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## Article

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## Time Disparity and Price Discovery: The Effect of the U.S. Futures on Korean Gold Market

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### ABSTRACT

We examine price efficiency of the Korea Exchange (KRX) gold market by showing price discovery factors in the market. This study put forward a hypothesis that the price change of the gold futures in the CME (Chicago Mercantile Exchange) would have a positive impact on the rate of return of the KRX gold market. In addition, this paper goes into detail about the international gold price having a negative correlation with the value of the United States (US) dollar. To test the goal of the research, both the rate of return of the CME gold futures at t-1 days and ICE (Intercontinental Exchange) dollar index futures at t-1 days are investigated to determine whether they have an impact on the market rate of return in the KRX gold market at t day using regression analysis and GARCH model in order to look closely at the factors that determine the market price of the KRX gold market. As results, we find following evidences. First, the rate of return of the CME gold futures at t-1 days has a positive significant impact on the market rate of return in the KRX gold market at t day. Second, the rate of return of ICE dollar index futures at t-1 day could not be confirmed to significantly determine the market rate of return in the KRX gold market at t day. We also investigate the effect of the NYSE United States 5-year bond yield and CBOE VIX futures on the KRX close-to-open rate of return in the KRX gold market and find significant impact of the VIX futures on KRX gold market price. To the extent that the futures market has a characteristic of leading the spot market, this study supports the view of a link between time disparity and price discovery in Korea and the U.S. financial market.

*Keywords: Time Disparity, Korea Exchange Gold Market, Gold Futures, Dollar Index Futures, VIX Futures*

## 1. Introduction

With the element symbol 'Au' and atomic number '79', gold is not only the investment asset which

investors prefer most but also real currency regardless of ages and countries. Gold is a material with a beautiful color which does not corrode and is easily processed and so gold is used in many fields including jewelry, real currency, industry, medical treatment, etc. For a long time, people have wished to possess gold because of these characteristics.

The methods the Korean investor could directly invest in gold before the day that the KRX (Korea Exchange) gold market opened on March 2014 were

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mainly in the wholesale and retail jewelry shops, gold banking in a bank, etc. Although the KRX gold market is implied to be highly efficient in regards to fees and taxes the investor must pay, there is little research supporting this.

Kim et al. (2015) explores various statistical approaches to examine the economic index which predicts gold prices and the variables having an effect on gold prices and compared their results to existing research related to gold. Hong (2013) also investigates factors having an effect on the amount of gold transactions so that the rise of variability in the United States (US) stock market positively affected the demand of gold futures. According to Lee (2014), gold variability has precedence over the variability index. Solt and Swanson (1981), Sjaastad and Scacciavillani (1996), and Xu and Fung (2005) conduct studies on the price determination factors of gold, and posit that there is a relationship between variability, the prime exchange rate, and gold price. As Hiller et al. (2006) points out, in the case of including gold in an investment portfolio as the representative of safe property, gold is said to have a diversified investment effect, lowering variability of the rate of return of the portfolio.

Regarding time disparity and price discovery, Barclay and Hendershott (2003) and Yeom et al. (2013) verify the price discovery effect by analyzing the significance of the influence between spot and futures time difference. As stated in Chan (1992), Lee and Lim (2002), Tse et al. (2006), and Yeom and Baek (2015), it is commonly accepted that the futures exchange market is leading the spot market. Barry et al. (2003) also suggests that the large price reversals in the U.S. gold and silver futures market tend to occur on days with lower trading volume and days with a sharp change in trading volume from the prior day. From this point of view, this study investigates the significance of influence between the rate of return variables and time differences.

In this paper, we examine the Korea Exchange (hereafter called 'KRX') gold market price efficiency by showing time disparity and price discovery factors in the market. This study put forward a hypothesis

that the price of the gold futures in the CME (Chicago Mercantile Exchange) would have a positive impact on the return of the KRX gold market. In addition, this paper goes into detail about the international gold price having a negative correlation with the value of the US dollar. To test the hypotheses of the paper, we investigate whether the rate of return of gold derivatives in the United States at  $t-1$  days significantly affects the gold spot market in Korea at  $t$  day. The rate of return of CME gold futures at  $t-1$  days is analyzed to determine whether there is a price discovery effect on the market rate of return of the KRX gold market by using the daily data from the 24<sup>th</sup> March, 2014 to the 23<sup>rd</sup> August, 2016 for the empirical analysis. Moreover, in order to verify the proposition that the international price of gold and the value of the US dollar have a negative correlation, this study performs an empirical analysis measuring the influence that the rate of return of the ICE dollar index futures at  $t-1$  days has an impact on the KRX gold market at  $t$  day.

The KRX gold market data is observed over two years from the opening day and the CME gold futures and ICE (Intercontinental Exchange) dollar index futures, the yield of NYSE 5-year bond and CBOE (Chicago Board of Option Exchange) VIX futures (Volatility Index futures) are also considered in terms of their influence on the KRX gold market. As shown in Figure 1, the amount of the KRX gold market transaction appeared to be an average of 24 million won (Korean currency, Won, *KRW*) a day in the opening year (2014). It grew constantly thereafter and became more than three times bigger than in the opening year, with the average trade cost being 77 million won (KRW) a day in 2016.

The empirical analysis result utilizing the regression analysis and GARCH model represents that the rate of return of the CME gold futures at  $t-1$  days positively affects the market rate of return of the KRX gold market at  $t$  day, while the significance of the rate of return of the ICE dollar index futures influencing the market rate of return of the KRX gold market was not clear. This result shows that the rate of return of the CME gold futures has the leading market rate

of return of the KRX gold market, and the KRX gold market will be able to be hedged by utilizing CME gold futures. Conversely, our study develops the general concept that the US dollar value is operated contrary to the gold price, and examines the influence of the variable with time difference, that is, whether the rate of returns of ICE dollar index futures at t-1 day's influence on the market rate of return of the KRX gold market at t day, but the statistical significance was unable to be found. We also investigate the effect of the NYSE United States 5-Year Bond Yield and VIX on the close-to-open rate of return of gold in KRX gold market. To the extent that the futures market has a characteristic of leading the spot market, this study supports the view of a link between time disparity and price discovery in Korea and the U.S. The subsequent part of the study presents an analysis of time disparity's role in the functioning of the Korean gold market from the point of view of price discovery.

