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Exploring the dynamic interdependence between gold and other financial markets

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Abstract

In this article, we explore the dynamic interdependence between gold and other financial markets by using an asymmetric dynamic conditional correlation model. The asymmetry in the dynamic conditional correlation is not recognized in many pair-wise assets and complimentary asymmetry is recognized only between gold and the euro/US dollar. In addition, we demonstrate that a structural break has occurred in the dynamic conditional correlation for the pair of gold and S&P500 index after the Lehman Brothers bankruptcy. Furthermore, we find evidence that although gold works as a safe haven in times of a stock market crash, its function is limited in the long run. We also show that the volatility index has a marginally significant explanatory power as the driving force behind the dynamic correlation between gold and the S&P500 index. This finding could be interpreted as a result of the flight to quality for gold through the recent financial turmoil.

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1. Introduction

This article attempts to uncover the dynamic interdependence between gold and other financial markets including the stock, bond, and foreign exchange markets over the last decade. For this purpose, we employ the asymmetric dynamic conditional correlation (A-DCC) model developed by Cappiello, Engle, and Sheppard (2006). It is important that we estimate, as precisely as possible, the correlation coefficient among the various assets because this decisively controls the effectiveness of the portfolio diversification.

It is often insisted that the gold market is separated from other traditional asset markets owing to its special characteristics[1]. The basis for such an insistence is partly the uncertain hypothesis that gold plays the role of a hedge or a safe haven for other traditional assets, especially stocks[2]. An analysis of this hypothesis holds important implications, not only for institutional investors but also for general investors and researchers.

While there are several studies on the correlation between the returns of stocks and bonds, research on the correlation between the stock and gold markets is scarce[3]. Thus, many issues regarding the interdependence of the gold market and other financial markets remain unsettled. In this article, we focus on the dynamic interdependence between the markets for gold, stocks, bonds, and exchange rates of the euro/US dollar. Since the first three variables are in US dollars, we conduct our analysis mainly from the perspective of investors in the US. A main contribution of this article is that the asymmetry in the dynamic conditional correlation estimation is taken into account. To our knowledge, this is the first study that introduces the asymmetry in a dynamic correlation analysis of the gold market. In addition, we expect our analysis to contribute towards effective portfolio diversification, asset allocation, and hedging strategies for investors.

Using the dynamic conditional correlation (DCC) analysis, Chong and Miffre (2009) investigate the conditional correlations between various commodity futures (i.e., agricultural, energy, livestock, and metal commodities) and stock and bond indexes. They find that precious metals (e.g., gold, silver, and copper) work as an effective risk diversifier in volatile stock market conditions. Along the same lines, Ciner, Gurdgiev, and Lucey (2010) estimate the DCC between gold, stocks, bonds, dollar, and oil in the US and UK. They show that the conditional correlation between gold and stocks is generally negative in the US and generally positive, except during the recent financial crisis (after the failure of Lehman Brothers), in the UK. In addition, by conducting a time variation analysis based on rolling regressions, they conclude that gold maintains its role as a hedge or a safe haven for most assets except oil[4].

Chiang, Jeon, and Li (2007) apply the DCC model to an analysis of financial contagion in the Asian crisis. They find the existence of a contagion effect (increasing correlation) in the early phase of the crisis and a herding behavior in its latter phase. Similarly, Naoui, Liouane, and Ibrahim (2010) apply the DCC model to an analysis of the financial contagion in the recent financial crisis caused by the subprime mortgage problem of 2005–2006. They examine the interdependence between the US and other developed and emerging countries and find that there exist two country groups, which have or do not have high correlation with

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1 For instance, such an insistence is seen in Lawrence (2003).

2 According to Baur and Lucey (2010), a hedge is an asset that is uncorrelated or negatively correlated with another asset or portfolio on average, while a safe haven is an asset that is uncorrelated or negatively correlated with another asset or portfolio mainly in times of market stress or turmoil. They analyze whether gold acts as a hedge or a safe haven asset in the US, the UK, and Germany.

3 For instance, refer to Baur and Lucey (2009), Cappiello, Engle, and Sheppard (2006) and Connolly, Stivers, and Sun (2005) for further research on the stock and bond markets.

