Commodity Exchange-Traded Funds and Price Discovery

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Motivation

Commodity ETFs, a new wave of financialization?

Wall Street Journal (Nov 2016):

ETFs That Hold Commodities Could Cause Trouble

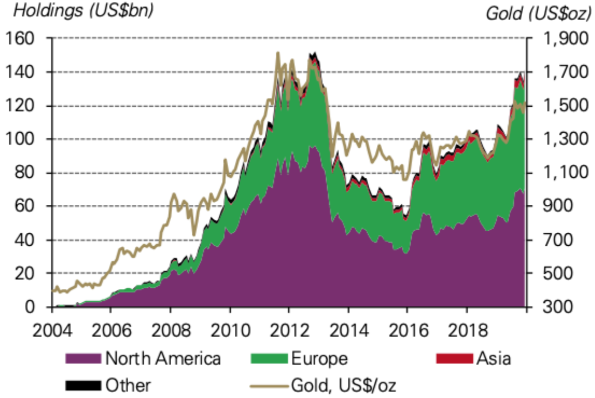
It is an issue for funds that hold the commodities, rather than merely track them

"**Could exchange-traded funds** that hold physical commodities **exacerbate price spikes or drops?** The potential is there, some experts say, and in fact **may have happened already**."

→ **Our empirical analysis: ETFs on precious metals, 2004-2020.**

The case of gold

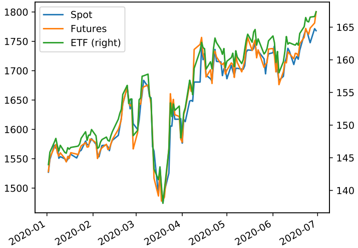
Chart 5: Gold-backed ETFs (and similar) holdings*

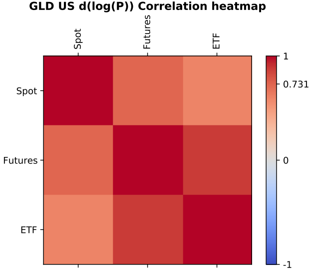


As of 31/12/2019

Source: Bloomberg, World Gold Council

Three gold prices: spot, futures, ETF (SPDR)





Price discovery in commodity markets

- When several markets are tightly connected, we wish to know where new information emerges AND how it impacts other markets
- "Shares" add up to 100%
- The methods are econometric and there are different schools
- We have focused on a method inspired by Garbade and Silber (1983)
- Permanent-Transitory decomposition of Gonzalo and Granger (1995)
  $\rightarrow$ Price discovery is where the price is closer to a common factor
- An alternative method has been proposed by Hasbrouck (1995)
  $\rightarrow$ Price discovery measures who moves first
- Both methods rely on a Vector Error Correcting Model (VECM)
- The VECM relies on a structural model

Research questions and contributions

- Spot vs. futures? Do futures markets really got the lion's share?
- With ETFs in the game, three markets interact

  $\longrightarrow$ Did ETFs take over the price discovery function?
- We extend Figuerola-Ferretti and Gonzalo (2010) to three markets:

  Spot, futures and one ETF
- Structural model partially identifiable with a VECM

  $\rightarrow$ Price discovery measures
- Applied to most precious metals with daily data:

  Gold, silver, platinum, palladium
- Two types of replications for the ETFs: physical and synthetic
- Increasing the dimension from 2 to 3 markets is not trivial

Theoretical model

The agents

- The economy is represented by three markets:
  - Spot: N_S participants, log-spot price s_t;
  - Futures: N_F participants, log-futures price f_t
  - ETF: N_E participants, log-ETF price p_t.
- Agent behaviour:
  - $E_{x,t}$ is the endowment of agent x at a date t.
  - $R_{x,t}$ is his reservation price, to hold $E_{x,t}$.
  - We assume linear demand functions for all markets:

$$\begin{cases} E_{i,t} - A\left(s_t - R_{i,t}\right) & \text{with } A > 0, \quad i = 1, \ldots, N_S \quad \text{for the spot} \\ E_{j,t} - A\left(f_t - R_{j,t}\right) & \text{with } A > 0, \quad j = 1, \ldots, N_F \quad \text{for the futures} \\ E_{k,t} - A\left(p_t - R_{k,t}\right) & \text{with } A > 0, \quad k = 1, \ldots, N_E \quad \text{for the ETF} \end{cases} \tag{1}$$