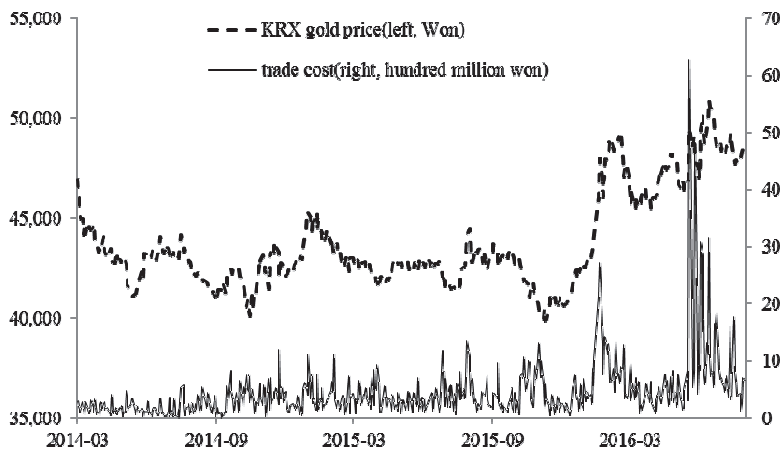
The rest of the paper is organized as follows. Section 2 introduces the KRX gold market briefly. Section 3 describes research data and method to test the hypotheses. Section 4 explains the results and section 5 outlines the conclusions of the study.

## II. Overview of KRX Gold Market

### A. Trading system of KRX gold market

According to the government policy for the legalization of gold transaction and the development of the precious metal industry, the KRX gold market utilized the HTS (home trading system) for the opening of the gold spot market making it possible to make real-time transactions, similar to stock trading. The role and goals of the KRX gold market were realized as the legalization of the underground economy through the eradication of illegal transactions, reliability and enhancement of price and quality, and preparation for the developing foundations of the precious metal industry were announced by the Financial Services Commission, the Ministry of Strategy and Finance, the Ministry of Trade, Industry and Energy, National Tax Service, and the Office of Customs Administration in July, 2013.

In the KRX gold market, there are a number of gold traders such as importers of gold, gold refiners, normal investor, etc. The traders deposit gold in the Korea Securities Depository, which is the custody facility. Meanwhile, gold buyers such as workmanship traders, the industry, normal investors, etc. have to deposit the cash being used to purchase the gold



**Figure 1.** KRX gold price and trade cost transition

The left axis is KRX gold price and the unit is Korean currency (KRW, Won), while the right axis is the amount of KRX gold market transaction and the unit is one hundred million won. The sample period is from the 24<sup>th</sup> March, 2014 to the 31<sup>st</sup> August, 2016.

into a KRX gold account which is set up by the securities company. A normal investor with non-membership sends an order into the exchange trading system through the securities company, who is the general member of the KRX gold market, for trading in the KRX gold market.

## B. Trading system in KRX gold market

Following the Korean gold market allows researchers to highlights time disparity and price discovery measures at a level of detail that would be hard to aggregate across countries. Korean gold market data have characteristics that make them particularly suitable for the price determinant investigation because of sufficient trade volume with newly stabilized system. It also involves time disparity between Korea and the U.S. because the U.S. futures are traded at Korean night time.

Gold bullion, which is the sales object of the KRX gold market, has 99.99% purity and its weight, as a raw material in gold bar form, is one kilogram or 100 grams. In 2014, when the KRX gold market was opened, the main asset of the KRX gold market was only 1 kg (= 1,000 grams). Then in 2017, the Korea Exchange added another type of 100 grams as an underlying asset. The eligible manufacturer and importer whom the Korea Exchange chooses to supply, has to pass a quality standard which the Korea Exchange and quality assurance agency choose. On the surface of a gold bullion are engraved the name of the refining industry, a trademark, purity, weight, manufacture’s serial number, etc.

The unit of transaction is one gram and the asking price is 10 won (KRW). The price is shown as won per 1g in the KRX gold market. A limit order is feasible and the maximum quantity per one bid is 5kg. The price limits are expressed as an upper price limit and a lower price limit. The standard price determines the restriction of the price range expressed as the upper limit price and lower price limit. The standard price is based on the latest closing price from the day before, just before the beginning of

a transaction day. The daily restriction of the price range is  $\pm 10\%$  of the standard price. The trading hours of the KRX gold market are from 9:00am until 15:30pm. 8:00 am until 9:00 am, that is, one hour before the transaction day starts, is the time frame for making a decision about buying at opening, while from 3:20 pm to 3:30 pm, that is, 10 minutes before closing the transaction day, is the time frame for making a decision about buying at closing.

**Table 1.** Trading system in KRX gold market

	Contents
Type	Purity: 99.99%, Weight: 1kg or 100g
Trade Unit	1g (Asking Unit: 1g)
Trading Hours	09:00am ~ 15:30pm
Price Mark	Won (KRW) per 1g
Asking Price Unit	10 Won (KRW)
Price Limits	Closing Price of the Previous Day $\pm 10\%$
Type of Order	Limited Order
Order Limit	5,000g (5kg) per bid
Settlement Day	Same Day Settlement (t day)
Customer Margin	Cash Margin 100%

Regarding the KRX gold market, transaction is connected through competitive sales, according to the ‘price-time’ priority between several asking prices, similar to the stock market. It is concluded that an execution of sales deal is feasible as soon as the asking price comes in. However, the trading methods of buying on opening and closing prices are accomplished using the singular price acquisition method. The payment in the KRX gold market is a same day settlement (t day) and the deposit and withdrawal of the gold bullion is feasible in 1kg or 100g units. If the withdrawal of the gold is requested of the custody facility through the trading securities company, the custody facility pays the gold to the fixer.

## C. Characteristics of KRX gold market

KRX gold market has certain advantages regarding transaction cost and taxes for investors. KRX gold

**Table 2.** Rate of return according to the gold market type

The closing price of the KRX gold market represents the purchasing price of gold, final purchase price of the major Korean commercial bank ('Shinhan Bank'), and the officially fixed price of the Korea Federation of Jewelry Sales Business by standards on the 10<sup>th</sup> April of 2015. The unit is by Korean currency (KRW).

	Purchasing price	Buyout fees	Sale price	Sale commission	Income tax	surtax	Rate of return (%)
KRX Gold Market	42,500	128	46,750	140			9.6
Gold Banking (Account Transaction)	42,742		46,085		552		6.5
Gold Banking (Spot Transaction)	44,435		46,398			4,444	-5.6
Outside Whole Sale	43,040		46,398			4,304	-2.2

market can invest in gold with a lower cost compared with the existing gold market, and can utilize HTS on a real time basis, similarly to stock trading, making it possible to deal with small (1g) gold transactions as follows.

