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## A study of first generation commodity indices: Indices based on financial diversification<sup>☆</sup>

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### Abstract

This study compares first generation, i.e. long-only passive, commodity indices based on financial diversification criteria, such as equal weight, equal risk contribution and global minimum variance, to the main first generation commodity indices used as vehicles for investment, namely the S&P GSCI (GSCI) and the BCOM. The GSCI and the BCOM are mainly computed according to the world individual commodity production. We find that commodity indices based on financial diversification offer better Sharpe ratios, lower volatilities, and lower correlation with bonds and equity. Finally, we provide evidence for a low-volatility anomaly of the commodity market.

*Keywords:* commodity indices, investment, diversification, commodity futures;  
*JEL:* G11, G12, G13.

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# A study of first generation commodity indices: Indices based on financial diversification

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## **Abstract**

This study compares first generation, i.e. long-only passive, commodity indices based on financial diversification criteria, such as equal weight, equal risk contribution and global minimum variance, to the main first generation commodity indices used as vehicles for investment, namely the S&P GSCI (GSCI) and the BCOM. The GSCI and the BCOM are mainly computed according to the world individual commodity production. We find that commodity indices based on financial diversification offer better Sharpe ratios, lower volatilities, and lower correlation with bonds and equity. Finally, we provide evidence for a low-volatility anomaly of the commodity market.

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## 1. Introduction

Standard and Poor’s Dow Jones (SP GS) has recently launched two commodity indices based on financial diversification: an Equal Weight Index in September 2010 (GSEW) and an Equal Risk Contribution Index in April 2013 (GSRW). The S&P GSCI (GSCI) and, to a lesser extent, the BCOM<sup>1</sup> are the two main indices used for investment and benchmark (Sanders and Irwin, 2013; Bianchi et al., 2015). The compositions of these two indices are mainly computed based on world production weights of individual commodities. The goal of our study is to compare the indices based on financial diversification to those based on the world commodity production. Our article thus belongs to the growing literature on commodity indices (Miffre, 2016; Daskalaki et al., 2017; Fernandez-Perez et al., 2018). We restrict our study to first generation commodity indices, *i.e.*, long passive investment in commodities.<sup>2</sup>

The introduction of the GSEW and GSRW reflects the increasing demand for investment in commodity indices in the 2000s (Basak and Pavlova, 2016), which has triggered an increase in the size of the commodity futures markets (Bhardwaj et al., 2015). This so-called financialization period of the commodity market (Tang and Xiong, 2012) has been accompanied by renewed interest in the study of investment strategies in commodity markets (*e.g.*, Miffre and Rallis, 2007; Fuertes et al., 2010; You and Daigler, 2010 and, recently, Fan et al., 2018; Fernandez-Perez et al., 2018).

While these studies have mainly focused on strategies based on signals and/ or long-short positions, the so-called second and third generations of commodity indices respectively, less attention has been paid to the first generation commodity indices, *i.e.*, long passive investments, in spite of their relevance to the commodity market. On the one hand, the majority of institutional investors have long-only mandates and were primary contributors to commodity financialization (Sanders and Irwin, 2013);<sup>3</sup> the bulk of the investment is carried out through the GSCI index (Basu and Miffre, 2013). On the other hand, the construction of first generation indices is still underdeveloped in the commodities market

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<sup>1</sup>Formerly the Dow Jones-UBS Commodity Index (DJ-UNSCI).

<sup>2</sup>Most studies of commodity indices have investigated second generation *i.e.*, active strategies, and/ or third generation, active strategies with possible short positions (*e.g.*, Bianchi et al., 2015; Cotter et al., 2017; Fuertes et al., 2015; Daskalaki et al., 2017). However, long investment in commodity indices, such as the GSCI and the BCOM, constitute an important part of commodity investment, as implied by Sanders and Irwin (2013). Studies that focus on diversification inside the commodity universe are scarce. A recent study of this topic was conducted by Bernardi et al. (2018); however, the strategies in Bernardi et al. (2018) are built on concepts such as minimum torsion and entropy. Because of their complexity, we rule them out as potential candidates for first generation commodity indices.

