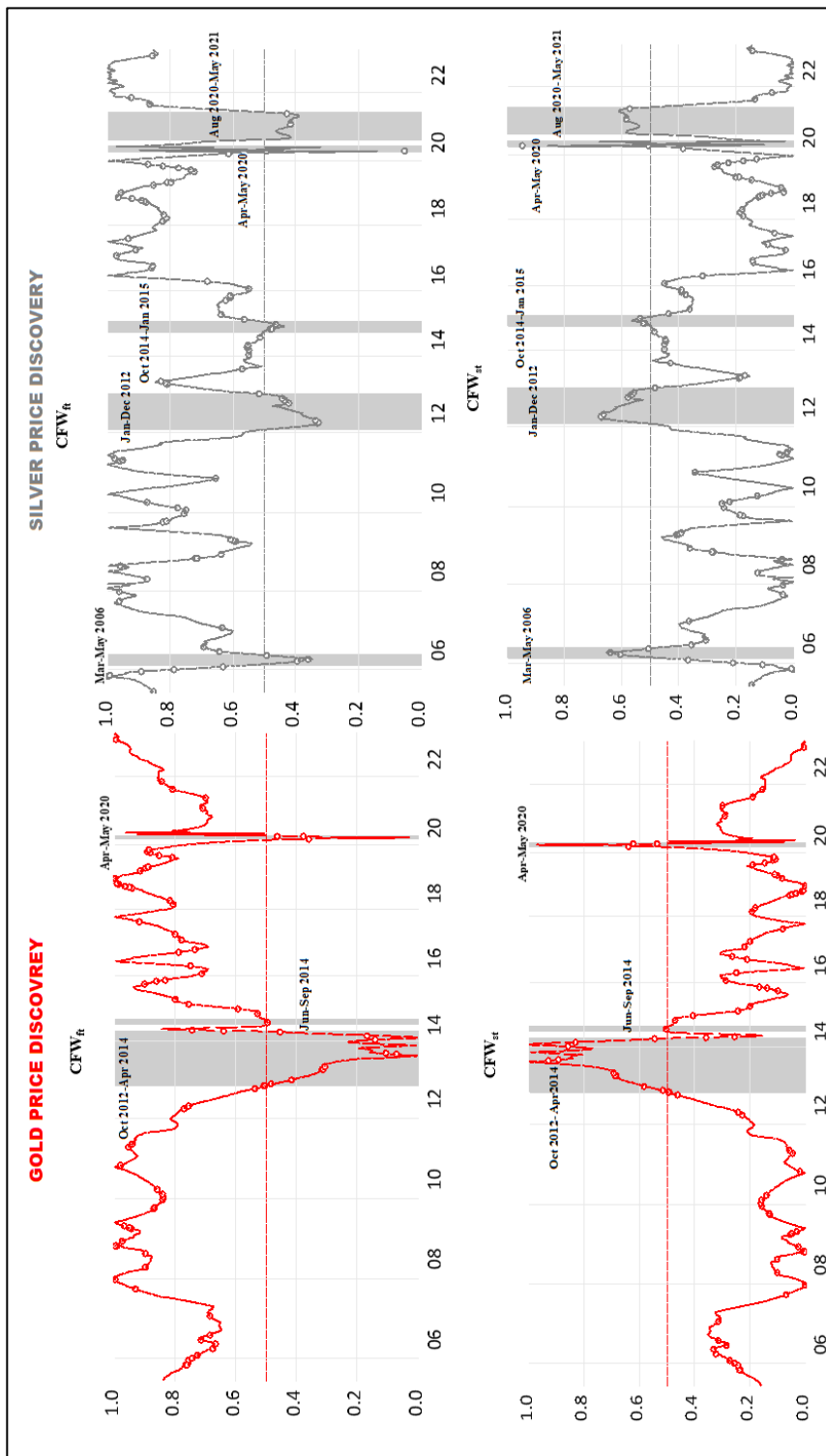
Sometimes, average price discovery gives misleading results (Adämmer et al., 2016; Adämmer & Bohl, 2018; Li & Xiong, 2021). So, we find out the time-varying behaviour of price discovery. In the case of Gold, time-varying behaviour in both futures and spot ECT terms is present. Figure 2 shows that most of the time, spot market ECT terms are positive and significant but insignificant during two short periods. However, the futures market ECT term is mostly insignificant but significant during two short periods. Both ECT terms indicate the time-varying formation of price discovery in the Indian Gold market. Figure 3 indicates that in the case of Gold,  $CFW_{ft}$  (common factor weight for futures) is more than 0.5, which indicates that most of the time, the futures market leads the spot market. However, during three short periods, Oct 2012 to April 2014, Jun to Sep 2014 and April to May 2020  $CFW_{st}$  (common factor weight for the spot market) is higher than 0.5, indicating that during this period, the spot market processes most of the information. While from Oct 2012 to April 2014,  $CFW_{st}$  increased to 1 (on July 29 2013 and January 28 2014), from April to May 2020, the  $CFW_{st}$  increased to 0.97. These short periods seemed to be shocking to the gold market as during the first and second period, various government measures were taken to curb the demand for Gold on account of the increasing current account deficit.