First, the KRX gold market has the advantage in terms of price when taking into consideration transaction costs including fees, taxes, purchase spread, etc. compared with the existing gold over-the-counter market (outside wholesale markets, the bank gold banking, jewelry shops, etc.). There is a tax benefit in which the transfer income tax is not imposed and is not included in the object of comprehensive taxation on financial income. As to the gold-related fund and gold banking, a 15.4% of profit income tax is imposed.

Second, if the spot gold is not delivered from a warehouse, the value added tax is not imposed at the KRX gold market. Therefore, in the case of using the KRX gold market for the investment purpose of forecasting the gold price rise, the investment efficiency, in comparison with the other gold markets, is higher. As shown in Table 2, when it is assumed that the price rises 10% shortly after purchasing the rate of return on investment using the KRX gold market is higher than the other markets. The transaction costs are simulated, considering that the transaction costs are usually around 0.3 %, although there are some differences between securities companies. Currently, investors in the KRX gold market have to pay only for the transaction, and they don't need to pay for the deposit. Deposit costs and other expenses are the structures covered by securities companies.

In particular, the price of the KRX commission is 0.07 percent (transaction fee is 0.056 percent plus settlement fee is 0.014 percent), and the commission fee is kept around 0.014 percent. That is, the rate of return in the KRX gold market is 9.6%, the account transaction of gold banking is 6.6%, the spot transaction of gold banking -5.6%, and the rate of return of the jewelry shop outside the wholesale market is -2.2%. In addition, in Table 2, for the Gold Banking (Account Transaction) 552 won (= 46,085-42,742), or 16.5 % Income Tax, for profit margin. Additionally, the Gold Banking and Outside Whole Sale cost 10 % surtax, or 4,444 won and 4,304 won, respectively.

### III. Data and Methodology

#### A. Data

Where there is time difference between the variables, Granger (1969, 1980) interpret this kind of dataset as a lead-lag relationship in case there is a cause-and-effect relationship existing in the situation. Moreover, considering the existing research that the futures market leads the spot market, it can be estimated that the rate of return of the CME gold futures and of ICE dollar index futures which traded at night Korean time (prior day) have an effect on the market rate of return of the KRX gold market when it opens at 09:00am the following day (Barry et al., 2003;

**Table 3.** Description of the variables

Variable	Description
$KRX_{co,t}$	Rate of return of KRX at t day (= KRX gold market opening price at the t day/closing price at t-1 days)
$CME_{cc,t-1}$	Rate of return of CME gold futures at t-1 days (= CME gold futures closing price at t-1 days/closing price at t-2 days)
$ICE_{cc,t-1}$	Rate of return of ICE dollar index futures at t-1 days (= ICE dollar index futures closing price at t-1 days/closing price at t-2 days)
$Yield_{cc,t-1}$	Rate of return of NYSE United States 5-year bond yield at t-1 days (=NYSE 5-year bond closing price at t-1 days/closing price at t-2 days)
$VIX_{cc,t-1}$	Rate of return of CBOE VIX futures at t-1 days (=CBOE VIX futures closing price at t-1 days/closing price at t-2 days)

Yeom et al., 2013). This means that the prices of the CME gold futures and ICE dollar index futures, United States 5-year bond and CBOE Volatility Index (VIX) futures, traded when it is night time in Korea can have price effect on the market rate of return of the KRX gold market when it opens because the price reflects the financial market news of the United States and major European countries. Table 3 presents description of the variables.

In order to utilize the regression analysis and GARCH model to provide empirical evidence, the daily data of the market rates of return in the KRX gold market from the 24<sup>th</sup> March 2014 to the 23<sup>rd</sup> August 2016, is set to the dependent variable. The market rate of return in the KRX gold market equals the opening price at t day divided by the closing price at t-1 day minus 1. Moreover, after setting the data of daily rate of returns of the CME gold futures and ICE dollar index futures, NYSE United States 5-Year Bond Yield and CBOE Volatility Index

to the independent variable, it is examined whether the independent variables have any significant effects on the market rates of returns of the KRX gold market, which are the dependent variable. The rate of return of the CME gold futures at t-1 day and the rate of return of ICE dollar index futures at t-1 day, the rate of NYSE United States 5-Year Bond Yield at t-1 day, and the rate of CBOE VIX futures at t-1 day are included by calculating the closing price at t-1 days after dividing the t-1 days closing price into the closing price at t-2 day minus 1.

Table 4 shows the summary statistics of the market rates of return of the KRX gold market at t day, the rate of returns of the CME gold futures at t-1 days, and the rate of returns of the ICE dollar index futures at t-1 days, the rate of NYSE United States 5-year bond yield at t-1 days and the rate of CBOE VIX futures at t-1 days. Sample period is from the 24<sup>th</sup> March, 2014 to the 23<sup>rd</sup> August, 2016. The absolute value of the maximum and minimum values

**Table 4.** Summary statistics

Sample period is from the 24<sup>th</sup> March, 2014 to the 23<sup>rd</sup> August, 2016.  $KRX_{co,t}$  is the rate of return of the KRX gold market at t day,  $CME_{cc,t-1}$  is the rate of return of CME gold futures at t-1 days,  $ICE_{cc,t-1}$  is the rate of return of ICE dollar index futures at t-1 days,  $Yield_{cc,t-1}$  is rate of return of NYSE United States 5-Year Bond Yield at t-1 days,  $VIX_{cc,t-1}$  is rate of return of CBOE VIX futures at t-1 days.