<sup>3</sup>Adams and Glück (2015): “Conservative estimates show that from 2000 to 2010 the number of commodity index traders, *i.e.* long-only investors such as pension funds and insurance companies, more than quadrupled.”

compared to the equity market; major commodity indices providers do not publish indices based on global minimum variance,<sup>4</sup> whereas equity indices suppliers such as FTSE Russell edit indices based on such objectives for various equity markets. In addition, recent studies outline the importance of minimum variance as an objective for investors (Bednarek and Patel, 2018).

Against this backdrop, we investigate whether it adds value to invest in these new first generation indices, computed according to financial diversification objectives, as explained in Demey et al. (2010). For this purpose, we construct the three following commodity indices:<sup>5</sup> Equal Weight (EW), Equal Risk Contribution (ERC)<sup>6</sup> and Global Minimum Variance (GMV). The building of our own indices based on financial diversification enables robustness checks for the following reasons. The GSEW (GSRW) is backdated to only mid-January (mid-February) 1995, which is a relatively short period of time for the monthly analyses that are typical in such studies (De Miguel et al., 2009).<sup>7</sup> These two indices are not directly comparable to the GSCI and BCOM: the number of commodities in the GSEW (14) is small compared to the numbers in the GSCI (24) and the BCOM (22),<sup>8</sup> and the risk contributions of the GSRW are the risk contributions of the sector subindices of the GSCI, not the risk contribution of individual commodities. For additional robustness checks, we include the light energy version of the GSCI: the GSLE.

We compare the Sharpe ratios, volatilities and correlations with the S&P 500 and the U.S. Treasury 10-year bond (hereafter T10YR) in our set of first generation indices. We conduct our study for the periods for which all the indices are available, beginning in March 1995. We find that the indices based on financial diversification offer better Sharpe ratios,

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<sup>4</sup>Global Minimum Variance indices do exist in the form of Eexchange Traded Funds (ETF), as demonstrated by the introduction in 2016 of such an ETF by Direxion, an American mutual funds and Exchange Traded Funds provider.

<sup>5</sup>Demey et al. (2010) provide an additional diversification strategy: the most-diversified portfolio. However, this strategy requires the use of the Sharpe ratio. It is thus a directional strategy that qualifies for the second generation set of commodity indices. In addition, it is well known that the Sharpe ratio is hard to pin down, as opposed to the estimation of the variance-covariance matrix, *i.e.*, volatilities and correlations.

<sup>6</sup>The composition of Equal Weight is a long-standing issue in investment, as explained by De Miguel et al. (2009). The Equal Risk Contribution is a much more recent financial diversification objective, as explained by Maillard et al. (2010). The risk contribution of an individual asset in a portfolio is its contribution to the volatility of the portfolio; the mathematical details are given in section 2 of this article.

<sup>7</sup>We obtain EW, ERC and GMV data from August 1970 onward because the GSCI data began in January 1970; we need 150 returns from that point forward to compute the variance-covariance matrix. We end our study in August 2017.

<sup>8</sup>The GSCI and BCOM indices are not identical. The GSCI and BCOM comprise 24 and 22 individual commodities, respectively; 19 of these commodities are common to both indices. We do not see any reason to favour one particular universe of the two commodity indices. Therefore, we consider the union of the two commodity universes, and our commodity universe comprises 27 individual commodities at the end of our study period.

lower volatilities and lower correlations with equity and bonds. Our results are not affected by the various kinds of robustness checks: analyses with the periods covering the full range of the GSCI and the BCOM, since January 1970 and 1991, respectively; and sub-sample analysis breaking our studying period down into financial expansionary and recessionary cycles (Bessler and Wolff, 2015).

The remainder of the article is organized as follows. Section 2 gives a technical account how our commodity indices are built. Section 3 summarizes our results for the period starting in March 1995 (the backdating of the GSRW). Section 4 presents the robustness checks. Section 5 offers some concluding remarks.

