The Relationship between the Gold Price, Crude Oil Price, Exchange Rate and Chinese Stock Market Indexes

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Abstract. One of the trickiest problems for investors is how the financial and commodity markets interact with each other. The volatility in one market might affect the price of the other market. This essay aims to clarify the relationship between gold, crude oil, exchange rates, and Chinese stock market indices. In order to do this, the Shanghai Stock Exchange Index and the China Industrial Index, two indices that reflect the Chinese financial market, were subjected to the DCC-GARCH model (Generalized Autoregressive Conditional Heteroskedasticity Model). By capturing the dynamic correlations of the time series' variance, covariance, and correlation coefficient, this model aids in illuminating the long-run dynamic correlation between returns. The findings show that gold and crude oil are positively correlated with both the Shanghai Stock Exchange Index and the China Industrial Index, while the correlations between the USD CNY exchange rate and the two Chinese stock indices are negatively correlated, using monthly data from 2000-01-03 to 2022-08-30. This paper shows that stock prices in China are weakly linked to international commodity markets and exchange rate with the US. Additionally, throughout the observation period, financial crisis (2008) and the COVID-19 pandemic breakout (2020) enhanced comovement between the Chinese stock market, commodities, and exchange rate in general.

Keywords: DCC-GARCH; Chinese stock market; gold; crude oil; exchange rate; volatility spillovers; dynamic correlations.

1. Introduction

It is believed that the prices of both crude oil and gold have an effect on the world stock market. This effect is particularly apparent in the real estate and financial markets' consumption, industrial production, and investment sectors, where the volatility of the gold and oil prices has an impact on stock prices, some spillover effects on the US capital market, and a knock-on effect on inflation and unemployment [1]. The stock market and exchange rate are the two primary international financial markets. These two marketplaces are crucial to international trade all across the world. Investors may gain more profitably with the least amount of risk by being aware of how the two markets interact.

Geopolitical and weather-related factors have an impact on the price of crude oil, which may result in unanticipated changes in supply and demand and may raise the volatility of the oil price. Understanding crude oil price volatility is essential, because it may generate uncertainty in all economic sectors and instability in the economy of both oil-exporting and oil-importing nations. Industrial producers and consumers are at danger due to the dependence of industrial firms on oil and oil-related goods. They are unable to charge fair pricing for their products and services. Since the value of a commodity is dependent on a contingent claim that is impacted by the volatility, the volatility of the oil price also has an effect on derivative markets. Additionally, oil price volatility leads to rising inflation and unemployment rates.

The precious metal gold is regarded as a commodity and a financial asset. It functions as an asset, a measure of value, and a medium of trade. In addition, gold is used to make jewelry and is considered a very liquid investment option. Since it serves as a hedge to diversify the escalating market risk, gold has historically been seen as an indicator of inflation, a hedge against inflation, a vital asset in portfolio allocation, and a tool in times of crisis. For the reason of economic security and diversity, central banks and international financial institutions keep a sizeable amount of gold on hand.

Several factors can have an impact on the market value of companies and stock prices, among them the fluctuations of exchange rate is a key one. Despite broad discussion, the research on how

the equity market and currency rate interconnect is far from conclusive. In line with the financial theory, exchange rates and rates of interest are supposed to influence a firm's value. Share prices of enterprises may be affected by exchange rate movements, positively or negatively. Suriani et al. examines the connection between the Chinese stock market and the USD-CNY exchange market [2]. They investigate the relevance between the capital market and rate of exchange in Pakistan. In their article, stock prices are replaced by the KSE-100 index while exchange rate exposure is calculated using the Pak Rupee to US Dollar exchange rate (Rs/US$). The time period of the monthly data cover the years January 2004 through December 2009. The study's findings imply that the exchange rate and stock price are totally unrelated.

The essay is set up as follows: Section 2 presents a review of the literature. Section 3 outlines facts and the method. At last, part 4 offers the findings and discussion.