Division	Minimum	Maximum	Mean	Standard deviation	Variance
$KRX_{co,t}$	-6.56	2.99	0.134	0.679	0.461
$CME_{cc,t-1}$	-3.14	6.21	0.005	0.977	0.956
$ICE_{cc,t-1}$	-2.22	2.46	0.028	0.528	0.280
$Yield_{cc,t-1}$	-14.61	12.62	-0.018	3.224	10.395
$VIX_{cc,t-1}$	-21.38	49.33	0.305	8.502	72.298

of CME gold futures and the KRX gold market, which are based on gold price, are greater than the ICE dollar index futures because the variability of gold price is greater than the dollar variability

## B. Research Hypotheses

According to the existing research, the futures market can perform the price discovery function and the price leading function over the spot market. Yeom and Baek (2015) finds that the rate of return of future stock at t-1 days can have a price discovery effect on the spot market at t day in the case that the rate of return of the stock price index futures at t-1 days affected the rate of return of the spot market at t day in Korea. For this purpose, the result of the empirical analysis shows the rate of return of KOSPI200 night futures at t-1 days significantly affects on the market rate of the return of KOSPI at t day, and they interpreted that the derivatives which precede time differences have price leading effects or price discovery functions over the spot market which lags in time difference. In addition, related research conducted by Rosenberg and Traub (2009), Chen and Gau (2010), and Choudhary and Bajaj (2013) show that the futures market performs at a higher price discovery function than the spot market. This study performs Hypothesis 1 from the estimation that the rate of return of CME gold futures at t-1 days positively influences the market rate of return of the KRX gold market at t day. This estimation is created based on the results of existing research.

**Hypothesis 1:** The rate of return of CME gold futures at t-1 day has a positive influence on the rate of return of the KRX gold market at t day.

Meanwhile, Capie et al. (2005) and Kaul and Sapp (2007) note that the gold price moves in the opposite direction to the value of the dollar. Park and Han (2014) also suggests that the value of the dollar has a negative effect on the international price of gold based on a sampling period where they examined the factors that had an effect on the gold price decision. They determined that the negative correlation between

the value of the dollar and the international price of gold appear more clearly in a specimen period when the international price of gold increased rapidly compared to a more stable specimen period. It is generally reported that the international price of gold negatively correlated with the value of the dollar in news article in Korea.<sup>1)</sup> In order to verify this estimation, Hypothesis 2 is formed based on the concept that the rate of return of ICE dollar index futures at t-1 day negatively influences the market rate of return of the KRX gold market at t day.

**Hypothesis 2:** The rate of return of ICE dollar index futures at t-1 day has a negative influence on the rate of return of the KRX gold market at t day.

Rising interest rates lower the demand for gold without the need for dividend returns, in general. Also, the dollar and the gold exchange are substitutes, and excessive issuance of bonds lowers the trust of the dollar. The higher the interest rate by these two routes, the lower the nominal price of the gold. Because of these patterns, the rate of interest in interest rates is equal to the yield rate and the negative relationship. The following hypothesis 3 establishes an inverse relationship between interest rates fluctuation and rate of return of the KRX gold market.

**Hypothesis 3:** The rate of return of NYSE United States 5-year bond yield at t-1 day has a negative influence on the rate of return of the KRX gold market at t day.

Uncertainty in the macroeconomic situation or economic systems raises the price of gold, which is a typical safety asset. We used VIX as an aid to uncertainty in the economy. Since VIX raises fears about investor sentiment, it is also known as the fear index in the market. Hypothesis 4 set a positive relationship between the growth rate of the CBOE VIX futures and the yield on the KRX gold market (Setianingtyas et al., 2015; Kim, 2016).

1) Referencing 'International Price of Gold, 0.4% Rising with the Weak Dollar' (Korean newspaper, 'Money Today' 02/09/2016), 'International Price of Gold, falling with the Strong Dollar' (Korean newspaper, 'News Tomato' 31/08/2016), 'International Price of Gold, Collapsing 1,320 dollars with the Strong Dollars' Influence' (Korean newspaper, 'Money Today' 31/08/2016).



**Hypothesis 4:** The growth rate of VIX at t-1 day has a positive influence on the rate of return of the KRX gold market at t day.

### C. Methodology

Equation (1) is prepared in order to verify our Hypotheses. In this research, as shown in equation (1), a regression analysis is utilized in order to analyze the influence that the rate of return of CME gold futures (CME), ICE dollar index futures (ICE), growth of yield (Yield), and growth of VIX (VIX) at t-1 days have effects on the market rate of return of the KRX gold market at t day as the dependent variable. Subscript CO means "Close to Open, market rate of return," and CC means "Close to Close, the rate of return". Regression equation (1) includes simple key variables in order to provide important information about the effect of our determinants on the market rate of return of the KRX gold market.

$$KRX_{co,t} = \beta_0 + \beta_1 CME_{cc,t-1} + \beta_2 ICE_{cc,t-1} + \beta_3 Yield_{cc,t-1} + \beta_4 VIX_{cc,t-1} + \varepsilon_t^2 \quad (1)$$

To estimate Equation (1), the statistic is used with low serial correlation. If the stochastic process of variables has unit root, the significance of regression results could not be trusted because of spurious regression. To avoid testing variables with unit root, we execute unit root test (ADF Test; Augmented Dicky-Fuller Test) before the regression test. In addition, most of the financial time-series variables are known to be auto-correlated, which is considered to account for the robustness of estimates by Equation (1). For considering this, we use GARCH (1,1) model as shown in equation (2) (Thiyagarajan, 2015).

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^p \alpha_i \sigma_{t-i}^2 + \sum_{j=1}^q \alpha_j \varepsilon_{t-j}^2 \quad (2)$$

In order to verify possible statistic model error, we conducted robustness testing regarding the price discovery function about the market rate of return

of the KRX gold market and other determinant variables, with unrestricted VAR model. By using VAR model, we can consider the endogenous effect of each variable. The specification of the model is represented in equation (3).  $R_t$  is a vector of the endogenous variables of rate of return we investigate while  $C$  and  $A_s$  are the coefficient matrix per each. In addition,  $m$  is the length of lag, and  $e_t$  is a vector of prediction error.

$$R_t = (KRX_{co,t}, CME_{cc,t}, ICE_{cc,t}, Yield_{cc,t}, VIX_{cc,t})^T, \quad R_t = C + \sum_{s=1}^m A_s R_{t-s} + e_t \quad (3)$$

## IV. Empirical Results

### A. Regression analysis

By using regression analysis, we test the effect of determinants on the market rate of returns of the KRX gold market by the rate of returns of CME gold futures, and the rate of returns of ICE dollar index futures, the rate of returns of ICE dollar index futures, the rate of returns of NYSE United States 5-year bond yield, and the rate of returns of CBOE VIX futures.

Preliminarily, the autocorrelation analysis of each variable and the partial correlation analysis are performed. As shown in Panel A of Table 6, no correlation of estimated residual of each variable exists, making our empirical results more reliable. The time difference is determined using up to fourteen items at maximum, analyzed on the basis of the lowest value of SIC (standard industry classification).

