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TIME-VARYING PRICE DISCOVERY IN BAHAR-E-AZADI GOLD COIN SPOT AND FUTURES CONTRACTS

Abstract

This paper aims to analyze the daily price discovery of Bahar-e-Azadi Gold Coin (GC) spot and futures contracts in Iran, using the fractionally cointegrated error-correction model (FCECM). The residuals of the FCECM are modeled by the BEKK-GARCH specification to calculate the time-varying conditional information share between GC spot and futures prices. Using data covering December 21, 2008 to April 14, 2018, the paper establishes the novel finding that the GC spot and futures price series are fractionally integrated of orders 0.98347 and 0.95169, respectively. This implies the long memory behavior in the price series. Further, the results show that the series are fractionally cointegrated of order 0.542. The empirical findings from the methodology indicate that in the price discovery process, the GC spot market dominates the GC futures market. This analysis is robust to alternative construction of futures price series and sub-samples decomposed based on structural breaks. One possible explanation could be the higher trading volume associated with the GC spot market compared to the GC futures market. Incompleteness and market frictions also can cause a delay in the process of information incorporation into the futures market and may discourage market players from trading in these markets.

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INTRODUCTION

Under the efficient market hypothesis, all new information arriving in the markets should be reflected in the prices of spot and futures simultaneously and immediately. Therefore, there will be no systematic lagged response, and hence, no risk-free arbitrage opportunity. However, several theoretical and empirical kinds of research document the importance of market frictions on commodity prices. Under theories of incomplete markets, market microstructure frictions can affect the process by which the new information is incorporated into the price. In this context, a good understanding of the relative contributions to the price discovery process between spot and futures markets is required. In particular, understanding the source of price discovery between spot and futures provides essential information to investors to facilitate deciding on hedging and risk management strategies.

The Bahar-e-Azadi Gold Coin (GC) futures contracts are the first commodity futures contracts listed on the derivatives floor of the Iran Mercantile Exchange (IME). However, since 2017, the GC futures market has been closed. During the ten years of the beginning of the GC futures contract in 2008, its trading value has grown rapidly. The increasing use of derivatives offers alternative investment instruments

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for efficient risk management. Despite the developments in the derivatives market, GC futures contracts are rather known financial instruments in IME, and the roles of GC spot and futures markets have been little understood, which has raised some questions: What is the contribution of spot gold and futures markets to convergence to the equilibrium? When the linked commodities are traded at different markets, concerns about price discovery between them arise?

1. LITERATURE REVIEW

The relative contributions to price discovery of spot and futures markets for equities have been examined extensively in the finance literature; among others, Ding et al. (1999), Lehmann (2002), Hasbrouck (2003), Theissen (2012), and Al-Shboul et al. (2016). Malkiel and Fama (1970) and Taylor (1989) argue that stock prices must immediately reflect all information. Shleifer and Vishny (1970) found that investors' behaviors affect price discovery. Merton (1987) shows that trading volume has contributed to the price discovery.

In the case of the commodity market, Stein (1961) in his seminal paper shows that spot and futures prices for a given commodity are determined simultaneously. Ederington et al. (2019) believe that Black (1976), in his seminal paper, considered the price discovery function of commodity futures markets as a facilitator of hedging and shifting risk. Garbade and Silber (1983) propose the terminology of Dominant and Satellite markets in analyzing the price discovery role of futures and cash markets for seven commodities. Their evidence reveals that about 75% of new information is incorporated first into the Dominant market prices. Hauptfleisch et al. (2016) show that the New York Futures play a dominant role in price discovery.

Recently, studies have concentrated on the dynamics of the spot and futures price series and testing for the causality or lead-lag relationship between them. Yang and Leatham (1999), using the error-correction model, show that futures markets have greatly contribute to price discovery. Yang et al. (2001) find that the cointegration relation between cash and futures prices is not affected by asset storability. Thus, futures markets provide the primary contribution to the price discovery function for all non-storable commodities. Figuerola-Ferretti and Gilbert (2005), employing the vector error-correction model, investigate the relative informational impact of futures trading on transaction prices for the underlying aluminum commodity. They find that price discovery exclusively takes place in the aluminum futures market.

Some studies employ the Hasbrouck (1995) methodology. For example, Tse and Xiang (2005), using the Hasbrouck measure, find that NYMEX E-mini futures contracts on natural gas and crude oil contribute more to price discovery than regular futures on natural gas.

Due to the poor-quality data, few studies have been conducted on the issue of price discovery in emerging markets. Naik and Jain (2002) examine six commodity futures markets of India in terms of price discovery and risk management via testing the cointegration relation between cash and futures prices. They conclude that the performance of commodity futures markets varies across commodities, exchanges, and maturity months of contracts. Liu and An (2011), using the multivariate generalized autoregressive conditional heteroskedasticity, analyze the cross-market price discovery contributions of the copper and soybean futures markets. The results from the information share method document the information linkage between Chinese and US futures markets.