2. Literature Review

Since the reform and opening-up in 1978, stock prices has become more informative in China compared with the United States [3]. Chinese stock markets are still more impacted by global financial markets than the other way around, though [4]. An investigation on the dynamic correlations and spillovers between China's new energy, rare earth and world oil markets shows that instability may move from the tombarthite market to the oil or new energy markets [5]. Zhang et al. investigate how regime shift impacts the capacity to anticipate the Chinese capital market volatility, using fluctuations in other markets. Applying the heterogeneous autoregressive (HAR) model, which they further expand by using a specific volatility metric from 27 different worldwide equity markets, they conduct their research. The findings from the in-sample estimation indicates that the transition probabilities are considerable, and the regime with a higher volatility is more volatile than the lower volatility regime [6]. Hou et al. give some fresh data on the volatility spillover effects between the fuel oil futures market and the Chinese stock index. They do this by applying a DCC-GARCH model on the data. The researchers also discovered that the mean volatility spillover has a bilateral orientation, and that stock indexes have a far higher influence on fuel oil futures than vice versa. This shows that the way information is processed is significantly influenced by the stock futures market. Stakeholders in the furnace oil sector as well as risk managing industry are supposed to take these results seriously.

Chinese and global economies both depend heavily on gold and oil. Gold is regarded as a hedging investment for crude oil because rising oil prices might induce economic inflation, which could have an impact on future interest rates and investment opportunities. Due to the significance of crude oil as a raw resource for industrial products, including petroleum, diesel oil, and aviation fuel [7], there is a relevance between oil values and economic performance. And gold is a precious metal owning both commodity and economic features. As a result, prices of gold and rock tar are positively related to a risk-related comovement mechanism. It is important to study the relationship between these two commodities' forward prices and stock prices [8]. With the VAR-DCC-GARCH method, the synergy between the nonferrous metal prices in China and around the world has been investigated. The findings show that nonferrous metal prices of the London Metal Exchange affect Chinese nonferrous metal pricing more, but not the other way around [9]. Later, Hashmi et al. employs the VAR-DCC-GARCH model to analyze effects of rock oil values on Chinese capital market and a few specific industries. They found that Shanghai Composite Index and a few industries are significantly impacted by Brent crude oil prices. Brent oil prices affect industries including mining, chemicals, nonferrous metals and steel, among others.

The volatilities and co-volatilities across markets are often studied using the multivariate GARCH models, which were developed to measure how news impacts the market volatilities [10]. There are several multivariate GARCH models, among whom the DCC-GARCH (Dynamic Conditional Correlation GARCH) models are most appreciated among researchers. Furthermore, MGARCH models combine the simplicity of parametric correlation with the adaptability of univariate GARCH

models. They are extensions of CCC-GARCH (Constant Conditional Correlation GARCH) models. Using the DCC-GARCH model [11]. Bouaziz et al. examine impacts of U.S. equity market's contagion on capital markets of other well-developed nations during the famous financial crisis around 2008. They discovered rising connections between these markets during the crisis period and believe it is clearly due to contagion.

3. Data and Methodology

3.1. Data

This paper studies the correlation between Shanghai Stock Exchange Index, China Industrial Index, and three international indices, two commodities and an exchange rate: COMEX gold forward price, NY Mercantile crude oil forward price and USD CNY exchange rate. Shanghai Stock Exchange Index and China Industrial Index are particularly chosen to represent the Chinese equity market. The time series data range from 2000-01-03 to 2022-08-30 on a monthly basis. Table 1 shows the descriptive statistics of the five series concerned.