A: elasticity of the demand, assumed $=$ for all participants, in all markets
$R_{x,t}$: reservation price at which the agent is willing to hold $E_{x,t}$

Arbitrage operations: long-run relations

- Arbitrage between spot and futures markets:

$$H_F\left((\beta_2 f_t + \beta_3) - s_t\right) \quad \text{with } H_F > 0, \tag{2}$$

- Arbitrage between the ETF and its underlying asset (spot or futures):

$$H_E\left(p_t - s_t\right) \quad \text{with } H_E > 0, \quad \text{for a physically backed ETF} \tag{3}$$

where H_i represents the limits to arbitrage.

- Clearing (for a physically-backed ETF):

$$\begin{cases} \sum_{i=1}^{N_S} E_{i,t} = \sum_{i=1}^{N_S} \{E_{i,t} - A(s_t - R_{i,t})\} & +H_F\left((\beta_2 f_t + \beta_3) - s_t\right) \quad +H_E\left(p_t - s_t\right) \\ \sum_{j=1}^{N_F} E_{j,t} = \sum_{j=1}^{N_F} \{E_{j,t} - A(f_t - R_{j,t})\} & -H_F\left((\beta_2 f_t + \beta_3) - s_t\right) \\ \sum_{k=1}^{N_E} E_{k,t} = \sum_{k=1}^{N_E} \{E_{k,t} - A(p_t - R_{k,t})\} & \qquad -H_E\left(p_t - s_t\right) \end{cases} \tag{4}$$

Getting the VECM

- Assuming that the mean reservation price is the price of the previous date plus innovation, following Gonzalo and Granger (1995), we get:

$$\Delta X_t = \underset{(p \times r)}{\alpha} \; \underset{(r \times p)}{\beta'} \; X_{t-1} + C + v_t \tag{5}$$

where:

- X_t is the $p \times 1$ vector of the variables s_t, f_t and p_t,
- α is the adjustment matrix,
- β' is the cointegration matrix, expressing the long-run relationships between the variables,
- r is the number of cointegration relations,
- C is a constant, a $p \times 1$ vector,
- v_t is the $p \times 1$ vector of short-term errors.

Empirical tests

Markets under study

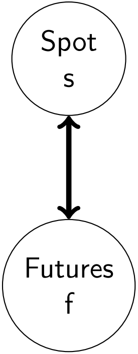
- Precious metals: gold, silver, palladium, platinum
- Spot prices: UK (LBMA) for physical, US (Forex) for synthetic
- Futures prices: CME group front-month
- ETF prices: the largest ETF per commodity and per replication

Commodity	Physical	Synthetic
Gold	SPDR Gold (GLD US)	Invesco DB Gold (DGL US)
Silver	iShares Silver (SLV US)	Invesco DB Silver (DBS US)
Palladium	Aberdeen Standard Physical Palladium (PALL US)	
Platinum	Aberdeen Standard Physical Platinum (PPLT US)	iPath Bloomberg Platinum Subindex Total Return (PGMFF US)

The cointegration relations

Table: Number r of cointegration relations (sign. 5 %)

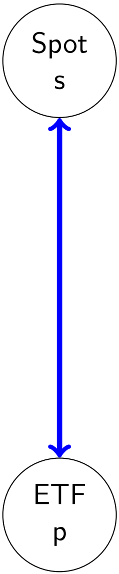
Commo.	ETF	Spot	Rep.	N.	$r(sf)$
Gold	GLDUS	UK	P.	3931	1
	DGLUS	US	S.	3514	1
Silver	SLVUS	UK	P.	3582	1
	DBSUS	US	S.	3515	1
Palladium	PALLUS	UK	P.	2626	1
Platinum	PPLTUS	UK	P.	2626	1
	PGMFFUS	US	S.	3129	1