Mahalik et al. (2014) study the price discovery process between spot and futures commodity markets in India. The results from the vector error-correction model (VECM) show that there is a flow of information from futures to spot markets for agriculture futures price index, energy futures price index, and aggregate commodity index. Mattos and Garcia (2004), using Johansen cointegration and vector autoregressive (VAR) procedures, study the price discovery function in the six Brazilian commodity spot and futures markets. They find that the thinly traded sugar futures market leads the spot market movements in the long run. Xiyu (2006), applying the Johansen cointegration test, the VAR model, and the vector moving average (VMA) model, finds that there

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are long-run relationships between Chinese spot and futures commodity markets, with commodity futures leading commodity spot in price discovery. Pavabutr and Chaihetphon (2010) analyze the price discovery process of standard and mini gold coin futures contracts in the Multi Commodity Exchange of India (MCX), applying the VECM model. The results from the estimated information share show that both futures contracts lead to spot prices. Ivanov (2013) examines the relationship between gold and silver Exchange-Traded Funds (ETFs) with their futures in terms of price discovery function. The results from Hasbrouck's information share represent the evidence of price discovery shifting from gold and silver futures to the ETF market. Peri et al. (2013) investigate the long-run relationship between spot and futures commodity prices. The results from the cointegration methodology, allowing to test for multiple structural breaks and causality tests, show that the causality relationships between the commodities exhibit different dynamics within each identified sub-period. Chinn and Coibion (2014) document that compared to energy and agricultural futures, precious and base metals are poor predictors of future spot price changes but unbiasedness. Using the nonlinear Granger causality test for the New York Mercantile Exchange (NYME), Zhang and Liu (2018) document a bi-directional Granger Causality relationship between futures and spot returns for natural gas. However, the result from the linear Granger causality test implies a dominant role of futures in the price discovery process. Lucey et al. (2013), using Hasbrouck's (1995) and Gonzalo and Granger's (1995) approach to price discovery, find that the dominance of London Fixings and New York Mercantile Exchange (COMEX) futures to price discovery is switching over time. Atilgan et al. (2022), for a sample of 18 emerging countries, found that the returns of exchange-traded funds (ETFs) can predict their underlying indices.

In terms of methodology, some studies develop the Hasbrouck (1995)'s information share (IS) approach and Gonzalo and Granger's (1995) component share (CS) model of the static price discovery. For example, Figuerola-Ferretti and Gonzalo (2010) develop an equilibrium no-arbitrage model of the price discovery process with the assumption of finite elasticity of arbitrage services and endogenous convenience yields and apply it to the London Metal Exchange (LME). They find that the futures price is information dominant for metals with liquid futures contracts. Karabiyik et al. (2017) propose the VECM within a panel data set and derive the panel estimates of IS and PT measures of price discovery. They show that for most Islamic stock markets, the price discovery is dominated by the spot market.

Recently, some research has extended fractional integration (or long memory) and fractional cointegration to the relation between spot and futures prices, both for hedging assessment and for analyzing the price discovery. Coakley et al. (2011) consider a long memory component in the error-correction terms in the ECM framework and investigate the hedging effectiveness of the fractionally integrated EC (FIEC) model over a range of commodities and their futures contracts. The results show fractional integration in the futures premium (the difference between the spot and futures prices). They demonstrate the superiority of the FIEC-BEKK hedging strategy over the conventional OLS technique. Aye et al. (2017), using annual data on gold prices and retail price index (RPI) from the UK, examine the hedging capability of gold against inflation in the UK. The univariate analysis shows that the price series are fractionally integrated with the different orders, which cannot reject the hypothesis. They find that gold and price level are fractionally cointegrated, which is evidence of the inflation hedging effectiveness of gold. On the other hand, Dolatabadi et al. (2018) examine the price discovery contribution of some commodities using a fractionally VAR approach. The empirical evidence from estimated adjustment coefficients reveals the dominance of spot markets for most commodities.

This study extends the existing literature in some important aspects that have important implications for empirical results. Most previous studies reviewed in the literature have primarily investigated the price discovery process between futures and spot commodity markets of other countries. In contrast, studies exploring the relative price discovery contributions of futures and spot commodity markets for Iran are rare. Since the introduction of the Bahar-e-Azadi gold coin futures contracts in IME, the relative contribution of GC spot and futures to price discovery has been largely neglected. Using spot daily data for the Bahar-e-Azadi gold coin and its corresponding futures, this study is looking to determine whether the Bahar-e-Azadi gold coin spot or futures leads to price discovery.

2. METHODS

This study uses Bahar-e-Azadi gold coin futures transactions data, which consist of daily closing prices for the period December 21, 2008 to April 14, 2018. The data are acquired from the IME through its website, www.ime.co.ir. As the IME does not offer an archive of spot prices, GC spot prices is collected from the Tehran Gold, Jewelry, and the Coin Union website, www.tgju.org.