Moreover, as shown in Panel B of Table 6, in order to confirm the probability of time series data, the result of performance of the unit root test (ADF Test; Augmented Dicky-Fuller Test) is interpreted. It is determined that there is no unit root or spurious regression phenomenon in the specimen due to dismissing the hypothesis of the unit root existence on all variables of significance at the 1% level or below.

**Table 5.** Autocorrelation analysis and ADF test

This table presents the results of autocorrelation analysis and ADF test. Sample period is from the 24<sup>th</sup> March, 2014 to the 23<sup>rd</sup> August, 2016.  $KRX_{co,t}$  is the market rate of return of the KRX gold market at t day,  $CME_{cc,t}$  is the rate of return of CME gold futures at t days,  $ICE_{cc,t}$  is the growth rate of ICE dollar index futures at t day,  $Yield_{cc,t}$  is NYSE United States 5-Year Bond Yield at t day, and  $VIX_{cc,t}$  is the growth rate of CBOE VIX futures at t day. The time difference is determined using up to 14 items at maximum, analysed on the basis of the lowest value of SIC.

<b>Panel A: Autocorrelation</b>										
Lag	Autocorrelation					Partial autocorrelation				
	$KRX_{co,t}$	$CME_{cc,t}$	$ICE_{cc,t}$	$Yield_{cc,t}$	$VIX_{cc,t}$	$KRX_{co,t}$	$CME_{cc,t}$	$ICE_{cc,t}$	$Yield_{cc,t}$	$VIX_{cc,t}$
1	-0.02	-0.05	-0.06	-0.08	-0.01	-0.02	-0.05	-0.06	-0.08	-0.01
2	0.02	-0.02	0.04	0.00	-0.02	0.02	-0.02	0.03	-0.01	-0.02
3	0.05	0.01	-0.06	0.05	0.02	0.05	0.01	-0.06	0.05	0.02
4	0.05	0.02	0.01	0.03	-0.09	0.05	0.02	0.00	0.04	-0.09
5	-0.04	0.07	-0.02	-0.09	-0.07	-0.04	0.07	-0.02	-0.09	-0.07
6	0.06	0.01	-0.09	0.01	-0.03	0.06	0.01	-0.09	-0.01	-0.04
7	0.07	-0.02	0.04	0.02	-0.01	0.07	-0.01	0.03	0.02	-0.01
8	0.04	0.00	0.01	-0.05	0.00	0.05	0.00	0.01	-0.04	-0.01
9	0.03	0.02	0.06	0.07	0.00	0.03	0.02	0.05	0.07	-0.02
10	0.05	-0.01	-0.06	-0.06	0.01	0.04	-0.02	-0.05	-0.07	-0.01
11	-0.06	-0.01	0.05	-0.10	-0.04	-0.07	-0.02	0.04	-0.11	-0.05
12	0.04	-0.06	-0.06	-0.02	0.02	0.03	-0.06	-0.05	-0.03	0.01
13	-0.04	0.03	0.00	0.00	0.01	-0.05	0.02	-0.01	-0.01	0.01
14	0.04	0.05	-0.06	-0.02	-0.11	0.03	0.05	-0.05	0.01	-0.11

<b>Panel B: Unit root test</b>					
	$KRX_{co,t}$	$CME_{cc,t}$	$ICE_{cc,t}$	$Yield_{cc,t}$	$VIX_{cc,t}$
Time Parameter	0	0	0	0	0
t-Statistics	-24.86	-25.68	-25.78	-26.32	-24.42
Significance probability	0.001	0.001	0.001	0.001	0.001

The rate of return of CME gold futures, ICE dollar index futures, NYSE United States 5-year bond yield, and the growth rate of CBOE VIX futures at t-1 days are set as the independent variables. The market rate of return of the KRX gold market is set to the dependent variable in order to examine the variables traded in the United States at night time in Korea has an influence on the KRX gold market in which the transactions don't started until 9:00 am on the next business day in Korean time.

Table 6 represents the interrelation among five variables before estimation analysis: the market rate of return of KRX gold market at t days, the rate of return of CME gold futures at t-1 days, and the rate of return of ICE dollar index futures at t-1 days,

the rate of return NYSE United States 5-year bond yield at t-1 days, and the rate of return CBOE VIX futures at t-1 days.

The analysis result of the correlation is that the market rate of return of the KRX gold market ( $KRX_{co,t}$ ) and the rate of return of CME gold futures at t-1 days ( $CME_{cc,t-1}$ ) positively related at 0.576 with a 1% level of significance. This correlation coefficient indicates that there is strong relationship following time disparity between the CME and KRX gold market. The correlation between the rate of return of the KRX gold market at t day ( $KRX_{co,t}$ ) and the rate of return of ICE dollar index futures at t-1 days ( $ICE_{cc,t-1}$ ) was negative (-0.147) with significance at the 1% level. It is noticeable that the negative

**Table 6.** Correlation analysis

This table presents Pearson correlations among rate of returns from the 24<sup>th</sup> March, 2014 to the 23<sup>rd</sup> August, 2016.  $KRX_{co,t}$  is the market rate of return of the KRX gold market at t day,  $CME_{cc,t-1}$  is the rate of return of CME gold futures at t-1 days,  $ICE_{cc,t-1}$  is the rate of return of ICE dollar index futures at t-1 days,  $Yield_{cc,t-1}$  is rate of return NYSE United States 5-Year Bond Yield at t-1 days,  $VIX_{cc,t-1}$  is rate of return of CBOE VIX futures at t-1 days. \*\*\* denotes the 1% significance level.

Division	$KRX_{co,t}$	$CME_{cc,t-1}$	$ICE_{cc,t-1}$	$Yield_{cc,t-1}$	$VIX_{cc,t-1}$
$KRX_{co,t}$	1	0.576***	-0.147***	-0.230***	0.157***
$CME_{cc,t-1}$		1	-0.344***	-0.395***	0.171***
$ICE_{cc,t-1}$			1	0.238***	-0.124***
$Yield_{cc,t-1}$				1	-0.330***
$VIX_{cc,t-1}$					1

**Table 7.** Regression analysis

This table presents the effect of CME gold futures and ICE dollar index futures on KRX gold market by regression analysis. Sample period is from the 24<sup>th</sup> March, 2014 to the 23<sup>rd</sup> August, 2016.  $KRX_{co,t}$  is the market rate of return of the KRX gold market at t day,  $CME_{cc,t-1}$  is the rate of return of CME gold futures at t-1 days,  $ICE_{cc,t-1}$  is the rate of return of ICE dollar index futures at t-1 days,  $Yield_{cc,t-1}$  is growth rate of NYSE United States 5-Year Bond Yield at t-1 days,  $VIX_{cc,t-1}$  is growth rate of CBOE VIX futures at t-1 days. \*\*\*, \*\* denote the 1%, 5% significance level, respectively.