The cointegration relations

Table: Number r of cointegration relations (sign. 5 %)

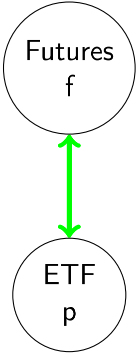
Commo.	**ETF**	**Spot**	**Rep.**	**N.**	$r(sf)$	$r(sp)$
Gold	GLDUS	UK	P.	3931	1	1
	DGLUS	US	S.	3514	1	
Silver	SLVUS	UK	P.	3582	1	1
	DBSUS	US	S.	3515	1	
Palladium	PALLUS	UK	P.	2626	1	0
Platinum	PPLTUS	UK	P.	2626	1	0
	PGMFFUS	US	S.	3129	1	



The cointegration relations

Table: Number r of cointegration relations (sign. 5 %)

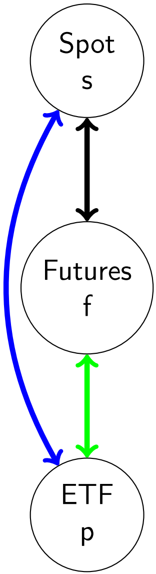
Commo.	ETF	Spot	Rep.	N.	$r(sf)$	$r(sp)$	$r(fp)$
Gold	GLDUS	UK	P.	3931	1	1	
	DGLUS	US	S.	3514	1		1
Silver	SLVUS	UK	P.	3582	1	1	
	DBSUS	US	S.	3515	1		0
Palladium	PALLUS	UK	P.	2626	1	0	
Platinum	PPLTUS	UK	P.	2626	1	0	
	PGMFFUS	US	S.	3129	1		0



The cointegration relations

Table: Number r of cointegration relations (sign. 5 %)

Commo.	ETF	Spot	Rep.	N.	$r(sf)$	$r(sp)$	$r(fp)$	$r(sfp)$
Gold	GLDUS	UK	P.	3931	1	1		2
	DGLUS	US	S.	3514	1		1	2
Silver	SLVUS	UK	P.	3582	1	1		2
	DBSUS	US	S.	3515	1		0	1
Palladium	PALLUS	UK	P.	2626	1	0		1
Platinum	PPLTUS	UK	P.	2626	1	0		1
	PGMFFUS	US	S.	3129	1		0	1



The pairwise relationships: full view

Table: Number r of cointegration relationships

Commo.	ETF	Rep.	N.	$r(sf)$	$r(sp)$	$r(fp)$	$r(sfp)$
Gold	GLD US	P.	3931	1	1	(1)	2
	DGL US	S.	3514	1	(1)	1	2
Silver	SLV US	P.	3582	1	1	(1)	2
	DBS US	S.	3515	1	(0)	0	1
Palladium	PALL US	P.	2626	1	0	(0)	1
Platinum	PPLT US	P.	2626	1	0	(0)	1
	PGMFF US	S.	3129	1	(0)	0	1

VECM: relations spot-futures-ETF

$$\Delta X_t = \alpha\beta' X_{t-1} + \sum_{i=1}^{k} \Gamma_i \Delta X_{t-i} + u_t$$

C	ETF	R	T	Adjustment matrix α	Cointegration matrix β'
G	GLD US	P	1 2 1	$\begin{pmatrix} -0.812^{***} & -0.005 \\ 0.042 & -0.009 \\ -0.100 & 0.009 \end{pmatrix}$	$\begin{pmatrix} 1 & -1.001 & 0 & 0.004 \\ 1 & 0 & -1.041 & -2.145 \end{pmatrix}$
	DGL US	S	2 2 1	$\begin{pmatrix} -0.160 & -0.003^{***} \\ 0.346^{***} & -0.001 \\ 0.244^{**} & -0.001 \end{pmatrix}$	$\begin{pmatrix} 1 & -1.002 & 0 & 0.013 \\ 0 & 1 & -0.490 & -5.507 \end{pmatrix}$

$$\beta' X_t \sim \begin{pmatrix} s_t & -f_t & 0 & 0 \\ s_t & 0 & -p_t & 0 \end{pmatrix}?$$

$$\sim \begin{pmatrix} -(\beta_2 f_t + \beta_3) + s_t \\ -(p_t - s_t) \end{pmatrix}? \text{ (}\sim\text{Arbitrage equations 2 and 3)}$$