It should be noted that the Bahar-e-Azadi gold coin futures contract started trading on November 25, 2008, and ended trading on September 2, 2018. The last contract that reached a cash settlement in the Bahar-e-Azadi futures market was the contract ending July 22, 2018. Therefore, in this study, the daily prices of Bahar-e-Azadi spot and futures contracts are collected from 2008 to 2018, for a period almost ten years. Matching the GC spot price data with the corresponding GC futures price data gives 2299 trading days.

This paper uses the fractionally cointegrated error-correction model (FCECM) with a BEKK-GARCH approach to allow for the time-varying conditional covariances and thereby the time-varying information share based on Hasbrouck's (1995) IS approach.

Fractionally Integration and Cointegration: Recent studies have found that the commodity prices may contain a long memory component or that it may be integrated of order d between zero and one. Regarding the latter assumption, it is reasonably argued that data can be characterized well by a general fractional integration $I(d)$ process (Cavaliere et al., 2015).

Let X_t be the vector of log prices of GC spot and GC futures, $(p_{s,t}, p_{f,t})'$, respectively. The process X_t is said to be integrated of order d, $I(d)$, if

$$\Delta^d X_t = (1-L)^d X_t = u_t, \quad t = 0, \pm 1, \ldots \tag{1}$$

where L is the lag operator ($LX_t = X_{t-1}$), and u_t is normally distributed. Then the Binominal expansion of the polynomial $(1 - L)^d$ is used, for all real d,

$$(1-L)^d = 1 - dL + \frac{d(d-1)}{2!}L^2 - \\ -\frac{d(d-1)(d-2)}{3!}L^3 - \ldots \tag{2}$$

when the above expression is applied to X_t, it yields the infinite-order autoregressive representation, as (Baillie, 1996)

$$X_t = dX_{t-1} - \frac{d(d-1)}{2!}X_{t-2} + \\ +\frac{d(d-1)(d-2)}{3!}X_{t-3} - \ldots + u_t, \tag{3}$$

If d is a non-integer value, X_t depends not only on a finite number of previous values, but on all its history; and, the higher the value of d is, the higher the level of dependence between the time series will be, implying that the parameter d determines the level of the persistence of the time series (Aye, 2017).

Fractionally Cointegrated Error-Correction Model: The fractional cointegration of the price series is given by the fractionally cointegrated error-correction model (FCECM) (Johansen, 2008; Johansen & Nielsen, 2010, 2012). This representation is shown as follows:

$$\Delta^d (X_t - \mu) = \gamma\beta'\Delta^{d-b}L_b(X_t - \mu) + \\ +\sum_{i=1}^{k}\Gamma_i \Delta^d L_b^i (X_t - \mu) + \varepsilon_t, \\ \varepsilon_t | \Omega_{t-1} \sim N(0, H_t), \tag{4}$$

where X_t is a vector of cointegrated log price series of dimension 2x1. ε_t is the zero-mean and serially uncorrelated vector of innovations of dimension 2x1, with the conditional covariance matrix H_t of dimension 2x2 at time t. represents the conditioning information set at time $t - 1$. μ is the constant mean term. d and $d - b$ denote the fractional order of integration and fractional degree of cointegration between spot and futures prices, respectively.

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Δ^d is the fractional difference operator, and $L_b = 1 - \Delta^b$ is the fractional lag operator. k is lag-length, determined by the AIC and BIC information criteria.

BEKK Model: Given the conditional covariance matrix of the FCECM model's residuals as H_t, a multivariate GARCH(1,1)-BEKK model for H_t, in a bivariate form is constructed as follows:

$$H_t = \begin{pmatrix} c_{ss} & c_{sf} \\ 0 & c_{ff} \end{pmatrix}' \begin{pmatrix} c_{ss} & c_{sf} \\ 0 & c_{ff} \end{pmatrix} + \\ + \begin{pmatrix} a_{ss} & a_{sf} \\ a_{fs} & a_{ff} \end{pmatrix}' \begin{pmatrix} \varepsilon_{s,t-1}^2 & \varepsilon_{s,t-1}\varepsilon_{f,t-1} \\ \varepsilon_{f,t-1}\varepsilon_{s,t-1} & \varepsilon_{f,t-1}^2 \end{pmatrix} \times \\ \times \begin{pmatrix} a_{ss} & a_{sf} \\ a_{fs} & a_{ff} \end{pmatrix} + \begin{pmatrix} b_{ss} & b_{sf} \\ b_{fs} & b_{ff} \end{pmatrix}' \times \\ \times \begin{pmatrix} h_{ss,t-1} & h_{sf,t-1} \\ h_{fs,t-1} & h_{ff,t-1} \end{pmatrix} \begin{pmatrix} b_{ss} & b_{sf} \\ b_{fs} & b_{ff} \end{pmatrix}, \tag{5}$$

where, ε_s and ε_f are the shocks obtained from the FCECM model for GC spot and futures, respectively.