4 Chan, Treepongkaruna, Brooks, and Gray (2011) offer the latest and most extensive examination of the linkages between the stock market and other asset markets covering the gold and housing markets.

the US[5].

Hyde, Bredin, and Nguyen (2008) investigate the stock market linkages between Asia-Pacific, the EU, and the US using an asymmetric generalized dynamic conditional correlation (AG-DCC) model. They confirm the significant asymmetry in correlations between these markets, thereby reinforcing the conventional view that correlations increase in response to negative news or shocks (e.g., financial turmoil). In turn, Yang, Zhou, and Leung (2010) apply the AG-DCC model to stock, bond, and securitized real estate markets. They find evidence of asymmetric volatilities and correlations in Commercial Mortgage-Backed Securities (CMBS) and Real Estate Investment Trusts (REITs). Furthermore, they present evidence of a structural break in the dynamic correlations during the recent financial crisis. Additionally, they regress the estimated dynamic correlations on several indicators reflecting macroeconomic conditions and demonstrate that the default spread and volatility index (VIX) have significant explanatory power for time-varying correlations[6]. Hammoudeh, Yuan, McAleer, and Thompson (2010) examine the correlation dependence and interdependence for four precious metals (gold, silver, platinum, and palladium) and the exchange rate (US dollar/euro) by employing the vector autoregressive moving average GARCH (VARMA-GARCH) model and DCC model. Their analysis suggests that gold is the safest haven against the US dollar[7].

As seen from the discussion above, existing literature with the DCC model mainly analyzes the cross-border dynamics of correlation in the stock and bond markets. Thus, a study that analyzes the correlation across financial markets while covering the gold market is rare. This article is an attempt to bridge this gap.

The rest of the article is organized as follows. In the next section, we briefly summarize the outline of the A-DCC model proposed Cappiello, Engle, and Sheppard (2006). We present the data used for our analysis and the descriptive statistics in section 3. Section 4 is devoted to our empirical results. Section 5 presents the conclusions.

2. Econometric method: Outline of the A-DCC model

In this section, we briefly summarize the estimation procedure of the A-DCC model developed by Cappiello, Engle, and Sheppard (2006)[8]. The procedure consists of three steps. In the first step, univariate volatility models, typically GARCH models, are estimated. In the second step, we standardize each residual by its standard deviation. In the final step, we estimate the dynamic conditional correlation model with conditional asymmetry.

To start with, suppose that r_t is a $k \times 1$ vector of random variables, for instance, the rate of return on assets, with mean zero and covariance matrix H_t:

$$r_t|\Omega_{t-1} \backsim N(0, H_t), \tag{1}$$

5 For more discussions on financial contagion, see Forbes and Rigobon (2002) and Baur and Lucey (2009). See also Yiu, Ho, and Choi (2010).

6 See also Akar (2011), which applies the DCC model to the Turkish stock and gold markets and foreign exchange returns to demonstrate the structural break in the 2001 crisis. Further, Kuper and Lestano (2007) apply the DCC model to Thailand and Indonesia. Kearney and Poti (2006) examine the correlation dynamics in the European stock markets of Germany, France, Italy, Netherlands, and Spain. For more applications of the model to real estate markets, see Liow, Ho, Ibrahim, and Chen (2009).

7 Further, refer to Joy (2011) and Pukthuanthong and Roll (2011) for the latest research on the relation between gold and exchange rate.

8 Bauwens, Laurent, and Rombouts (2006) and Enders (2010) present instructive and comprehensive discussions on the dynamic conditional correlation model. For details of the model, refer to Engle (2002).

$$H_t = D_t R_t D_t, \tag{2}$$

where Ω_{t-1} is the information set at time $t-1$, D_t is a diagonal matrix of which the element is the conditional standard deviation (i.e., $\sqrt{h_{i,t}}$) obtained from estimating the univariate volatility models. R_t is a time-varying correlation matrix to describe the dynamics of correlation, which is assumed to be as follows:

$$R_t = Q_t^{*-1} Q_t Q_t^{*-1}, \tag{3}$$

where $Q_t = \sqrt{q_{ij,t}}$ is the conditional variance-covariance matrix between the standardized residuals and $Q_t^{*-1} = diag(1/\sqrt{q_{11,t}}, \cdots, 1/\sqrt{q_{kk,t}})$ is a diagonal matrix with a square root of the *i*-th diagonal element of Q_t at its *i*-th diagonal position. The standardized residuals are written as