Figure 2: Time-varying Spot and Futures ECT (Error Correction term) for Gold and Silver Market



Note: Here area between LWCI (lower Confidence interval) and UPCI (upper confidence interval) represent 95% Confidence region. Shaded regions show the significant ECT terms.

Figure 3: Time-varying Common Factor Weights (CFW) for Spot and Futures Market in The Case of Gold and Silver



Note: Here, highlighted short periods indicate where the spot market is superior in terms of price discovery as compared to the futures market.

Consequently, noise traders are activated in the futures and decrease the futures market's efficiency, leading to most of the price formation in the spot market. The third period is during April-May 2020, which is related to the COVID-19 period. In this period, a spike in  $CFW_{st}$  was seen that reached up to 0.97. This happened due to uncertainty among investors that again activated noise traders in the market; consequently, most of the price formation occurred in the spot market.

In the case of Silver also, there is seen time-varying behaviour of both spot and futures ECT term. Figure 2 shows that the spot ECT term is significant for most of the period, but it becomes insignificant only in three short periods. While the futures market ECT term is insignificant for most of the period, it becomes significant during six short periods. Both ECT terms indicate the time-varying behaviour of price formation of the silver market. In Figure 3, it is seen that most of the time  $CFW_{ft}$  (Common factor weight for futures) is more than 0.5, indicating that most of the time, price formation happens in the futures market. Still, during five short periods (March to May 2006, Jan to Dec 2012, Oct 2014 to Jan 2015, April to May 2020, and Oct 2020 to May 2021)  $CFW_{st}$  (Common factor weight for the spot) is more than 0.5 (reached at the highest level 0.66, 0.66 0.56, 0.92 and 0.66 respectively during 5 short periods) indicating spot market process most of the information during this period. During the first period, Silver prices suddenly hiked due to the dollar value being lower than the euro (The Economic Times, 2007) . This news creates shock among Indian investors. While in the second and third periods, import duty was increased on Silver.

On the other hand, during the fourth and fifth periods, the Covid-19 pandemic emerged, creating uncertainty among investors. These short periods are shocking to the silver market and situation of uncertainty due to which noise traders are activated in the futures market, which decreases the efficiency of the futures market, leading to the supremacy of the spot market. Here, one more thing is observed: import duty's increased impact on Gold spot market price discovery is more than that of Silver spot market price discovery. This difference is because most of the Gold supply is based on imports. However, most of the supply of Silver is mined by India itself. Similarly, Li and Xiong (2021) state that, commodities that are highly dependent on imports from other nations, market-oriented policy adjustments do not improve the price discovery performance of most futures markets in their study.

The impact of the coronavirus pandemic is quite the same on both the Gold and Silver Spot markets. From these results, both hypotheses  $H_1$  and  $H_2$  are rejected,



suggesting that over time, price discovery oscillates between futures and spot markets depending upon specific commodity-related events. These findings are in line with the study of (Andersen et al., 2007; Caporale et al., 2010; Chang & Shi, 2020; Mohamad & Inani, 2022; Narayan & Sharma, 2018; Vollmer et al., 2020). Price discovery, according to (Andersen et al., 2007), depends on the cycle that each security faces. Likewise, examining price discovery in 15 commodity futures and spot markets, Narayan & Sharma (2018) also note that the price discovery is related different events faced by the particular commodity.

Finally, the study looks into the impact of the factors related to futures contract characteristics and Covid-19 on the price discovery of the gold and silver futures market. Following (Yu et al., 2023), the study used  $\log(\text{volume})$ ,  $\log(\text{open interest})$ , speculative intensity  $\frac{\text{volume}}{\text{open interest}}$ , volatility  $(\log(\frac{\text{close}_t}{\text{close}_{t-1}}))^2$  and information flow  $\log(\frac{\text{open}_t}{\text{close}_{t-1}})$  that measure information flow from the end of the last trading day to the beginning of the current trading day, COVID-19, a dummy variable that takes one value from March 24 2020 to June 16 2021 ( as this period represents COVID-19 lockdown), and trend variable is included for better result. Table 6 reports the results of the relationship between price discovery of the futures market in the case of both gold and silver markets and their trading characteristics.