## 2. The construction of the ERC, EW and GMV indices

Let us denote by  $\Omega_{nt}$  the time- $t$  variance-covariance matrix of commodity futures returns, where  $n$  stands for the number of commodities in the portfolio. We consider the individual commodities present in the GSCI and BCOM and build our indices backward by including these futures contracts when they are available in the futures market. The number of individual commodity futures contracts,  $n$ , ranges from 10 at the beginning of our study in August 1970 to 27 in August 2017.<sup>9</sup> The prices of the futures contracts were downloaded from the Bloomberg database. We estimate the variance-covariance matrix using historical moments with 150 past daily commodity futures returns.<sup>10</sup>

Let us denote by  $\pi_{nt}^{(GMV)}$  and  $\pi_{nt}^{(ERC)}$  the time- $t$   $n$ -dimensional portfolios of the GMV and ERC indices invested in the commodity futures markets. According to Demey et al. (2010), these portfolios are solutions to the following constrained optimization programs:

$$\begin{cases} \pi_{nt}^{(GMV)} = \underset{\pi_{nt}}{\operatorname{argmin}} \pi_{nt}' \Omega_{nt} \pi_{nt} \\ s.t. \pi_{nt}^{(GMV)'} \mathbf{1}_n = 1, \pi_{nt}^{(GMV)} \geq_n \mathbf{0}_n; \end{cases} \quad (1)$$

$$\begin{cases} \pi_{nt}^{(ERC)} = \underset{\pi_{nt}}{\operatorname{argmin}} \sum_{i,j} (RC_{it} - RC_{jt})^2 \\ s.t. \pi_{nt}^{(ERC)'} \mathbf{1}_n = 1, \pi_{nt}^{(ERC)} \geq_n \mathbf{0}_n, \end{cases} \quad (2)$$

where  $\mathbf{1}_n$  ( $\mathbf{0}_n$ ) is the  $n$ -dimensional vector of ones (zeros) and  $\geq_n$  is the  $n$ -dimensional component-wise inequality sign.  $RC_{it}$  denotes the marginal contribution to the risk of

<sup>9</sup>The list of futures contracts as of 2017 is given in the appendix.

<sup>10</sup>Equity indices, such as the FTSE Global Equal Risk Contribution Index and the FTSE Global Minimum Variance Index, rely on an estimation window of approximately 500 days. We believe that 150 returns is a good compromise between a reliable estimation and a past horizon too long to reflect the dynamics of the variance-covariance matrix. Given the important numbers of securities in their index, FTSE also relies on a PCA analysis to compute the variance-covariance matrix. Our number of commodities, 27, is sufficiently limited for us to not have to resort to this methodology.

the portfolio of the commodity futures contract  $i$ . It is proportional to the marginal contribution of the futures contract  $i$  to the volatility of the portfolio:  $RC_{it} \equiv \pi_{int} \partial \sigma(\pi_{nt}) / \partial \pi_{int}$ , where  $\pi_{int}$  is the weight of asset  $i$  in the portfolio  $\pi_{nt}$ . The Equally Weighted portfolio is given simply by  $\pi_{nt}^{(EW)} = (1/n)1_n$ . The ERC, EW and GMV indices then start on July 1970 and are normalized at that date to the value of 100. With obvious notations, the variation of an index  $I$  between two trading dates is computed as follows:

$$I_{t+1}^{(J)} = I_t^{(J)} + I_t^{(J)} \sum_{i=1}^n \pi_{int}^{(J)} \left( \frac{F_{i(t+1)} - F_{it}}{F_{it}} \right), \quad J \in \{ERC, EW, GMV\}, \quad (3)$$

where  $F_{it}$  is the time  $t$  futures price of the commodity associated with the weight  $i$ . We focus on the Sharpe ratio of indices, their volatilities and their correlation with bonds and equity. As such, we do not need to collateralize our indices. The futures price,  $F_{it}$ , is defined as the nearest futures contracts; when a futures contract expires, the second nearest futures contract is used. We ensure that our strategies are attainable by an investor in the commodity futures markets. The composition of an index is changed only when a futures contract expires.

### 3. The empirical comparison of first generation commodity indices

This section compares all the first generation commodity indices: the BCOM, ERC, EW, GMV, GSCI, GSLE, GSEW, GSRW and GSLE. The period starts in March 1995 (the backdating of the GSRW) and includes 270 monthly returns until August 2017. We start with some summary statistics in Table 1. Table 1 demonstrates that the indices computed after the risks of the commodity futures contracts, namely, the GMV, ERC, EW, GSEW and GSRW, have higher Sharpe ratios than do the indices based on commodity world production, the BCOM, GSCI and even the GSLE. Table 1 shows that the Sharpe ratios of the commodity indices are lower than the Sharpe ratio of the S&P 500. This result is unusual in the literature, as shown by Bhardwaj et al. (2015), and is related to our short data set.<sup>11</sup> Table 1 also shows that the correlation between commodity indices and the S&P 500 (T10YR) is low and positive (negative). This low correlation with other asset classes is typical in the literature (Bessler and Wolff, 2015).