Information Share: The conditional time-varying (daily) information share is produced by replacing the time-invariant covariance matrix with its conditional counterpart obtained by the time-varying covariance matrix, H_t, of the FCECM model's residuals. The IS measure is then derived by estimating the Cholesky factorization of the covariance matrix H_t of $n = 2$ commodity price series to eliminate contemporaneous correlation: $H_t = M^t M_t^T$, where M_t is a lower triangular matrix with elements $M_t = (m_{ij})_{i,j=1,2}$. As a result, one can identify the unique impact of innovation on commodity prices.

Due to factorization, different orderings of the commodity prices in FCECM produce different IS, and the resulting IS will not be unique. Instead, the upper and lower IS bounds are calculated by applying the Cholesky factorization to both alternative orderings (Elder et al., 2014).

The upper and lower bounds of information share for each commodity k, $k = s$ and f, are therefore derived from the error-correction coefficient γ_i and the elements of the covariance matrix H_t, as follows (Baillie et al., 2002):

$$IS_{s,t} = \frac{\left(\gamma_s^{\perp} m_{ss,t} + \gamma_f^{\perp} m_{fs,t}\right)^2}{\left(\gamma_s^{\perp} m_{ss,t} + \gamma_f^{\perp} m_{fs,t}\right)^2 + \left(\gamma_f^{\perp} m_{ff,t}\right)^2}, \tag{6}$$

$$IS_{f,t} = \frac{\left(\gamma_f^{\perp} m_{ff,t}\right)^2}{\left(\gamma_s^{\perp} m_{ss,t} + \gamma_f^{\perp} m_{fs,t}\right)^2 + \left(\gamma_f^{\perp} m_{ff,t}\right)^2}, \tag{7}$$

where $\gamma_i^{\perp}$ is the orthogonal vector to γ_i. Since the conditional covariance matrix H_t is employed, the above equations calculate the information share for day t. The upper (lower) information share bound occurs when the commodity is first (last) in the FCECM model, assuming that the cross-correlation coefficient ρ is positive (Chen & Chung, 2012). Baillie et al. (2002) argue that the average of Hasbrouck's (1995) upper bound and lower bound of the information share provides a sensible measure of the contribution of the commodity market to the production of the efficient price.

3. RESULTS

In the first step, the daily price time series is transformed using natural logarithms. The transformed time series have been plotted in Figure A1. It is observed that the two series are generally increasing over time. But noticeable changes in the trend are observed in several points from December 21, 2008 to April 14, 2018. During this period, Iran has witnessed some severe economic and political instabilities, leading to structural breaks in the commodities spot and the futures prices; it is needed to test for structural breaks in the price time series.

Next, the suitability of the FCECM model for the sample data needs to be evaluated. First, in the univariate context, the augmented Dickey-Fuller (ADF), the KPSS, and the Ng-Perron (NP) methods are used to assess the order of integration of GC spot and futures prices. These tests are conducted on the cases of a constant and a constant with a linear time trend (Gil-Alana et al., 2017), and the results are shown in Panel A of Table 1. Based on the results of ADF and NP tests, there is one unit root in both the log prices of GC spot and GC futures, so they are $I(1)$. However, KPSS test results suggest stationarity and hence $I(0)$. The ambiguous results underline the need to test for fractional integration. On the other hand, the results of the Johansen test document the cointegration among the two $I(1)$ series with the one cointegration vector (Panel B of Table 1).

Table 1. Unit root and Johansen cointegration test results

Exogenous Regressors	GC spot	GC futures	
Panel A			
ADF test			
Intercept	–1.245668	–2.493922	
Trend and Intercept	–1.685341	–2.660181	
KPSS test			
Intercept	4.862686	1.028703	
Trend and Intercept	0.528635	0.723321	
Ng–Perron test			
Intercept			
MZa	–0.13578	–0.91374	
MZt	–0.10406	–0.40570	
MSB	0.76638	0.44400	
MPT	34.6603	14.1358	
Trend and Intercept			
MZa	–6.51941	–7.24907	
MZt	–1.73727	–1.88499	
MSB	0.26648	0.26003	
MPT	14.0157	12.6084	
Panel B			
Johansson's cointegration test			
Hypothesized: No. of CE(s)	**Eigenvalue**	**Trace St.**	***p*-value**
None*	0.013214	32.08194	0.0001
At most 1	0.000682	3.841466	0.2108

Notes: The maximum lags order of ADF, KPSS, and NP tests was determined by the Schwartz Information Criterion (BIC). The critical values for the ADF test for the null hypothesis that the series is trend stationary are (1%: −3.962; 5%: −3.411; 10%: −3.127). The critical values for the KPSS for the null hypothesis that the series is trend stationary are (1%: 0.216; 5%: 0.146; 10%: 0.119). Finally, the NP test is included a constant and a constant with a linear time trend. The NP critical values are the following: MZa (1% = −23.8; 5% = −17.3; 10% = −14.2); MZt (1% = −3.42; 5% = −2.91; 10% = −2.62); MSB (1% = 0.143; 5% = 0.168; 10% = 0.185); MPT (1% = 4.03; 5% = 5.48; 10% = 6.67). * denotes rejection of the null hypothesis at the 0.05 level of significance.