$$z_t = D_t^{-1} \varepsilon_t. \tag{4}$$

Under the setups described above, the A-DCC(1,1) model is given by:

$$Q_t = (1 - a_1 - b_1)\bar{Q} - g_1 \bar{N} + a_1 \varepsilon_{t-1} \varepsilon'_{t-1} + g_1 n_{t-1} n'_{t-1} + b_1 Q_{t-1}, \tag{5}$$

where a_1, b_1 and g_1 are the parameters to be estimated and $\bar{Q} = E[\varepsilon_t \varepsilon'_t] = T^{-1} \sum_{t=1}^{T} \varepsilon_t \varepsilon'_t$ is the unconditional variance-covariance matrix. Also, $n_t = I \odot \varepsilon_t$, where I is a $k \times 1$ indicator function which takes on value 1 if $\varepsilon_t < 0$ and 0 otherwise while $\odot$ denotes the Hadamard product and $\bar{N} = E[n_t n'_t] = T^{-1} \sum_{t=1}^{T} n_t n'_t$.

The typical correlation estimator is represented as follows:

$$\rho_{ij,t} = \frac{q_{ij,t}}{\sqrt{q_{ii,t} q_{jj,t}}}, \qquad i,j = 1,2,\cdots,k. \tag{6}$$

3. Data and descriptive statistics

We construct the daily PM fixing of the London gold price in US dollars per troy ounce. The London gold fixing is the spot price of gold and is determined twice in a business day, at 10:30 AM and 3:00 PM[9]. The data are from the London Bullion Market Association (LBMA) homepage[10]. In case the PM fixing price is not available, we replace the data with the next day's opening AM fixing price. As noted in the beginning of this article, our analysis is mainly based on the perspective of the US investors. We obtain the S&P500 index and euro/US dollar exchange rate[11] from the Federal Reserve Bank of St. Louis homepage[12, 13]. We take the World Government Bond Index in US (WGBIUS) as a rate of return on bonds.

9 The determination process of gold fixing is described briefly in Capie, Mills, and Wood (2005).

10 Refer to http://www.lbma.org.uk/pages/index.cfm.

11 We also estimate the A-DCC between gold and the British Pound, Swiss Franc, and Japanese Yen and obtain qualitatively similar results to the A-DCC estimation between gold and the EUR/USD. Details of the empirical results are offered on request.

12 Refer to http://www.stlouisfed.org/.

13 The S&P500 index is the daily closing value. The euro/US dollar exchange rate series are daily noon buying rates in New York City for cable transfers payable in foreign currencies. Refer to http://www.stlouisfed.org/ in details.

The WGBIUS is provided by Citigroup Inc. and is globally accepted as a benchmark government bond index. We obtain the data from Fixed Income Direct, Citigroup Inc.

In this study, the sample period is from January 4, 2000, to July 29, 2011, and the number of observations is 2,876. Table I presents the descriptive statistics of our data set. For all data series, the natural logarithms are taken and each return series is calculated as follows: $r_t = \{ln(y_t) - ln\,(y_{t-1})\} \times 100$, where y_t is the gold price, S&P500 index, WGBIUS, or EUR/USD exchange rate. The mean gold and WGBIUS returns are positive (0.061 for gold and 0.024 for WGBIUS), while the remaining two series are negative (-0.004 for the S&P500 index and -0.012 for the EUR/USD exchange rate[14]). The S&P500 index is most volatile in these four variables (the standard deviation is 1.367). The standard deviation of gold returns is 1.155, whereas that for EUR/USD is about one-half of that of the S&P500 index (0.667). The WGBIUS has the minimum standard deviation (0.316). Skewness is negative for all return series. Kurtosis exhibits leptokurtic distribution, and clearly, as shown by the Jarque-Bera's test statistic and its *p*-value, the all-return series are not normal at the 1% significance level.