Arbitrage hypothesis testing!

Price discovery metrics on gold, component shares (CS)

- Price Discovery metrics : Component Share (CS). We take the orthogonal of α and normalize it to 1.

Market	Commodity	Replication	N	Lag	T	CS
Spot (UK)					1	-3.84%
Futures					2	50.83%
GLD US	Gold	Physical	3931	4	1	**53.02%**
Spot (US)					2	-16.80%
Futures					2	-307.40%
DGL US	Gold	Synthetic	3514	4	1	**424.20%**
Spot (UK)					1	-34.95%
Futures					3	-73.92%
SLV US	Silver	Physical	3582	5	2	**208.87%**

- Same finding than Shrestha, Subramaninam & Thiyagarajan (2020), except that we are in a three dimensional system.

Component shares (CS) and Information shares (IS)

- CS: the price series with greater weight moves more closely with the common efficient price
- IS: measures the speed of adjustment, whatever the noise

	Market	N	T	CS	Mean IS
Gold (P)	Spot (UK)	3931	1	-0.04	0.21
	Futures	3931	2	0.51	0.39
	GLD US	3931	1	0.53	0.4
Gold (S)	Spot (US)	3514	2	-0.17	0.13
	Futures	3514	2	-3.07	0.18
	DGL US	3514	1	4.24	0.69
Silver (P)	Spot (UK)	3582	1	-0.35	0.07
	Futures	3582	3	-0.74	0.33
	SLV.US	3582	2	2.09	0.6

Component shares (CS) and Information shares (IS)

IS is a measure:

- sensitive to the order of the variables
- that is not unique when price innovations across markets are correlated

	Market	N	T	CS	IS						
					SFP	SPF	FSP	FPS	PSF	PFS	Mean IS
Gold (P)	Spot (UK)	3931	1	-0.04	0.63	0.63	0	0	0	0	0.21
	Futures	3931	2	0.51	0.33	0.03	0.96	0.96	0.03	0.03	0.39
	GLD US	3931	1	0.53	0.04	0.34	0.04	0.04	0.97	0.97	0.4
Gold (S)	Spot (US)	3514	2	-0.17	0.24	0.24	0.01	0	0.29	0	0.13
	Futures	3514	2	-3.07	0	0.11	0.23	0.23	0.11	0.39	0.18
	DGL US	3514	1	4.24	0.76	0.65	0.76	0.77	0.6	0.6	0.69
Silver (P)	Spot (UK)	3582	1	-0.35	0.18	0.18	0.01	0.02	0.03	0.02	0.07
	Futures	3582	3	-0.74	0.51	0.04	0.68	0.68	0.04	0.05	0.33
	SLV.US	3582	2	2.09	0.31	0.79	0.31	0.31	0.93	0.93	0.6

On going work and future developments

Ongoing work:

- Back to two dimensions
- Further investigating asynchronicity issues
- Analysis of other measures (Yang and Zivot, 2010, Putnins 2013)
- Dynamic analyses

Future developments:

- Going deeper into the gold and silver markets: how about the other ETFs?
- Platinum and Palladium: why is there no cointegration relation?
  - Characteristics of the funds?
  - Evolution of the funds during the period?
- High frequency data

Conclusion

- We develop an equilibrium model à la Figuerola-Ferretti and Gonzalo (2010) with a third market, an ETF, resulting in a VECM.
- We differentiate physical and synthetic replication (which results in different arbitrage operations) and derive price discovery measures. We show that they are the same, whatever the replication strategy.
- These metrics should help to identify the most influential ETFs and their impact.