Next, each price series is examined to estimate the order of fractional integration d. To test for fractional differencing of price series, this study performs the Local Whittle (LW) estimator (Robinson, 1995), which is based on the frequency-domain Gaussian likelihood function restricted to the vicinity of origin (Al-Shboul et al., 2016). The results for the log prices of GC spot and futures are presented in Table 2[1]. It is observed that the GC spot and futures prices are fractionally integrated of orders 0.98347 and 0.95169, respectively, which are close to 1, but cannot reject the $I(1)$ hypothesis. This implies the long memory behavior in the price series.

Table 2. Results of local LW test for order of fractional integration

Variable	LW estimator
GC spot	0.98347
GC futures	0.95169

First, the optimal lag length is determined by applying the Akaike Information Criterion (AIC) and Schwartz Information Criterion (BIC). AIC with a value of -4473.91 suggests lag three, and BIC with a value of -4385.70 suggest lag 1. Therefore, the best lag order of the FCECM model is set to 2. The results are reported in Table 3.

Table 3. Results of lag selection for FCECM model

Lag (*k*)	AIC	BIC
3	–4,473.91	–4,364.85
2	–4,471.66	–4,385.55
1	–4,448.84	–4,385.70
0	–3,632.31	–3,592.13

After deciding on the optimal lag length, the cointegrating rank must be selected. From Table 4, the rank test fails to reject the null of rank one against the alternative of rank 2. Hence, the optimal cointegration rank is set to 1 with a Log-Likelihood value of 2,250.795. Therefore, there is a stationary long-run equilibrium in the GC spot and futures prices.

Here, this study, focusing on the primary empirical analysis, seeks to estimate the FCECM model for the GC spot and futures prices. The results[2] from Table 4 show that the parent price series are fractionally cointegrated with an estimated value of 0.542, which is statistically significant at the 0.05 level and below 1. Previously, the value of the cointegration rank estimator was selected to be 1. These results imply that there indeed exists the fractional cointegration relationship between price series. First, the estimated values of the adjustment vector of the FCVAR model reveal the relative speed of adjustment of each price series toward long-run equilibrium. From Table 5, it is

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evident that despite the error-correction coefficients having the expected sign: for both GC spot and futures equations, it is negative, only the coefficient on GC futures is significant with a value of –0.00123, suggesting that GC futures prices correct the deviations from the long-run equilibrium. However, there is not any contribution of spot prices to the long-run price; in other words, the spot price is weakly exogenous and is dominant in the price discovery process. The estimation results of the model parameters are reported in Table 6.

Table 4. Results of cointegration rank test and fractional cointegration parameter d

D	0.542* (0.018)
Rank Test	Log-Likelihood
0	2,236.826
1	2,250.795
2	2,250.829
Cointegrating Rank	1
Lag-order	2

Notes: Standard errors are given in parentheses. * represents statistical significance at the 0.05 level.

Table 5. Adjustment coefficient matrix

Variable	Adjustment coefficient (γ)
GC spot	–0.00032 (0.000201)
GC futures	–0.00123* (0.000271)

Notes: Standard errors are given in parentheses. * represents statistical significance at 0.05 level.

Table 6. Estimation results of the FCECM model

Coefficients	Value
Fractional Parameter	
d	0.542
Cointegrating Vector	
β	–49.556
c	1.000
Adjustment Coefficients	
α_1	–0.000 (0.0002)
α_2	–0.001* (0.0002)
Level Parameter	
μ_1	7.699* (0.151)
μ_2	15,920* (0.057)
Short-run Parameters (*k*=1)	
Γ_{11}	0.840* (0.074)
Γ_{12}	–0.023 (0.043)
Γ_{21}	–0.012 (0.036)
Γ_{22}	–0.826* (0.041)
Short-run Parameters (k=2)	
Γ_{11}	0.117 (0.062)
Γ_{12}	–0.025 (0.078)
Γ_{21}	–0.007 (0.042)
Γ_{22}	–0.540* (0.077)
Log-Likelihood 2,250.795 AIC –4,473.589 BIC –4,393.226	

Notes: Standard errors are given in parentheses. * represents statistical significance at the 0.05 level.

To investigate whether the FCVAR model is more suitable than the CVAR model, the null hypothesis $d = b = 1$ against $d = b \neq 1$ is tested. The rejection of the null hypothesis implies that the FCVAR model with fractional integration is more appropriate than the standard cointegration approach. In Table 7, the results of the LR test statistics and its p-value are reported. The empirical test rejects the null hypothesis at the 0.05 significance level, and therefore the data follow the FCVAR model. So, the GC spot and GC futures price series are fractionally cointegrated with an order of 0.542, implying the presence of a long-run equilibrium relationship between the prices that takes a long time to converge compared to standard cointegration approaches (Gil-Alana et al. 2017).

Table 7. Results of testing the CVAR model against alternative FCVAR model

Unrestricted log-likelihood	2,250.795
Restricted log-likelihood	2,083.727
Test results (df = 1)	
LR statistic	334.135*
p-value	0.000

Note: * denotes rejection of the null hypothesis at the 0.05 level of significance.