4. Empirical results and further analysis

4.1. The A-DCC estimation and interpretation

In the first step, we estimate a set of AR(k)-EGARCH(p, q) processes with generalized error distribution for all return series[15]:

$$r_t = a_0 + \sum_{i=1}^{k} a_i\, r_{t-i} + u_t, \qquad u_t|\Omega_{t-1} \backsim GED(\kappa), \tag{7}$$

$$ln(\sigma_t^2) = \omega + \sum_{i=1}^{p}(\,\alpha_i \left|\frac{u_{t-i}}{\sigma_{t-i}}\right| + \gamma_i \frac{u_{t-i}}{\sigma_{t-i}}) + \sum_{i=1}^{q} \beta_i\, ln(\sigma_{t-i}^2), \tag{8}$$

where r_t denotes gold, S&P500 index, WGBIUS, or EUR/USD returns and u_t is the error term with heteroskedasticity. κ is a positive parameter, which measures the skewness of distribution. We set the maximum lag order in the AR part as ten and consider (1,1), (1,2), (2,1), and (2,2) as the specifications for EGARCH part in the choice of the model. From among these specifications, we select the final model based on the Akaike information criterion (AIC) and the diagnostic test for autocorrelation of residuals. The estimation results of the AR-EGARCH model are given in Table II. According to Table II, β_1 is close to 1 for gold, WGBIUS, and EUR/USD ($\beta_1 + \beta_2$ for S&P500 index), implying the persistence of volatility.

Table III reports the estimation results of the A-DCC model. All parameters except for g_1 in the equations of gold, the S&P500 index, and the WGBIUS are statistically significant at the 5% level or better. The asymmetric term, g_1, is significant with a negative sign only for the pair of gold–EUR/USD. This result shows that there exists complementary asymmetry between gold and the EUR/USD; that is, gold and the EUR/USD tend to move in the same direction. On the contrary, there is no evidence to imply the existence of this asymmetry in the pairs of gold and S&P500 index or gold and WGBIUS. Therefore, in the long run, gold does not offer compensation for the losses caused by negative shocks in the stock, bond, or exchange markets.

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[14] The negative return for the EUR/USD exchange rate shows the appreciation of the euro against the US dollar.

[15] For the ARCH model and its extension, including the EGARCH model, refer to Bollerslev, Chou, and Kroner (1992) and Enders (2010). For details on the EGARCH model, refer to Nelson (1991).

The behavior of the coefficient estimate of the pair-wise dynamic conditional correlation is given in Panels A to C in Figure 1. First, Panel A illustrates the evolution of the dynamic conditional correlation between gold and the S&P500 index. The conditional correlation fluctuates in the range of 0.3 to about -0.3. Thus, we can confirm several sharp drops in the correlation. The first period corresponds to the bursting of the dot-com bubble and the occurrence of the terrorist attack (September 2001) in the US. We also observe that the correlation declines at the end of the sample (May 2010 and March 2011). These periods correspond to the upsurge of the economic recession concern which has been triggered by sovereign debt crisis in euro area, especially, credit rating lowering of Greece, Spain and Portugal by major credit rating agencies. Roughly, the gold and stock markets show almost no correlation throughout the sample period.

Next, Panel B displays the evolution of the dynamic conditional correlation between gold and the WGBIUS. It seems that the sample is divided into two different regime periods; that is, although the correlation was relatively volatile from 2000 to 2004, it became milder after 2005. We can confirm that the correlation increases with the burst of the dot-com bubble and the September 11 terrorist attacks.

Finally, Panel C illustrates the evolution of the dynamic conditional correlation between gold and the EUR/USD. The correlation is negative throughout the sample period. Thus, over the whole sample period, gold and the euro complement each other. This is a natural consequence of gold prices persistently increasing while the euro exhibits an appreciation trend against the US dollar throughout the analyzed period. The significance of g_1, previously confirmed, shows that the complementarity strengthens even more when negative shocks occur simultaneously in both markets.