[INSERT TABLE 1 AROUND HERE]

Table 2 displays the difference in Sharpe ratios and tests its statistical significance according to the test of Memmel (2003), as in Basu and Miffre (2013). Table 2 presents some interesting features: the differences in Sharpe ratios between the GMV, ERC, EW,

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<sup>11</sup>Please refer to section 4 on robustness checks for the statistics over a longer period, which are consistent with the results in the existing literature.

GSEW and GSRW, on the one side, and the BCOM, GSCI and GSLE, on the other side, are all positive. Further, they are almost all statistically significant when the differences are computed with respect to the BCOM and GSLE.<sup>12</sup>

[INSERT TABLE 2 AROUND HERE]

[INSERT TABLE 3 AROUND HERE]

Table 3 compares the ratios of volatilities of the commodity indices and analyses their statistical significance using the Pitman-Morgan test.<sup>13</sup> First, Table 3 shows the (very) low volatility of the GMV. By construction, the volatility of the GMV is lower than that of other commodity indices. However, the theory does not indicate the extent to which this volatility is lower or statistically significant. All the ratios are highly statistically significant, and the ratio of the volatility of the GMV and the volatilities of the BCOM, GSCI and GSLE is, at most, 56.3%. Moreover, the volatility of the GMV is always less than 80% that of other indices. Second, Table 3 shows that the indices based on equal risk weighting perform second best in terms of volatility, after the GMV. The indices based on equal weighting perform third best.<sup>14</sup> Finally, the indices based on world commodity production perform very poorly in terms of volatility. The evidence supports a low volatility anomaly for the commodity markets: indices with low volatility tend to offer better Sharpe ratios than do indices with high volatility.

[INSERT TABLE 4 AROUND HERE]

[INSERT TABLE 5 AROUND HERE]

Table 4 (5) shows the differences in the correlations of the commodity indices with the S&P 500 (T10YR).<sup>15</sup> The statistical significance of these differences relies on the insight of Meng et al. (1992). Table 4 presents a striking result: the correlation of the GMV index with the S&P 500 is lower than that of any other commodity index. In addition, the difference is very significant, except for the correlation with the GSCI.<sup>16</sup> As far as the correlations of the commodity indices with the T10YR are concerned, the ERC and EW indices offer the best perspective: both have lower correlations with the T10YR than they have with other indices, with statistical significance outside the GSLE and GSCI indices. It is worth noting that their SP GS counterparts, namely the GSEW and GSRW, do not offer such results.

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<sup>12</sup>The exception is the difference computed between the GMV and GSLE.

<sup>13</sup>Del Brioa et al. (2018), for example show the importance of studying commodity volatility.

<sup>14</sup>The EW built on more commodities performs better in terms of volatility than the GSEW based on fewer commodities.

<sup>15</sup>The reader can refer to Narayana et al. (2017) for economic analysis between the commodity, bond and equity markets

<sup>16</sup>Interestingly, the GSCI is the second-best index in terms of its correlation with the S&P 500. The GSLE also displays a low, but not statistically significant, correlation with the S&P 500.

#### 4. Robustness checks

In this section, we extend our study to cover a longer backdated data set of the GSCI and GSLE. The five indices available for this period are then the ERC, EW, GMV, GSCI and GSLE. The study period starts in August 1970, with a dataset of 565 monthly returns. The results provided by this robustness check are in line with those of section 3, with the following minor differences. The Sharpe ratios of the ERC, EW and GMV are of the same order of magnitude as the S&P 500 (Bhardwaj et al., 2015), whereas those of the GSCI and GSLE are approximately half those of the Sharpe ratios. The positive statistical differences in the Sharpe ratios between the indices based on financial diversification and those based on the production of commodities are greatly improved. The correlations of the commodity indices with the S&P 500 are lower than are the correlations in the short period.