Here, it is shown that using standard methods of unit roots and cointegration with integer degrees of differentiation, the two series seem to be individually $I(1)$ though cointegrated with the one cointegration vector. Using fractional techniques, it is shown that first, each price series is fractionally integrated, and second, there exists a fractional cointegration relationship between the two price

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series, with an order of about 0.542, implying that there is a long-run equilibrium relationship between the prices that takes a long time to converge compared to standard cointegration approaches. Moreover, the empirical test reveals the suitability of FCECM against the ECM model for GC spot and futures prices.

The time-varying IS measure is calculated for each of the commodities based on Eqs. (6) and (7), which are constructed from BEKK-GARCH(1,1) specification for residuals in the FCECM model, over the sample period, December 21, 2008 to April 14, 2018. Figure A2 plots the evolution of the monthly time-series average values of the lower and upper information share bounds for GC spot and GC futures. The average value of IS for GC spot changes between 84.64% to 95.93%, with the minimum value of the differences between the upper and lower bounds approach in the sample in 2012 (Mehr in 1391, according to the Persian calendar). The minimum value of the lower bound of the IS approaches to 88.38% for only one period during the sample. In contrast, the average value of IS for GC futures is always less than 15.36%, with a minimum value of upper bound that is 11.62% by only one period during the sample. Figure A3 plots the evolution of the daily time-series average values of the lower and upper information share bounds for GC spot and GC futures. These findings reinforce that the price discovery is dominated by GC spot than GC futures. While there are several drops in the IS of GC spot during the sample period, the information share of GC futures is consistently below that of the GC spot.

Next, the robustness of the evidence of price discovery is checked in two ways. First, price discovery measures' results are estimated and compared in sub-periods of the original sample. In particular, different sub-sample periods are examined by testing for structural breaks. For this purpose, the multiple breakpoint algorithm tests of Bai and Perron (2003) are used. The sequential F-statistic and *WDmax* test statistic determine five breaks and the *UDmax* test statistic determine four breaks, in multiple equations relating to the log price series of GC spot and futures, with the assumption that the breaks may occur in any period of the sample, based on global minimizers for the break dates along with allowing for heterogeneous in error distributions across the breaks (Bai & Perron, 2003). The breaks took place on August 7, 2010 (16 Mordad in 1389), July 8, 2012 (18 Tir in 1391), March 25, 2014 (5 Farvardin in 1393), and January 25, 2017 (6 Bahman in 1395). This evidence confirms the observation made in Figure A1. Moreover, the fractional-order of integration and cointegration (long memory behavior) between price series may also result from structural breaks (Al-Shboul & Anwar, 2016).

Descriptive statistics of the two-price series are shown in Panel A of Table 8. Averages across the two commodities are higher than their volatilities during all sub-periods. The kurtosis and skewness measures indicate the distributions of price series are not normal regardless of the sub-period considered. The two series are autocorrelated and show strong ARCH effects in each sub-period.

Panels B and C of Table 8 report the estimated values of the upper and lower IS bounds and their averages for each sub-period. First, in Panel B of Table 8, the estimation results for the static model for each sub-period are reported. The mean value of information share for GC spot is 99.9% across all sub-periods. For the time-varying model, the empirical results are reported in Panel C. The average information share of GC spot obtained over 2299 estimates of daily mean information share, is about 94.14%. The average information share of GC spot across all sub-periods, except the second sub-period, is higher than that of GC futures, indicating that the GC spot has the dominant information share.

To be more conservative, the estimation result of the lower bound of information share for GC spot is considered. The results from the static model, reported in the second row of Panel B, show a mean lower bound of 99.8%, while the results from a time-varying model of Panel C show a daily lower bound of 94.05% for GC spot versus 5.78% for GC futures. Overall, it can be concluded that the dominance of GC spot in the price discovery process is robust across sub-samples, as empirical results derived from the estimated model are not sensitive to the sub-samples considered.

Second, the robustness of these results is examined using the alternative roll-over method to construct GC futures price time series. The price discovery be-

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Table 8. Descriptive statistics (Panel A) and static price discovery (Panels B & C) for GC spot and (adjusted) futures price series.