Table 1. The performance series of the two Chinese stock indexes, the two commodities, and the exchange rate in descriptive statistics

	R_SH	R_CI	R_GOLD	R_OIL	R_Exchange
Mean	0.01	0.01	0.01	0.01	0.00
Median	0.01	0.01	0.01	0.02	0.00
Maximum	0.27	0.28	0.14	0.88	0.04
Minimum	-0.25	-0.26	-0.18	-0.54	-0.03
Std. Dev.	0.07	0.08	0.05	0.11	0.01
Skewness	-0.11	-0.29	-0.06	1.24	1.43
Kurtosis	1.72	1.59	0.64	15.13	7.11
Jarque-Bera	32.85	31.316	4.8025	2516.6	629.22
Probability	7.357e-08	1.584e-07	0.09061	2.2e-16	2.2e-16
Observations	252	252	252	252	252

Notes: “R_SH” stands for the return of Shanghai Stock Exchange Index, “R_CI” for the return of China Industrial Index, “R_GOLD” for the return of COMEX gold futures, “R_OIL” for the return of NY Mercantile crude oil futures and “R_Exchange” for the return of USD CNY exchange rate.

This research investigates the return of prices since economic time series usually look stationary modified into first order difference. In this article, the return’s formula is “price / lag 1 price - 1”. The unit root tests, which are shown in the second table, support this assertion by refusing the original assumption that there is a unit root in the form of returns. This indicate that the whole time series set in this research is stable. As a result, all of the time-series data utilized are returns using the first order difference of prices.

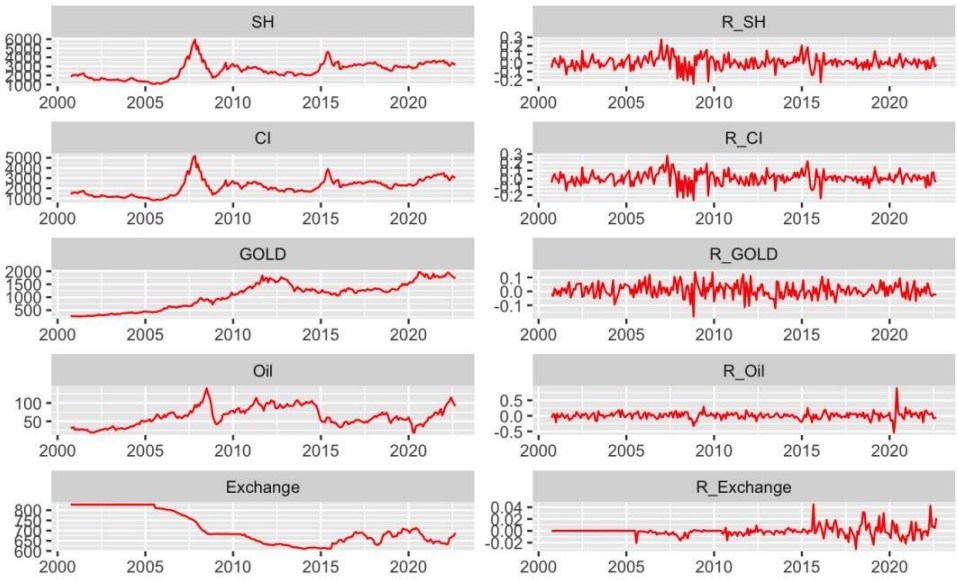


Fig 1. Fluctuation in closing prices and returns of the time series data

Source: Wind [12], National Bureau of statistics of the People's Republic of China [13], Yahoo Finance [14], State Administration of Foreign Exchange [15]

Figure 1 displays the trends of prices and returns of Shanghai Stock Exchange Index, China Industrial Index, the two commodities gold and crude oil, and exchange rate. Units of Shanghai Stock Exchange Index, China Industrial Index and USD CNY exchange rate are Chinese Yuan while units of Gold and Crude oil forward prices are U.S. Dollar.