**Table 6: Relationship between Futures Market Time-varying Price Discovery ( $CFS_{ft} = \frac{|\rho_{st}|}{|\rho_{st}|+|\rho_{ft}|}$ ) and its Trading Characteristics**

	$CFS_{ft}$ for Gold	$CFS_{ft}$ for Silver
Log volume	-0.040180*** (-5.60)	-0.026490*** (-3.85)
Log open interest	0.051622** (2.53)	0.049131** (2.27)
Volatility $(\log(\frac{\text{close}_t}{\text{close}_{t-1}}))^2$	-64.12769*** (-3.27)	-10.84730*** (-2.87)
Speculative intensity $\frac{\text{volume}}{\text{open interest}}$	0.025861*** (4.76)	0.010796* (1.83)
Information flow $(\log(\frac{\text{open}_t}{\text{close}_{t-1}}))$	2.581244** (2.42)	0.238313 (0.49)
Covid-19	-0.095864*** (-5.11)	-0.300671*** (-11.23)
Constant	0.610645*** (3.72)	0.478551*** (2.59)
trend	0.0000114***	0.0000256***

	<i>CFS<sub>ft</sub></i> for Gold	<i>CFS<sub>ft</sub></i> for Silver
	(2.58)	(4.57)
Adjusted R <sup>2</sup>	0.03	0.16
F-statistics	22.36***	132.35***
Durbin Watson	0.038	0.027

Notes: 1. \*\*\*, \*\* and \* indicate  $p < 0.01$ ,  $p < 0.05$  and  $p < 0.1$  respectively.

2. As the Durbin Watson is lower than 2, it indicates autocorrelation. Therefore, in dealing with it, the model is run with the HAC option for calculating the co-variance matrix and true standard errors.

It depicts that the futures trading characteristics and COVID-19 significantly negatively impact the price discovery process in the futures market in both precious metals case. Covid-19 impact on the price discovery process has also been confirmed in Figure 3. Additionally, the results depict that the volume and volatility significantly negatively impact both precious metals futures price discovery. Meanwhile, other futures market characteristics, i.e., open interest and speculative intensity, have significantly positively impacted the price discovery process in the case of both precious metals. Information flow is positively significant in the case of Gold. Although our findings are similar to those of Yu et al. 2023 with respect to negative relation between futures price discovery and futures contract characteristics, we differ regarding the positive relation between futures price discovery and speculative intensity. Speculators' important role in fulfilling the demand of hedgers (Hirshleifer, 1990), enhancing market liquidity and information flow and non-participation in noise trading could be the reason (Fung & Tsai, 2021).

## Conclusion

The study analysed the average and time-varying price discovery in the Indian precious metal market (Gold and Silver) counterparts (spot and futures) as sometimes only average price contribution gives misleading results (Adämmer et al., 2016; Adämmer & Bohl, 2018; Li & Xiong, 2021; Narayan & Sharma, 2018; Yu et al., 2023). Generally, price discovery happens in the futures market for Gold (72%) and Silver (80%). However, time-varying price discovery depicts the time-varying behaviour of price discovery in the case of both Gold and Silver. While most of the period of price discovery happened in the futures market, when any shocking news arrives (import duty increase, Covid-19 pandemic), noise traders become activated in the market, decreasing the efficiency of the futures market, which leads to the supremacy of the spot market in price discovery in case of both Gold and Silver. However, a new shock in the form of the import duty increase has more impact on Gold than on Silver. This is because most of the Gold supply is dependent on imports, while India itself mines most Silver. Furthermore, the study finds that futures volume,

volatility and COVID-19 significantly negatively impact the futures market price discovery process in both precious metals case. At the same time, other futures market characteristics, i.e., open interest and speculative intensity, positively affect the futures market price discovery process in the case of both precious metals. It may be because of speculators' significant contribution to market liquidity, information flow, hedgers' needs being met (Hirshleifer, 1990), and their lack of involvement in noise trading (Fung & Tsai, 2021). However, in the Indian precious metals market, speculators' noise trade is mainly in shocking news scenarios, as evidenced by spot market dominance in price discovery during shocking news. So, the Indian futures market regulators are suggested to ensure stability in that scenario. Moreover, investors are advised to follow the futures market in normal conditions. In contrast, in case of any shocking news, they are suggested to follow the spot market for their investment decision.

The research article has contributed to the literature on price discovery in precious metals in many ways. Firstly, we found time-varying behaviour of price discovery in the Indian precious market. Furthermore, the study reveals that the price discovery of precious metals depends upon specific precious metals-related events. In the shocking news scenario, the spot market leads the futures market, while reverse happens in normal situations. This understanding of market dynamics provides insights to investors and academicians. It also helps investors in the development of short-term trading strategies and risk management strategies, especially in stressful situations. Secondly, the study also sheds light on the relationship between future market characteristics and future price discovery. Speculators' intensity positive relationship with futures price discovery is an interesting aspect. Despite the positive relation with speculator intensity, in the shocking news scenario, the futures market is not efficient. This emphasises the need for further research. In future, research can also be conducted by considering other commodities, as the scope of the research article is limited to precious metals.

### **Declaration of Conflicting Interests**

The authors declared no potential conflict of interest with respect to the research, authorship, and publication of this article.

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