References

Figuerola-Ferretti, Isabel and Jesús Gonzalo (2010). 'Modelling and Measuring Price Discovery in Commodity Markets'. *Journal of Econometrics* 158 (1), pp. 95–107. DOI: http://dx.doi.org/10.1016/j.jeconom.2010.03.013. URL: http://www.sciencedirect.com/science/article/pii/S0304407610000552.

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Theoretical developments

Spot and futures prices

- Equilibrium between spot and futures markets: from the storage theory (Kaldor, 1939), in log-prices

$$f_t = s_t + Cs_t - Cy_t \tag{6}$$

- Following Figuerola-Ferretti and Gonzalo (2010), we introduce a convenience yield that is a linear combination of spot and futures prices:

$$Cy_t = \gamma_1 s_t - \gamma_2 f_t \text{ ,with } \gamma_i \in (0,1)\,,\ i = 1,\ 2.$$

- We can rewrite Equation 6 as:

$$s_t = \beta_2 f_t + \beta_3 \tag{7}$$

with $\beta_2 = \frac{1-\gamma_2}{1-\gamma_1}$ and $\beta_3 = \frac{-Cs_t}{1-\gamma_1}$

Clearing for synthetic ETFs

$$
\begin{cases}
\sum_{i=1}^{N_S} E_{i,t} = & \sum_{i=1}^{N_S} \{E_{i,t} - A\left(s_t - R_{i,t}\right)\} \quad +H_F\left(\left(\beta_2 f_t + \beta_3\right) - s_t\right) \\
\sum_{j=1}^{N_F} E_{j,t} = & \sum_{j=1}^{N_F} \{E_{j,t} - A\left(f_t - R_{j,t}\right)\} \quad -H_F\left(\left(\beta_2 f_t + \beta_3\right) - s_t\right) \quad +H_E\left(p_t - f_t\right) \\
\sum_{k=1}^{N_E} E_{k,t} = & \sum_{k=1}^{N_E} \{E_{k,t} - A\left(p_t - R_{k,t}\right)\} \qquad -H_E\left(p_t - f_t\right)
\end{cases}
\tag{8}
$$

From the VECM to the Price Discovery (PD)

- We can retrieve arbitrage operations (spot-futures and ETF-underlying) in the adjustment matrix:

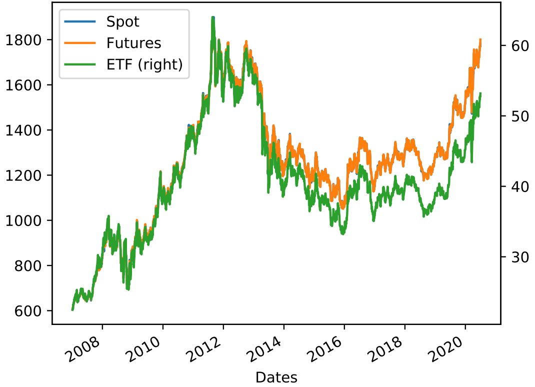
$$\gamma^P = \begin{pmatrix} N_S & 0 & 0 \\ 0 & N_F & 0 \\ 0 & 0 & N_E \end{pmatrix}^{-1} \begin{pmatrix} 1 & 1 \\ -1 & 0 \\ 0 & -1 \end{pmatrix} \qquad \gamma^S = \begin{pmatrix} N_S & 0 & 0 \\ 0 & N_F & 0 \\ 0 & 0 & N_E \end{pmatrix}^{-1} \begin{pmatrix} 1 & 0 \\ -1 & 1 \\ 0 & -1 \end{pmatrix}$$

- Using the Permanent-Transitory decomposition of the VECM (Gonzalo and Granger, 1995), the normalized orthogonal (null space) of γ gives the contribution of each price in Price Discovery (PD):