	Model 1	Model 2	Model 3	Model 4	Model 5
$CME_{cc,t-1}$	0.401*** (14.981)				0.410*** (12.735)
$ICE_{cc,t-1}$		-0.189*** (-3.368)			0.079 (1.372)
$Yield_{cc,t-1}$			-0.048*** (-5.938)		0.002 (0.305)
$VIX_{cc,t-1}$				0.013*** (4.113)	0.005** (2.035)
Constant	0.132*** (5.803)	0.140*** (5.046)	0.134*** (4.930)	0.131*** (4.748)	0.128*** (5.589)
Serial Correlation Robust	yes	yes	yes	yes	yes
No. of Observations	595	595	595	595	595
Adjusted R <sup>2</sup>	0.331	0.020	0.051	0.023	0.335

correlation between the rate of return of CME gold futures at t-1 days and ICE dollar index futures at t-1 days (-0.344) is more negative than the correlation between the market rate of return of the KRX gold market at t day ( $KRX_{co,t}$ ) and the rate of return of CME gold futures at t-1 day ( $ICE_{cc,t-1}$ ; -0.147) because the business hours of CME gold futures and ICE dollar index futures almost coincided with each other and night time in Korean standard time.

We consider the potential serial correlation of

errors, so we suggest t-statistics, which is robust on the serial correlation of errors. We conduct univariate test using each parameter (model 1~4) and add regression analysis using all variables (model 5). The regression analysis results are shown in Table 7. The results show that the rate of return of CME gold futures at t-1 days ( $CME_{cc,t-1}$ ) has a positive effect on the market rate of return of the KRX gold market at t day with 1% level of significance. These results are not only interpreted as a result of a regression

analysis with  $CME_{cc,t-1}$  but also in models with all variables included. This means that Hypothesis 1, the rate of return of CME gold futures at t-1 days positively affects the rate of return of the KRX gold market at t day, is established.

However, the significance of ICE dollar index futures at t-1 days ( $ICE_{cc,t-1}$ ) affecting the market rate of return of the KRX gold market at t day is not clear. Although the effect is significant in univariate test in model 2, it is not significant in model 4 with other variables. Therefore, Hypothesis 2 (The rate of return of ICE dollar index futures at t-1 days negatively affects the market rate of return of the KRX gold market at t day) could not be supported in the regression result.

The impact of changes in overseas interest rates is not significant in the daily data. This means that Hypothesis 3 (The rate of return of NYSE 5-year bond yield at t-1 days has a negative influence on the market rate of return of the KRX gold market at t day) is not explained. On the contrary, the uncertainty of the VIX index shows the positive effect of the gold circulation rate. This reaffirmed the existing insight that the uncertainty of the external environment increases the nation's gold demand as a result of supporting Hypothesis 4.

To check the robustness of the results, we assume

GARCH for model 5 as the error volatility process. Based on the AIC, BIC, and LR test, the GARCH model is the best suited for the results. The estimated results are presented in Table 8. The result of the introduction of the GARCH (1,1) process is not significantly different from the regression results presented in Table 7. ICE dollar index futures at t-1 days ( $ICE_{cc,t-1}$ ) affecting the market rate of return of the KRX gold market at t day is positively significant, which is the opposite pattern to Hypothesis 2. The result is that although the gold price in the global market has a negative relationship with the dollar, the price of the dollar can increase the price of the KRX gold market.

The regression analysis shows that the CME gold futures and CBOE VIX futures present a positive influence on the KRX open-to-close gold returns while the interest rate changes and price variation of the ICE futures are not statistically significant.

The following sections analyse the impact of the CME gold futures price, the price of the ICE dollar futures, and the VIX on the KRX open-to-close gold returns considering interaction effect. Daily return is excluded because the impact on the KRX open-to-close gold returns is not significant and the impact on other variables is also limited. However, although the impact of the ICE futures on the KRX gold market is not

**Table 8.** Regression analysis with GARCH (1,1)

This table presents the effect of CME gold futures and ICE dollar index futures on KRX gold market by regression analysis. Sample period is from the 24<sup>th</sup> March, 2014 to the 23<sup>rd</sup> August, 2016.  $KRX_{co,t}$  is the market rate of return of the KRX gold market at t day,  $CME_{cc,t-1}$  is the rate of return of CME gold futures at t-1 days,  $ICE_{cc,t-1}$  is the rate of return of ICE dollar index futures at t-1 days,  $Yield_{cc,t-1}$  is the growth rate of NYSE United States 5-Year Bond Yield at t-1 days,  $VIX_{cc,t-1}$  is growth rate of CBOE VIX futures at t-1 days. \*\*\* denotes the 1% significance level.

	Division	Coefficient	t-Statistics	Significance probability
Regression structure	(Constant)	0.166***	8.371	0.000
	$CME_{cc,t-1}$	0.414***	20.264	0.000
	$ICE_{cc,t-1}$	0.122***	3.010	0.003
	$VIX_{cc,t-1}$	0.007***	2.953	0.003
	$Yield_{cc,t-1}$	0.004	0.566	0.571
Variance structure	(Constant)	0.015***	3.322	0.001
	$\hat{\epsilon}_{t-1}^2$	0.161***	4.874	0.000
	$\hat{\sigma}_{t-1}^2$	0.821***	24.615	0.000
	Adjusted $R^2$	0.330	Durbin-Watson	1.919

significant, it is analysed in the analysis to examine the effects on the CME gold futures and the KRX open-to-close gold returns.