Table 2. Stationarity testing of the five time series

	R_SH	R_CI	R_GOLD	R_OIL	R_Exchange
ADF statistic	-4.4331	-4.4987	-5.9734	-6.5053	-5.3857
Prob.*	<0.01	<0.01	<0.01	<0.01	<0.01
PP statistic	-254.82	-253.26	-265.52	-191.08	-196.47
Prob.*	<0.01	<0.01	<0.01	<0.01	<0.01
KPSS statistic	0.055648	0.048922	0.30257	0.08619	0.32496
Prob.*	>0.1	>0.1	>0.1	>0.1	>0.1

Notes: ADF stands for the Augmented Dickey-Fuller test, PP for the Phillips Perron test, and KPSS for the Kwiatkowski, Phillips. Schmidt, Shin-test. The null hypothesis for the first two tests is non-stationarity, and the original assumption for the KPSS test is stationarity. The differences between monthly price observations is used to determine percentage returns.

The ADF and the PP test both result in p-values that are less than 0.05, rejecting their null hypothesis, according to the stationarity test for the five models. Furthermore, all of the p-values for the KPSS test are higher than 0.05, indicating that the original hypothesis is taken. As a result, all yield series are level-stationary. The yield series are heteroskedastic, as shown by the ARCH-LM heteroskedasticity test (Table 3), and ARCH and GARCH series models may be used to all the data even when the probability of the exchange rate's return is more than 0.05, indicating insignificance.

Table 3. Heteroscedasticity test (ARCH-LM test)

	nR^2	Prob
R_SH	56.624	0.0000
R_CI	73.477	0.0000
R_GOLD	22.696	0.03042
R_OIL	26.41	0.009387
R_Exchange	18.236	0.1087

3.2. Methodology

The goal of this paper is to explore the changing relations among the Chinese equity market indexes, gold, rock var, and the USD CNY currency rate. Although many scholars explore this correlation using GARCH-series models, there are certain drawbacks. It is required to evaluate the change in correlation to investigate the relevance between various assets' results. The literature suggests a number of methods to look at how the correlation varies, especially in the GARCH family. Estimation and interpretation of these models are challenging. The DCC, created by Engle in 2002, is a useful tool for analyzing how the correlation between asset returns varies over time. For one thing, DCC-GARCH preserves the positive aspects of the conventional GARCH-type model; for another thing, it reduces the conventional model's computing cost, and contributes to increasing the estimation accuracy. Table 3 demonstrates the heteroskedasticity of the yield series. These features support the application of DCC-GARCH, enabling researchers to identify dynamic correlations of time series' variance, covariance, and correlation coefficient. DCC-GARCH also helps to depict the dynamic long-term connection in returns. Following that, the DCC-GARCH models' correlation and conditional volatility plots are shown to explain how fluctuations in gold and oil impact the series' conditional variance.

3.2.1 Model ARCH and GARCH

The ARCH model (Autoregressive Conditional Heteroskedasticity Model) was developed by Robert F. Engle in1982. He applied this method in an essay in *Econometrica*.

The ARCH model is giving by the following equation:

$$\varepsilon^2 t = \omega + \alpha_1 \varepsilon^2_{t-1} + \alpha_2 \varepsilon^2_{t-2} \ldots + \alpha_p \varepsilon^2_{t-p} + v_t \quad (1)$$

The GARCH model (Generalized Autoregressive Conditional Heteroskedasticity Model) was developed by Tim Bollerslev in 1986. He did his PH. D under Robert F. Engle on the same topic. Tim introduced this method in an article in *Journal of Econometrics*.

The model GARCH is demonstrated as the equation below:

$$Y(t) = h(t)^{1/2} * a(t) \quad (2)$$

$$h(t) = h(t - 1) + a(t - 1)^2 \quad (3)$$

A (t) is a random variable with an independent identical distribution, and h (t) is the conditional variance. A (t) follows a conventional normal distribution, and h (t) and a (t) are independent variables. The conditional mean equation in formula (1) and the conditional variance equation in formula (2) describe the properties of the dynamic conditional variance in time series.