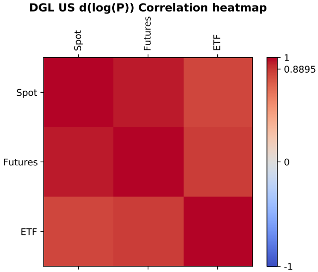
$$PD = \left[\frac{N_S}{N_S+N_F+N_E}, \quad \frac{N_F}{N_S+N_F+N_E}, \quad \frac{N_E}{N_S+N_F+N_E} \right] \tag{9}$$

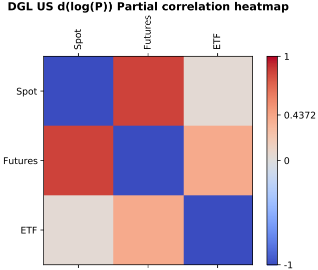
Time series and correlations of spot, futures and ETF prices

DGL US prices

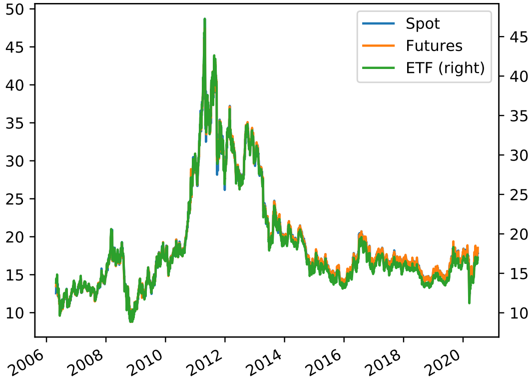


Tracking DBIQ Optimum Yield Gold Index Excess Return

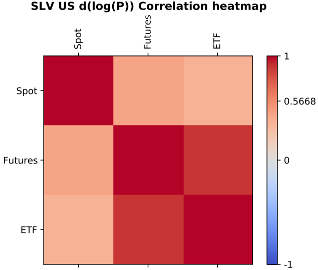


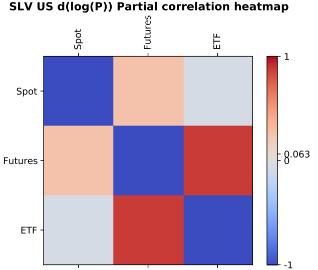


SLV US prices

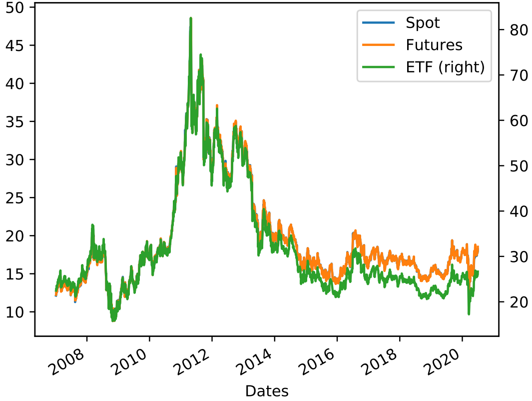


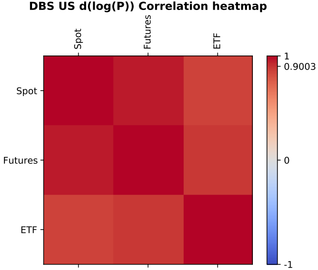
Tracking LBMA spot price (pm)