## B. Empirical analysis utilizing VAR model

To account for the impact of the variables affecting each other, we used VAR model to test the influence on the market rate of return of the KRX gold market. We consider all variables except rate of return of NYSE 5-year bond, which turns out not to affect the close-to-open return of KRX gold market. We apply optimal lag variables into the analysis by AIC, BIC, and LR criteria as shown in table 9.<sup>2)</sup>

Through results of this analysis, we re-examine the significance that the rate of return of CME gold futures at  $t-1$  days has a significant impact on the market rate of return of the KRX gold market at  $t$  day in order to verify the Hypothesis 1 (The rate of return of CME gold futures at  $t-1$  days positively affects the market rate of return of the KRX gold market at  $t$  day). The rate of return of CME gold futures at  $t-1$  day reveals that with below the 1% level of significance, there is a positive correlation (0.414) about the market rate of return of the KRX gold market at  $t$  day. Since the rate of return of CME gold futures at  $t-1$  days has the price discovery function and the leading effect about the market rate of return of the KRX gold market at  $t$  day, this result is interpreted as one that coincided with the result of the regression analysis mentioned above.

In addition, our study also measures the influence that the rate of return of ICE dollar index futures at  $t-1$  days has an influence on the market rate of return of the KRX gold market at  $t$  day using the estimation of the VAR model. As a result, we couldn't verify Hypothesis 2. This means that the rate of return of ICE dollar index futures at  $t-1$  days does not negatively affects the market rate of return of the KRX gold market at  $t$  day.

In sum, price movement of the CME gold futures

of the prior day significantly and positively affects the Korea gold market on the following day while ICE dollar index futures does not have predicted impact on the Korea gold market.

To show the price effect of the U.S. futures at prior day on Korean gold market, this study also performs variance decomposition and impulse response analysis by utilizing the coefficient value of the analyzed results from the unrestricted VAR model in Table 9. In the case of variance decomposition, Cholesky decomposition is used and the result of the variance decomposition analysis is presented in Table 10.

The number of tables indicates predicted error dispersion of the variable on the left having an effect on the top variables with percentages. In the analyzed result of variance decomposition, one has to take notice of the KRX line in order to examine whether to support Hypothesis 1, 2, 3, 4. The rate of return of CME gold futures contributes to the predicted error dispersion of the market rate of return of the KRX gold market being considerably high at the 33% level, whereas the rate of return of ICE dollar index futures is less than 0.3%. That is, the rate of return of CME gold futures can be interpreted as having a price discovery effect that is higher than that of ICE dollar index futures on the market rate of return of the KRX gold market.

Also, variance decomposition analysis, which shows that the impact of the VIX futures while the uncertainty of the economy is increasing on the price of the KRX gold futures, presents low significance level. Meanwhile, as the line of the rate of return of CME gold futures is seen, over 99% of it is explained by itself and the predicted error dispersion of the rate of return of CME gold futures shows low importance of being explained by other variables. That is, the market rate of return of the KRX gold market is explained at a considerable level (33% level) by the rate of return of CME gold futures but the opposite is not the case in this analysis. These results suggest that the price of the KRX gold market is significantly affected by the price movements of the CME gold futures market indicating the price synchronization of the two global markets.

2) We obtain similar result to the results in the paper when we consider the rate of return of NYSE 5-year bond in VAR analysis.

**Table 9.** Unrestricted VAR analysis

This table presents unrestricted VAR analysis results among all exchanges. Sample period is from the 24<sup>th</sup> March, 2014 to the 23<sup>rd</sup> August, 2016.  $KRX_{co,t}$  is the market rate of return of the KRX gold market at t day,  $CME_{cc,t}$  is the rate of return of CME gold futures at t days,  $ICE_{cc,t}$  is the rate of return of ICE dollar index futures at t days,  $Yield_{cc,t}$  is growth rate of NYSE United States 5-Year Bond Yield at t days,  $VIX_{cc,t}$  is growth rate of CBOE VIX futures at t days. \*\*\*, \*\*, \* denote the 1%, 5% and 10% significance level, respectively.

	Division	$KRX_{co,t}$	$CME_{cc,t}$	$ICE_{cc,t}$	$VIX_{cc,t}$
$KRX_{co(t-1)}$	Coefficient	-0.002	-0.035	0.043	0.119
	Standard Deviation	(0.034)	(0.059)	(0.032)	(0.519)
	t-value	[-0.047]	[-0.583]	[ 1.327]	[ 0.229]
$CME_{cc(t-1)}$	Coefficient	0.405***	-0.068	-0.011	-0.257
	Standard Deviation	(0.025)	(0.044)	(0.024)	(0.387)
	t-value	[ 16.110]	[-1.529]	[-0.448]	[-0.664]
$ICE_{cc(t-1)}$	Coefficient	0.078*	-0.040	-0.071	0.180
	Standard Deviation	(0.046)	(0.081)	(0.044)	(0.710)
	t-value	[ 1.702]	[-0.494]	[-1.619]	[ 0.253]
$VIX_{cc(t-1)}$	Coefficient	0.005*	0.004	-0.005*	0.001
	Standard Deviation	-0.003	-0.005	-0.003	-0.042
	t-value	[ 1.942]	[ 0.752]	[-1.768]	[ 0.031]
	Adjusted R <sup>2</sup>	0.332	0.004	0.006	0.001
	F- Statistics	74.429	0.723	1.854	0.192

**Table 10.** Forecast error decomposition analysis

This table reports unrestricted forecast error decomposition analysis results. Sample period is from the 24<sup>th</sup> March, 2014 to the 23<sup>rd</sup> August, 2016.  $KRX_{co,t}$  is the market rate of return of the KRX gold market at t day,  $CME_{cc,t}$  is the rate of return of CME gold futures at t days,  $ICE_{cc,t}$  is the rate of return of ICE dollar index futures at t days,  $Yield_{cc,t}$  is growth rate of NYSE United States 5-Year Bond Yield at t days,  $VIX_{cc,t}$  is rate of return of CBOE VIX futures at t days. \*\*\* denotes the 1% significance level.