3.2.2 Model DCC-GARCH

DCC estimators are proposed which have the flexibility of univariate GARCH but not the complexity of multivariate GARCH. This model explicitly parameterizes conditional correlations. Assuming that the model's variables have a constant relationship is the simplest approach to model the correlation structure. And the conditional correlation matrix is constant throughout time in the CCC-GARCH model, meaning:

$$P_t = P \quad (4)$$

The DCC-GARCH model is presented as below:

$$r_t = \mu_{t-1} + a_t \quad (5)$$

With

$$a_t = H_t^{1/2} \varepsilon_t, \quad (6)$$

Where ε_t is a random vector k * 1 whose mean value is 0. H_t stands for a matrix k * k that is positively defined. In addition, the covariance matrix can be broken down into $H_t = D_t R_t D_t$ on the ground of the matrix decomposition theory.

The benefit of the DCC-GARCH is it uses just two parameters, α and β, to drive the correlation process. In addition to measuring the data's flexibility, DCC-GARCH also directly models the variance and covariance. α DCC and β DCC suggest that the DCC-GARCH's estimators are dynamic and time-varying. α DCC assesses the short-term volatility impact and shows how long-lasting the standardized residuals from the prior period are. β DCC, which stands for the persistence of the conditional correlation process, assesses the influence of a shock's lasting effects on conditional correlations. The two parameters' total is less than 1, which indicates that the conditional correlation in the model is not stable over time.

4. Results and Discussions

This work aims to estimate two models of Chinese equity market index series and their correlations to exchange rates, crude oil, and gold. Table 4 displays the findings of the estimations.

Table 4. Model estimation using DCC-GARCH

	R_SH	R_CI
C_{M0}	0.001384 (0.696171)	0.002170 (0.561740)
C_{V0}	0.000314 (0.021898)	0.000335 (0.013840)
α_0	0.215500 (0.016822)	0.205774 (0.000968)
β_0	0.737570 (0.000000)	0.744319 (0.000000)
$\alpha + \beta$	0.953070	0.950093
C_{MGold}	0.007129 (0.006314)	0.007129 (0.006350)
C_{VGold}	0.000192 (0.443641)	0.000192 (0.443824)
α_{Gold}	0.127571 (0.083005)	0.127571 (0.082712)
β_{Gold}	0.792150 (0.000002)	0.792150 (0.000002)
$\alpha + \beta$	0.919721	0.919721
$C_{MCrude\text{-}oil}$	0.010350 (0.040351)	0.010350 (0.040458)
$C_{VCrude\text{-}oil}$	0.001540 (0.030184)	0.001540 (0.029633)
$\alpha_{Crude\text{-}oil}$	0.332477 (0.015971)	0.332477 (0.015987)
$\beta_{Crude\text{-}oil}$	0.572252 (0.000000)	0.572252 (0.000000)
$\alpha + \beta$	0.904729	0.904729
$C_{MExchange}$	-0.001323 (0.007774)	-0.001318 (0.008238)
$C_{VExchange}$	0.000002 (0.000921)	0.000002 (0.000333)
$\alpha_{Exchange}$	0.058142	0.059095

	(0.195501)	(0.196936)
$\beta_{Exchange}$	0.928785	0.927056
	(0.000000)	(0.000000)
$\alpha + \beta$	0.986927	0.986151
	Correlation parameters	
α	0.020594	0.014099
	(0.471957)	(0.576604)
β	0.789928	0.855400
	(0.003330)	(0.000013)
$\alpha + \beta$	0.810522	0.869499

Notes: The numbers in the table are coefficients and the figures in the brackets are p-values.