Panel A	GC spot						GC futures					
	Summary Statistics											
	Sub-period 1	Sub-period 2	Sub-period 3	Sub-period 4	Sub-period 5	Whole sample	Sub-period 1	Sub-period 2	Sub-period 3	Sub-period 4	Sub-period 5	Whole sample
Mean	7.87	8.61	9.30	16.11	14.97	12.02	16.03	16.34	15.58	16.26	16.44	16.32
Std.Dev	0.14	0.27	0.38	0.08	1.04	3.63	0.15	0.16	0.26	0.18	0.18	0.25
Skewness	0.00	-0.09	14.42	0.68	0.49	0.11	-11.92	0.13	-3.18	4.73	-6.17	-0.39
Kurtosis	1.50	1.67	295.26	2.48	1.28	1.13	192.39	1.83	28.97	136.18	88.84	25.22
Q(16)	0.890*	0.895*	0.147*	0.869*	0.840*	0.979*	0.233*	0.848*	0.541*	0.132*	0.420*	0.666*
ARCH(16) LM Test	328.9613*	440.8942*	32.1532*	729.7480*	321.8903*	2278.5*	77.8357*	436.0985*	224.0343*	120.8541*	172.8569*	1558.8*
Panel B	**GC spot**						**GC futures**					
	Unconditional Information share of Hasbrouck (1995)											
Upper Bound	93.5%	88.4%	99.6%	98%	99.8%	99.9%	8.1%	19.1%	0.8%	2.6%	0.4%	0.0%
Lower Bound	91.9%	81%	99.2%	97.4%	99.6%	99.8%	6.5%	11.6%	0.4%	2%	0.2%	0.0%
Average of Bounds	92.7%	84.7%	99.4%	97.7%	99.7%	99.9%	7.3%	15.35%	0.6%	2.3%	0.3%	0%
Panel C	**GC spot**						**GC futures**					
	Time-varying Information share of Hasbrouck (1995)											
Upper Bound	92.91%	28.34%	99.99%	99.77%	94.62%	94.22%	9.91%	93.51%	1.18%	31.38%	8.66%	5.95%
Lower Bound	90.09%	6.49%	98.82%	68.62%	91.34%	94.05%	7.09%	28.34%	0.002%	0.23%	5.38%	5.78%
Average of Bounds	91.5%	17.42%	99.41%	84.19%	92.98%	94.14%	8.50%	60.92%	0.59%	15.81%	7.02%	5.86%

Notes: * represents statistical significance at the 0.05 level.

Table 9. Time-varying price discovery for GC spot and (unadjusted) GC futures price series for the whole sample

Time-varying Information share of Hasbrouck (1995)	GC spot	GC futures
Upper Bound	89.32%	14.13%
Lower Bound	85.87%	10.68%
Average of Bounds	87.60%	12.40%

tween the GC spot and futures is examined using the futures price time series been built without adjusting on the roll-over date. In Table 9, it is found that the empirical results are not very different from those reported in Table 8. From Table 9, the average information share across the most sub-samples is higher for GC spot than GC futures.

4. DISCUSSION

Overall, the empirical results obtained in this paper appears to be strong enough to support the dominant role of GC spot in price discovery. In contrast, theoretically, price discovery is expected to be dominated by the futures market. One possible explanation for this evidence could be the higher trading volume associated to the GC spot market compared with the GC futures market. Incompleteness and market frictions also can cause a delay in the process of information incorporation into the futures market (Hou & Moskowitz, 2005; Merton, 1987; Shleifer & Vishny, 1997) and may discourage market players from trading in these markets.

This paper is not the first to document the dominance of the gold spot in the price discovery process. In commodity markets, for instance, Dolatabadi et al. (2015), using the fractionally cointegrated VAR approach, find that for some commodities, price discovery takes place exclusively in the spot market.

Contrary to the present study, Hauptfleisch et al. (2016) employ some information share measures and find that the London gold futures market has a more significant contribution to price discovery than the gold spot market. These findings are also contrary to the empirical work of Mahalik et al. (2014), who use the VECM model and document the dominance of commodity futures to spot markets from India.

In conclusion, price discovery results are appealing and relevant research areas, given the nascence feature of commodity markets in Iran. However, the markets do not seem to be competitive. Since the development of commodity markets in Iran has been a policy objective, these findings could have tremendous implications for investors, policymakers, and researchers in these markets, especially in GC spot and futures markets. For future research, it would be interesting to investigate the determinants of price discovery in the GC spot market, including the investors' trading structure and other market microstructure frictions. If the intraday data of the commodities were available, another avenue for future research could be to explore the price discovery process using time series data sampled at high frequencies. These topics will be left for the future research.

CONCLUSION

There is no knowledge on whether the price discovery process concerning Iran Bahar-e-Azadi gold coin is spot market or futures market-driven. Thus, this paper aims to fill this research gap by adopting the fractionally cointegrated error-correction model (FCECM). This paper takes advantage of the bivariate BEKK-GARCH (1,1) approach to model the FCECM's residuals to calculate the time-varying conditional information share between GC spot and futures prices.

The empirical results show that the price series are fractionally integrated with the estimated values of the differencing parameters to be close to 1. Moreover, there exists a fractionally cointegrated relationship between the GC spot and futures prices.

The time-varying information share model demonstrates that the price discovery process is significantly dominated by GC spot.

This result may reflect the higher trading volume associated with the GC spot compared to the GC futures contracts. Moreover, incompleteness and market frictions also can cause a delay in the process of information incorporation into the futures market and may discourage market players from trading in these markets. The evidence that the empirical results are robust to different sub-periods considered and alternative construction of continuous futures time series are also presented. The findings from the robustness checking suggest that in the price discovery process, the GC spot market dominates the GC futures market.