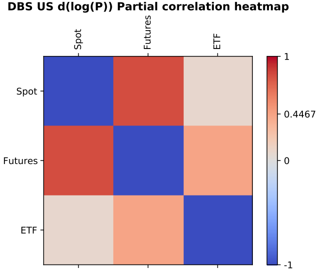




DBS US prices

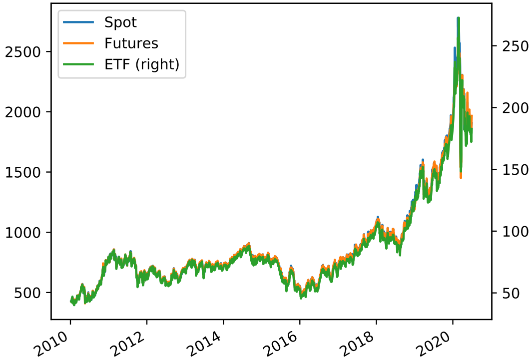




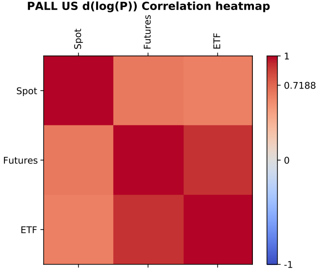


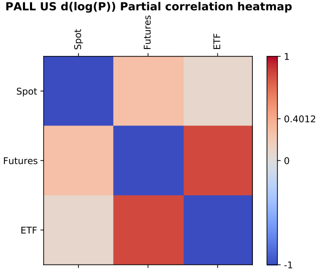
Tracking DBIQ Optimum Yield Silver Index Excess Return

PALL US prices

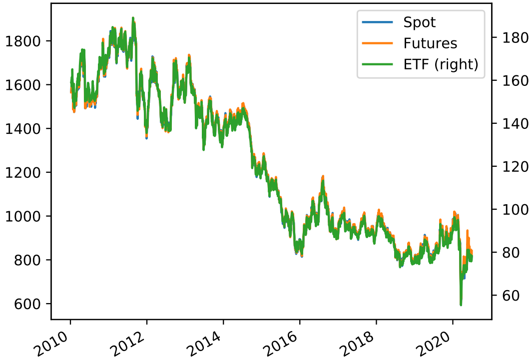


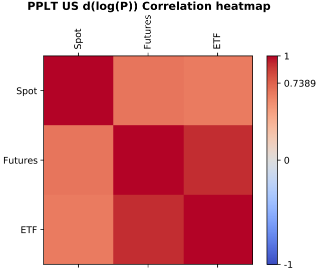
Tracking LBMA spot price (pm)

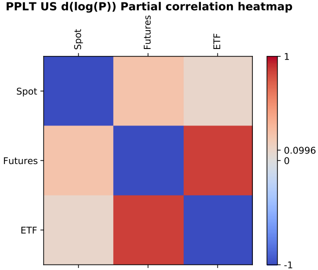




PPLT US prices

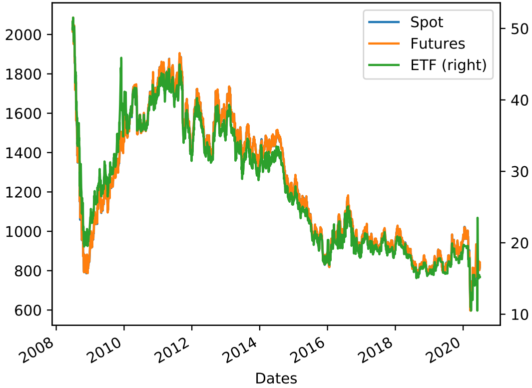




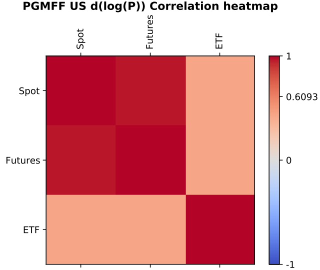


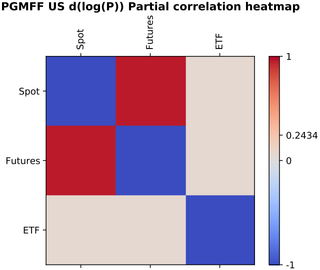
Tracking LBMA spot price (pm)

PGMFF US prices



Tracking Bloomberg Platinum SubIndex Total Return





Additional empirical results

The spot-futures-ETF relationships

$$\Delta X_t = \alpha\beta' X_{t-1} + \sum_{i=1}^{k} \Gamma_i \Delta X_{t-i} + u_t$$