4.2. Test of structural break and driving force of correlation

In this subsection, we extend the empirical results obtained in the previous section. Specifically, we estimate the following first order autoregressive (AR(1)) model including a dummy variable and exogenous variable:

$$\hat{\rho}_t = \alpha + \beta\hat{\rho}_{t-1} + \delta DUM_{crisis} + \xi X_{t-1} + \nu_t, \tag{9}$$

where $\hat{\rho}_t$ is the estimate of the dynamic conditional correlation, α and β are parameters to be estimated, and DUM_{crisis} is a dummy variable representing the current financial crisis. We define the crisis period as from September 15, 2008, to the end of sample; that is, the dummy variable takes a value of 1 after September 15, 2008, and 0 otherwise. This assumption is based on the fact that the bankruptcy of Lehman Brothers is a symbolic event embodying the current financial crisis. X_t represents the exogenous variable that drives the dynamics of the correlation. Similar to Yang, Zhou, and Leung (2010), we choose the VIX as an exogenous driving force of the conditional correlation. The VIX is a proxy for the uncertainty about future prospects[16].

Table IV reports the AR(1) results of the estimated DCC coefficients. R^2 shows that all equations fit quite well. According to these results, a structural break has occurred only in the conditional correlation of the pair of gold and S&P500 index. δ in the regression of the gold–S&P500 index correlation is positive and statistically significant, implying that the correlation of both returns increased after the failure of Lehman Brothers. A possible

16 The VIX data are from the Chicago Board Options Exchange (CBOE). Refer to http://www.cboe.com/.

explanation for this result is that gold prices increased persistently and independently of the stock market, whereas the S&P500 index also exhibited the recovery tendency even as it experienced some swings. In addition, for this result, we can infer that gold plays the role of a safe haven in times of a stock market crash, but its role is limited in the long run. Furthermore, the statistically significant negative sign of ξ implies that flight to quality for gold was caused by increased market uncertainty[17].

On the other hand, both δ and ξ are insignificant in their correlations for the pairs of WGBIUS and EUR/USD against gold. This means that these interdependencies remain unchanged by the current financial crisis, and we can confirm that their relationships are not influenced by changes in the uncertainty[18].

5. Conclusion

In this article, we explore the dynamic interdependence between the gold, stock, bond, and foreign exchange (the euro against the US dollar) markets by using the A-DCC model developed by Cappiello, Engle, and Sheppard (2006). We identify complimentary asymmetry in the dynamic conditional correlation between gold and the euro/US dollar only. In addition, we demonstrate that a structural break has occurred in the dynamic conditional correlation for the pair of gold and S&P500 index after the collapse of Lehman Brothers. Furthermore, we find some evidence that gold works as a safe haven in times of a stock market crash, but its function is limited in the long run. Besides, we show that the VIX has a significant explanatory power as the driving force behind the dynamic correlation between gold and the S&P500 index. This finding can be interpreted as a result of the flight to quality for gold through the recent financial turmoil.

[17] Additionally, although not reported in the table, if DUM_{crisis} is omitted, the VIX loses its explanatory power for correlation dynamics. Therefore, we can conclude that the role of uncertainty in predicting the correlation dynamics increased after the current financial crisis.

[18] However, as mentioned before, we can identify that the correlation between gold and WGBIUS fell after 2005. Thus, we do not discuss this movement.

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Table I: Descriptive statistics

	Gold (%)	S&P500 index (%)	WGBIUS (%)	EUR/USD (%)
Mean	0.061	-0.004	0.024	-0.012
Median	0.057	0.055	0.036	0.000
Std. Dev.	1.155	1.367	0.316	0.667
Maximum	7.706	10.424	1.944	3.003
Minimum	-7.852	-9.470	-1.942	-4.621
Skewness	-0.073	-0.172	-0.192	-0.119
Kurtosis	8.092	10.497	4.922	5.110
Jarque-Bera	3109.898	6749.025	460.101	540.465
p-value	0.000	0.000	0.000	0.000

Note: The *p*-value corresponds to the Jarque-Bera test statistic.