Division	Period	$KRX_{co,t}$	$CME_{cc,t}$	$ICE_{cc,t}$	$VIX_{cc,t}$
$KRX_{co,t}$	2	66.505	32.793	0.275	0.425
	5	66.392	32.862	0.301	0.443
	10	66.392	32.862	0.301	0.443
$CME_{cc,t}$	2	0.035	99.818	0.050	0.095
	5	0.035	99.817	0.050	0.095
	10	0.035	99.817	0.050	0.095
$ICE_{cc,t}$	2	0.438	11.997	87.039	0.524
	5	0.439	12.107	86.923	0.530
	10	0.439	12.107	86.923	0.530
$VIX_{cc,t}$	2	0.079	3.008	0.483	96.428
	5	0.079	3.013	0.483	96.424
	10	0.079	3.013	0.483	96.424

Table 11 presents the result of the impulse responses of the market rate of return of the KRX gold market on the rate of return of CME gold futures, ICE dollar index futures, NYSE United States 5-year

**Table 11.** Impulse Response analysis

This table presents impulse response analysis results. Sample period is from the 24<sup>th</sup> March, 2014 to the 23<sup>rd</sup> August, 2016.  $KRX_{co,t}$  is the market rate of return of the KRX gold market at t day,  $CME_{cc,t}$  is the rate of return of CME gold futures at t days,  $ICE_{cc,t}$  is the rate of return of ICE dollar index futures at t days,  $Yield_{cc,t}$  is rate of return of NYSE United States 5-Year Bond Yield at t days,  $VIX_{cc,t}$  is rate of return of CBOE VIX futures at t days.

	Period	$KRX_{co,t}$	$CME_{cc,t}$	$ICE_{cc,t}$	$VIX_{cc,t}$
$KRX_{co,t}$	0	0.554	0.000	0.000	0.000
	1	0.000	0.389	0.035	0.044
	2	-0.004	-0.024	-0.011	0.009
	3	0.000	-0.002	0.001	-0.000
$CME_{cc,t}$	0	0.005	0.976	0.000	0.000
	1	-0.017	-0.053	-0.021	0.030
	2	0.000	-0.010	0.001	-0.002
	3	0.000	0.001	0.000	-0.000
$ICE_{cc,t}$	0	-0.025	-0.183	0.494	0.000
	1	0.024	-0.004	-0.032	-0.038
	2	-0.001	0.018	-0.000	0.004
	3	-0.000	-0.002	0.000	0.000
$VIX_{cc,t}$	0	0.233	1.454	-0.587	8.386
	1	0.060	-0.282	0.088	0.010
	2	0.009	0.058	0.004	-0.009
	3	-0.001	0.003	-0.001	0.002

bond yield, and VIX futures. It is analyzed how  $KRX_{cc}$  reacted to  $KRX_{co,t}$ ,  $CME_{cc,t}$ , and  $ICE_{cc,t}$ ,  $Yield_{cc,t}$ ,  $VIX_{cc,t}$  with one standard error per each given ratio. The market rate of return of the KRX gold market at t day will react on the shock of the rate of return of CME gold futures at t-1 days and ICE dollar index futures at t-1 days, taking business hours into consideration. That is, the reaction the following day needs to be examined, not the day of the impact. If the reaction of the market rate of return of the KRX gold market about the shock of the rate of return of CME gold futures at t-1 days is examined, the coefficient is shown as 0.388, which is much bigger than those of the market rate of return of the KRX gold market at t-1 days (0.000) and the rate of return of ICE dollar index futures at t-1 days (0.035). In addition, the impact response analysis confirms that the impact coefficient of the VIX futures on KRX gold market yield is very low.

This result can be interpreted as supporting Hypothesis 1, which explain that the rate of return of CME gold futures at t-1 days positively affects

the market rate of return of the KRX gold market at t day, can also support the result of the regression analysis mentioned above.

In sum, our empirical results provide that consistent relationships between ICE dollar index futures and the KRX gold market do not exist. However, the price movement of the KRX gold market reacts positively and significantly to the movement of CME gold futures while there is no significant reverse pattern.

## V. Summary and Conclusion

In this paper, we examine the price efficiency of the Korea Exchange (KRX) gold market and the determinants which have an effect on the close-to-open return of gold price in the KRX gold market. We research this price efficiency by showing time disparity and price discovery factors in the market.

Korean gold investors find a route that they can invest in gold and save investment costs such as fees and taxes by the introduction of the KRX gold market. The implication of this paper is that the KRX gold market is developing to be the most efficient gold market among the existing gold investment methods in Korea. Moreover, despite the enormous influence of gold on other real or financial assets in Korea, the related research is scarce, especially the investigation of gold market price discovery. We examine the causal price sequence between the American derivatives market yesterday and KRX gold market today, which can suggest a substantial contribution to this field of research.

The futures markets could lead spot markets according to existing research on the relationship between futures market and spot market. Moreover, when the time difference exists, the futures price at  $t-1$  day affects the  $t$  day time point. This can be interpreted as the price discovery function. In this research, we use the regression analysis such as GARCH and VAR model to investigate the significance of the rate of return of the CME gold futures, ICE dollar index future, NYSE United States 5-year bond yield, and CBOE VIX futures which are traded at night time in Korea have impact on the close-to-open return of gold price in the KRX gold market in the next morning. The results show that the CME gold futures at  $t-1$  day significantly and positively affect the rate of return of the KRX gold market several hours later. This result can be interpreted as supporting the existing evidence that the futures market has a price discovery effect on the spot market.

In addition, we find the result that the rate of return of ICE dollar index futures at  $t-1$  days could not be confirmed to significantly determine the market rate of return in the KRX gold market at  $t$  day opposite to generally mentioned knowledge, which is that 'value of the dollar moves contrary to the gold price'. We cannot discover the result of whether or not the rate of return of ICE dollar index futures at  $t-1$  days negatively affects the significance of the market rate of return of the KRX gold market at  $t$  day. It may be because the gold price in Korean market is directly

influenced by exchange rate between Korean currency and United States dollar. The effect of ICE dollar index futures is even not significant when we consider the interaction among variables by using VAR. We also investigate the effect of the NYSE United States 5-year bond yield and CBOE VIX futures on the KRX close-to-open rate of return of the KRX gold market and find significant impact of the VIX futures on KRX gold market price.

In this regard, this study put forward a hypothesis that the rate of return of the gold futures in the CME would have a positive impact on the market rate of return of the KRX gold market. In addition, this paper goes into detail about the international gold price having a negative correlation with the value of the United States (US) dollar. To the extent that the futures market has a characteristic of leading the spot market, this study supports the view of a link between time disparity and price discovery in Korea and the U.S. financial market.

Meanwhile, we have seen a steady increase in transaction prices since the KOSPI opened on March 24, 2014. The increased liquidity of the KRX gold market is believed to contribute to the efficiency of the KRX gold market. In this paper, however, the company did not conduct an empirical analysis on the efficiency of the KRX gold market by increasing liquidity. This is because we have only two years since the market opened, and we have considered that there is a limit to our analysis of liquidity, and we will be working on it for future research.

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