This article makes the assumption that the DCC-GARCH model (1,1)'s univariate conditional earnings of rock var or gold are substantial. DCC-GARCH may therefore be divided into halves, with a marginal model including the parameters shown below, where C_{M0}, C_{V0}, α_0 and β_0 are for univariate GARCH model:

$$C_{M0}, C_{V0}, \alpha_0, \beta_0, C_{MGold}, C_{VGold}, \alpha_{Gold}, \beta_{Gold}, C_{MCrude\text{-}oil}, C_{VCrude\text{-}oil}, \alpha_{Crude\text{-}oil}, \beta_{Crude\text{-}oil}, C_{MExchange}, C_{VExchange}, \alpha_{Exchange}, \beta_{Exchange} \quad (7)$$

As shown in Table 4, $\alpha_0 + \beta_0$, $\alpha_{Gold} + \beta_{Gold}$, $\alpha_{Crude\text{-}oil} + \beta_{Crude\text{-}oil}$ and $\alpha_{Exchange} + \beta_{Exchange}$ are all smaller than 1. It follows that the markets for gold, oil, and currency rates all shows persistent volatility. The values $\alpha + \beta$ are obtained among COMEX gold forward, NY Mercantile crude oil forward and USD CNY currency rate for two stock indices Shanghai Stock Exchange Index and China Industrial Index are respectively equal to 0.810522 and 0.869499. This means that the variation of the correlation over time is to return to its average standard among oil, gold and exchange rate markets.

Usually the coefficients of the DCC-GARCH (1,1) are almost statistically significant at level 1%, with few exceptions of the constant parameters of the mean and variance models. This is true even though there are several non-significant parameters for the connections among gold, currency rate, and the two stock indices.

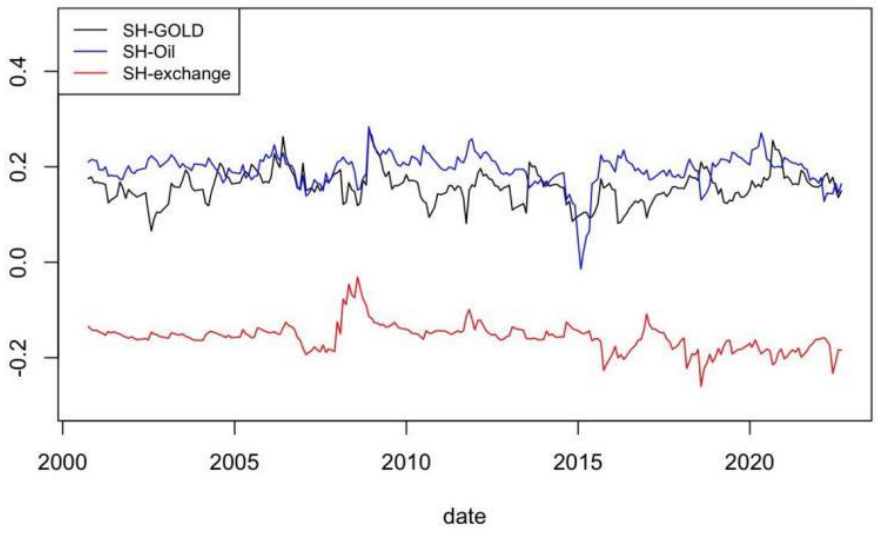


Fig 2. Dynamic correlation between Shanghai Stock Exchange Index and Gold, Crude oil and exchange rate