Table II: The estimation results of the AR-EGARCH model

Regression models

$$r_t = a_0 + \sum_{i=1}^{k} a_i \, r_{t-i} + u_t, \qquad u_t | \Omega_{t-1} \backsim GED(\kappa)$$

$$ln(\sigma_t^2) = \omega + \sum_{i=1}^{p} (\alpha_i \left| \frac{u_{t-i}}{\sigma_{t-i}} \right| + \gamma_i \frac{u_{t-i}}{\sigma_{t-i}}) + \sum_{i=1}^{q} \beta_i \, ln(\sigma_{t-i}^2)$$

	Gold		S&P500 index		WGBIUS		EUR/USD	
Parameter	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.
a_0	0.060***	0.015	0.034**	0.016	0.030***	0.005	-0.019*	0.011
a_1	-0.027	0.017	-0.068***	0.016	-0.012	0.018	-0.014	0.017
a_2	0.016	0.017	-0.044***	0.017	-0.067***	0.019		
a_3	-0.002	0.017						
a_4	0.007	0.017						
a_5	-0.010	0.017						
a_6	-0.032*	0.017						
a_7	0.021	0.016						
a_8	0.000	0.016						
a_9	0.039**	0.016						
ω	-0.072***	0.010	-0.060***	0.012	-0.069***	0.012	-0.069***	0.009
α_1	0.098***	0.014	-0.151***	0.042	0.074***	0.012	-0.076*	0.045
α_2			0.227***	0.050			0.159***	0.044
γ_1	0.040***	0.010	-0.243***	0.026	0.018***	0.006	0.080***	0.029
γ_2			0.184***	0.025			-0.072***	0.028
β_1	0.992***	0.003	1.434***	0.109	0.995***	0.002	0.994***	0.002
β_2			-0.443***	0.107				
Log-L	-4056.130		-4182.309		-568.619		-2718.801	
$Q(20)$	25.355		15.712		17.489		20.366	
p-value	0.188		0.734		0.621		0.435	
$Q^2(20)$	9.589		24.239		24.197		23.958	
p-value	0.975		0.232		0.234		0.244	

Notes: This table reports the AR-EGARCH estimation results based on Eqs. (7) and (8) for returns on gold, S&P500 index, WGBIUS, and EUR/USD. *, **, and *** indicate the statistical significance at the 10%, 5%, and 1% levels, respectively. $Q(20)$ and $Q^2(20)$ denote the Ljung-Box test statistic for no autocorrelation of standardized residuals and squared standardized residuals up to 20 lags, respectively.

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Table III: The estimation results of the A-DCC model

Regression model

$$Q_t = (1 - a_1 - b_1)\bar{Q} - g_1\bar{N} + a_1\varepsilon_{t-1}\varepsilon'_{t-1} + g_1 n_{t-1} n'_{t-1} + b_1 Q_{t-1}$$

	Parameter	Estimate	S.E.
Gold versus S&P500 index	a_1	0.014***	0.004
	b_1	0.975***	0.007
	g_1	0.000	0.002
Gold versus WGBIUS	a_1	0.017***	0.005
	b_1	0.959***	0.016
	g_1	0.002	0.005
Gold versus EUR/USD	a_1	0.019***	0.003
	b_1	0.970***	0.006
	g_1	-0.008**	0.003

Notes: This table reports the A-DCC estimation results based on Eq. (5). *, **, and *** indicate the statistical significance at the 10%, 5%, and 1% levels, respectively.

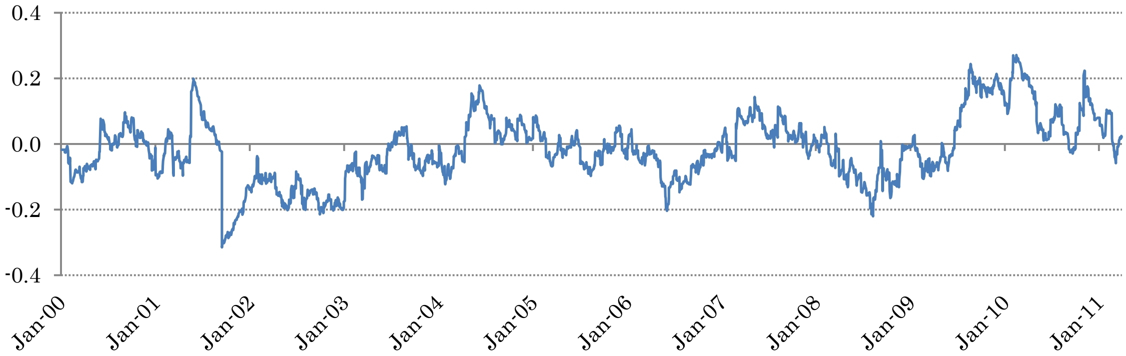
Table IV: The AR(1) estimation results of the estimated DCC coefficients