C	ETF	R	T	Adjustment matrix α	Cointegration matrix β'
G	GLD US	P	$\begin{matrix}1\\2\\1\end{matrix}$	$\begin{pmatrix}-0.691^{***} & 0.009^{***}\\-0.170 & 0.001\\-0.348^{*} & 0.004\end{pmatrix}$	$\begin{pmatrix}1 & -0.996 & 0 & -0.040\\1 & 0 & -0.674 & -4.531\end{pmatrix}$
	DGL US	S	$\begin{matrix}2\\2\\1\end{matrix}$	$\begin{pmatrix}-0.146 & -0.003^{***}\\0.276 & -0.002^{***}\\-0.033 & 0.000\end{pmatrix}$	$\begin{pmatrix}1 & -1.001 & 0 & 0.004\\0 & 1 & -0.874 & -4.181\end{pmatrix}$
S	SLV US	P	$\begin{matrix}1\\3\\2\end{matrix}$	$\begin{pmatrix}-0.530^{***} & -0.008^{*}\\0.037 & -0.013^{**}\\-0.148 & -0.010\end{pmatrix}$	$\begin{pmatrix}1 & -1.000 & 0 & -0.001\\1 & 0 & -0.920 & -0.302\end{pmatrix}$
	DBS US	S	$\begin{matrix}2\\2\\1\end{matrix}$	$\begin{pmatrix}-0.068 & -0.003^{**}\\0.165 & -0.002\\-0.030 & 0.000\end{pmatrix}$	$\begin{pmatrix}1 & -1.001 & 0 & 0.002\\0 & 1 & -0.912 & -0.094\end{pmatrix}$
Pl	PALL US	P	$\begin{matrix}1\\3\\2\end{matrix}$	$\begin{pmatrix}-0.057 & -0.019^{**}\\0.173^{***} & -0.018\\0.120^{*} & -0.012\end{pmatrix}$	$\begin{pmatrix}1 & -1.015 & 0 & 0.096\\1 & 0 & -1.026 & -2.250\end{pmatrix}$
Pt	PPLT US	P	$\begin{matrix}1\\3\\2\end{matrix}$	$\begin{pmatrix}-0.194^{**} & -0.063^{***}\\-0.051 & -0.029\\-0.201^{*} & -0.033\end{pmatrix}$	$\begin{pmatrix}1 & -1.003 & 0 & 0.023\\1 & 0 & -0.944 & -2.618\end{pmatrix}$
	PGMFF US	S	$\begin{matrix}1\\3\\2\end{matrix}$	$\begin{pmatrix}0.092\\0.236\\-0.069\end{pmatrix}$	$\begin{pmatrix}1 & -0.998 & -0.004 & 0.003\end{pmatrix}$

Some hypothesis tests

Market	C.	R.	$\alpha H_{0,0}$	$\beta H_{0,0}$	Arb $H_{1,-1}$
Spot (EU)			0.00%	0.00%	
Futures			0.00%	0.00%	52.56%
GLD US	G	P	0.11%	65.02%	
constant			NA	55.93%	
Spot (US)			0.37%	0.00%	
Futures			0.31%	0.00%	12.32%
DGL US	G	S	99.70%	33.73%	
constant			NA	5.39%	
Spot (EU)			0.00%	0.00%	
Futures			25.14%	0.00%	24.77%
SLV US	S	P	26.31%	57.05%	
constant			NA	40.02%	
Spot (US)			9.33%	0.00%	
Futures			5.65%	0.00%	95.55%
DBS US	S	S	95.15%	37.22%	
constant			NA	89.84%	
Spot (EU)			17.60%	0.00%	
Futures			2.28%	0.00%	0.25%
PALL US	Pl	P	19.61%	64.82%	
constant			NA	59.53%	
Spot (EU)			1.17%	0.05%	
Futures			48.97%	0.08%	17.78%
PPLT US	Pt	P	60.01%	30.21%	
constant			NA	32.26%	