AUTHOR CONTRIBUTIONS

Conceptualization: Elham Farzanegan.
Data curation: Elham Farzanegan.
Formal analysis: Elham Farzanegan.
Funding acquisition: Elham Farzanegan.
Investigation: Elham Farzanegan.
Methodology: Elham Farzanegan.
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Validation: Elham Farzanegan.
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APPENDIX A

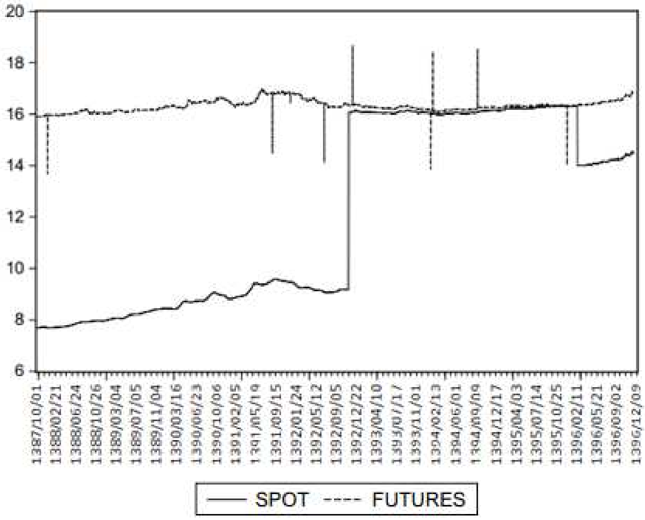


Figure A1. Daily movements of log prices of GC spot and GC futures during the whole sample period

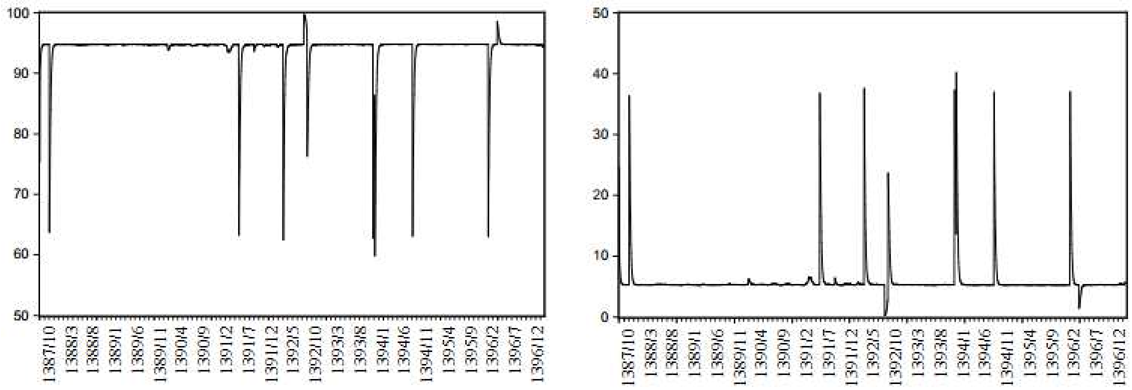
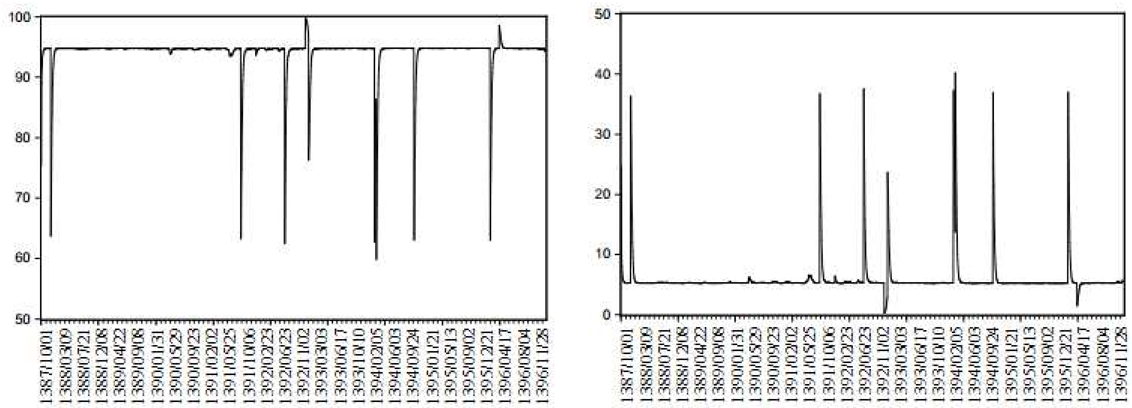


Figure A2. Monthly average of information share of GC spot (above) and futures (below)



Notes: 1. For the FCECM model, the results were obtained using the MATLAB computer program (Nielsen & Popiel, 2014). 2. The results were obtained using the MATLAB computer program (Nielsen & Popiel, 2014).

Figure A3. Time series of information share of GC spot (above) and futures (below)

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