Regression model

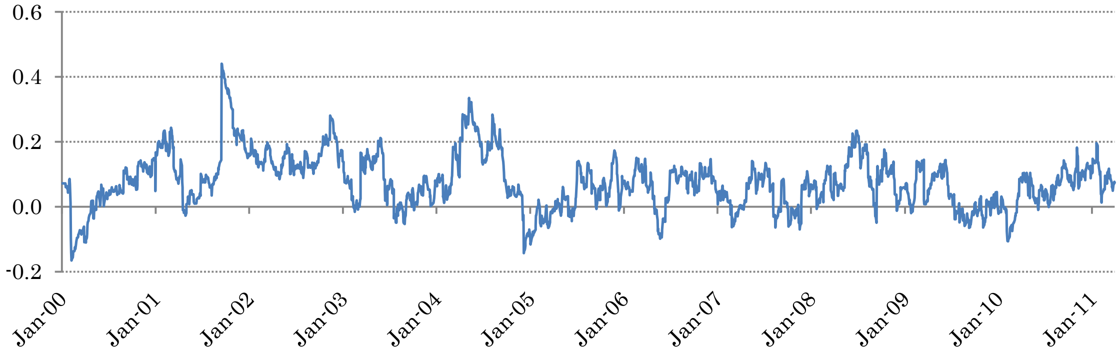
$$\hat{\rho}_t = \alpha + \beta\hat{\rho}_{t-1} + \delta DUM_{crisis} + \xi X_{t-1} + \nu_t$$

	Parameter	Estimate	S.E.
Gold versus S&P500 index			
	α	0.001*	0.001
	β	0.981***	0.004
	δ	0.003***	0.001
	ξ	-0.0001***	0.000
	R^2	0.976	
Gold versus WGBIUS			
	α	0.001	0.001
	β	0.975***	0.004
	δ	-0.001	0.001
	ξ	0.000	0.000
	R^2	0.953	
Gold versus EUR/USD			
	α	-0.006***	0.002
	β	0.986***	0.003
	δ	0.001	0.001
	ξ	0.000	0.000
	R^2	0.973	

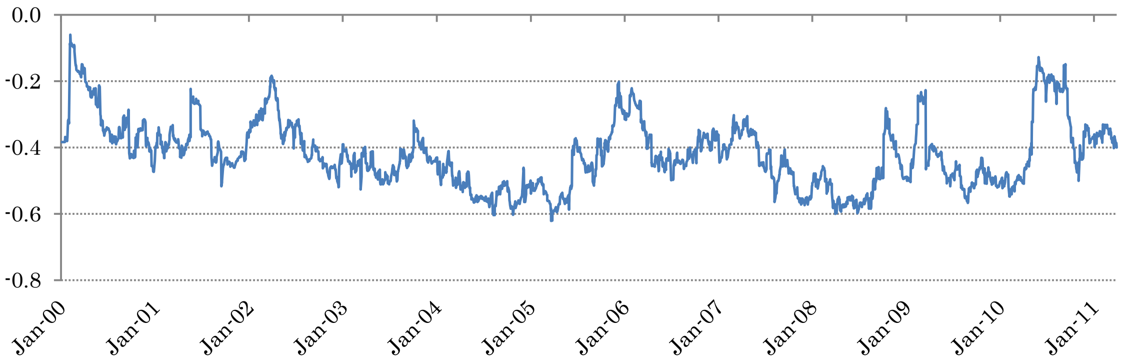
Notes: This table reports the AR(1) estimation results of DCC coefficients based on Eq. (9). The dummy variable takes a value of 1 after September 15, 2008, and 0 otherwise. *, **, and *** indicate the statistical significance at the 10%, 5%, and 1% levels, respectively.



Panel A: Gold versus S&P500 index



Panel B: Gold versus WGBIUS



Panel C: Gold versus EUR/USD

Figure 1: The evolution of the pair-wise dynamic conditional correlation

Notes: Panels A, B, and C illustrate the evolution of the pair-wise dynamic conditional correlation based on Eq. (5). The sample covers the period from January 4, 2000, to July 29, 2011.