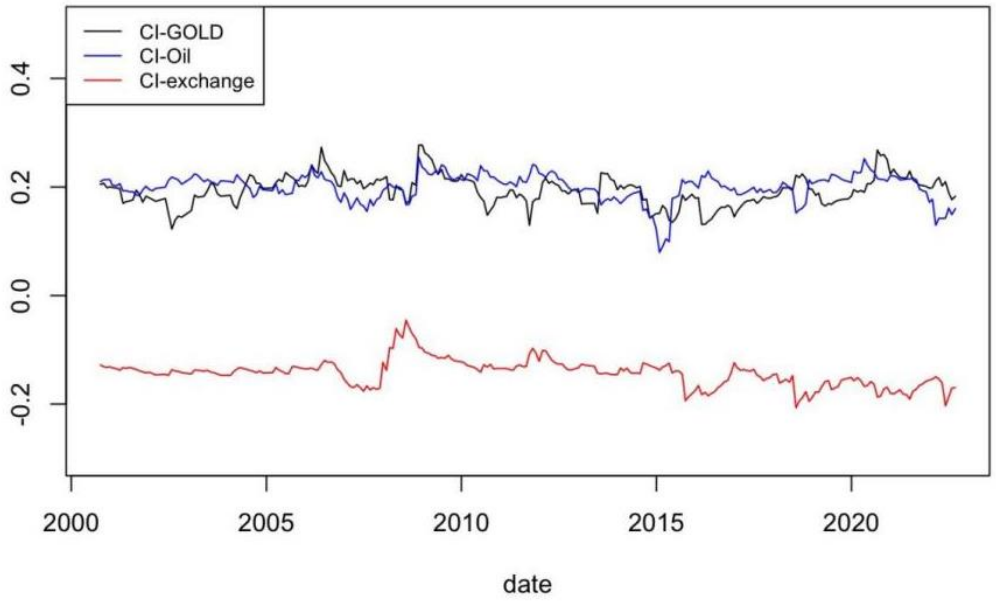


Fig 3. Dynamic correlation between China Industrial Index and Gold, Crude oil and exchange rate

Considering dynamic correlation, the influence of volatility fallouts is easily understood. Figure 2 and figure 3 depict the dynamic relationships between indexes, gold, rock var and currency rate with DCC-GARCH. The two stock indices and two commodities have a steady positive correlation in general, whereas the exchange rate and the two stock indexes have a negative correlation.

The goal of this research is to study volatility spillovers and dynamic correlations between Chinese equity market, represented by the Shanghai Stock Exchange Index and the China Industrial Index, and international gold and oil forward prices and USD CNY exchange rate. Using monthly data from 2000-01-03 to 2022-08-30, this paper examined the first order difference return of the prices, and the DCC-GARCH model indicates some important results.

First, two international commodities gold and crude oil are positively correlated with the two equity indexes, while the correlations between USD CNY currency rate and the two Chinese stock indices are negative. And the correlation between gold, oil and stock indexes are relatively low (around 0.2). Second, the returns of China's stock market have lower correlations during times of crisis, which is represented by the 2008 subprime crisis and the 2020 public health issue. The correlations between gold, oil and Chinese equity indexes rose sharply short after the financial crisis, because economies started to recover and commodity prices rose which led to the revival of the stock market. In contrast, the connection between exchange rate and China's stock market fell significantly during the financial crisis.

For fund managers and equities investors, these findings are crucial. Financial players should adjust their portfolios when exchange rate fluctuation expands, especially during times of turmoil, according to the negative correlations between Chinese equity markets and exchange rate market. The potential contribution of gold to portfolio diversification is shown by the poor connection between equity market's and gold market's volatility. When gold prices fluctuate, they have the most effects on the stock market because they are widely available and may be used as a hedge against inflation. Investors can respond to gold value fluctuations through taking this precious medal as an ideal alternative to stocks. Due to the strong rigidity of oil and its wide impact on China's economy, the continuous rise of oil prices will cause many industries, such as petrochemical and manufacturing, face increasing costs and reducing profits. And the performance of listed companies may be significantly affected. However, it is not realistic for Chinese investors to utilize the negative effect of oil to stock prices, because short selling is illegal in China. Also, if there is a positive neutralization in other aspects, the stock values of oil-related sectors may continue to rise. It is observed by economists that the USD CNY exchange rate are not necessarily related to Chinese stock market according to historical data. Overall, the low connection between Chinese stock markets and global

commodity markets suggests that China's financial industry has to be opened up more, so that it can better reflect the world economy's information and deeply participate in the international economy.

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