We also extend our analysis of correlation with equity to other stock markets such as Canada (S&P TSX), France (CAC 40), Germany (DAX 30), Japan (NIKKEI 225) and United-Kingdom (FTSE100).<sup>17</sup> We convert all indices in U.S. dollars and obtain similar results: the correlations of the GMV with the equity markets are lower than the correlations of other commodity indices with the same equity markets. The difference in correlations is also statistically significant - the significance is reduced for the NIKKEI 225, though.

We perform additional robustness checks. First, we test our results for the period covered by the backdating of the BCOM to January 1991. The results offered by this period are in line with those of section 3 and those offered by the period covered by the GSCI explained in the preceding paragraph. We also break our sample down into a financial expansionary (recessionary) subperiod (Belousova and Dorfleitner, 2012; Bessler and Wolff, 2015).<sup>18</sup> In sum, the results of our paper remain unchanged in expansionary and recessionary financial cycles. Finally, while a complete study of transaction costs is outside the scope of this short article, our indices based on financial risks should not produce abnormal transaction costs for the following reasons. The transaction costs in the commodity futures markets are low (Bianchi et al., 2015). Our results are valid for our own indices: the EW, ERC and GMV. The construction of these indices minimizes the transaction costs since a change in portfolio is only made when a futures contract expires and is then necessary.

#### 5. Conclusion

In 2010 and 2013, Standard and Poor's Dow Jones launched two first generation commodity indices based on equal weight and equal risk contribution (Demey et al., 2010).

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<sup>17</sup>We thank an anonymous referee for this suggestion.

<sup>18</sup>We follow the same methodology used in Bessler and Wolff (2015) to distinguish an expansionary period from a recessionary period: we combine monetary and stock market signals based on the 24-month moving averages of the S&P 500 and the federal funds target rate.

This article compares these indices based on financial diversification with the two indices mainly used for investment: the GSCI and BCOM. The GSCI and BCOM are based on the world production of commodities. We introduce another type of first generation index based on global minimum variance. Interestingly, such indices do not exist for the commodity markets, while they are largely edited in the equity market. Our study demonstrates that first generation commodity indices based on financial risk diversification offer better Sharpe ratios, lower volatilities and lower correlations with equity and bonds than do the two main indices used for investment based on commodity production. Our study thus encourages economic agents to invest in indices based on financial risk diversification and index providers to launch an index based on global minimum variance for the commodity market.

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Table 1: Summary statistics of monthly return for indices

	GMV	ERC	EW	BCOM	GSCI	GSEW	GSRW	GSLE	T10YR	S&P500
Mean (%)	3.104	4.476	5.379	0.654	5.878	6.447	5.128	3.753	2.535	8.573
Vol. (%)	8.771	10.988	13.930	15.584	21.727	15.786	11.324	15.722	8.682	14.692
Sharpe ratio	0.354	0.407	0.386	0.042	0.271	0.408	0.453	0.239	0.292	0.584
Corr. (S&P500)	0.190	0.371	0.382	0.318	0.253	0.355	0.311	0.320	-0.228	1.000
Corr. (T10YR)	-0.067	-0.157	-0.159	-0.099	-0.134	-0.120	-0.094	-0.135	1.000	-0.228
Obs.	270	270	270	270	270	270	270	270	270	270

Note: This table provides the summary statistics of monthly returns from March 1995 to August 2017.

Table 2: Comparison of Sharpe ratios

	GMV	ERC	EW	BCOM	GSCI	GSEW	GSRW	GSLE	T10YR	S&P500
GMV	-	-0.015	-0.008	0.089*	0.025	-0.014	-0.027	0.033	0.017	-0.061
		(-0.377)	(-0.155)	(1.528)	(0.382)	(-0.237)	(-0.598)	(0.588)	(0.196)	(-0.789)
ERC	0.015	-	0.006	0.103***	0.039	0.001	-0.012	0.048*	0.032	-0.047
	(0.377)		(0.365)	(3.355)	(0.877)	(0.023)	(-0.451)	(1.576)	(0.344)	(-0.683)
EW	0.008	-0.006	-	0.097***	0.033	-0.006	-0.019	0.041**	0.026	-0.053
	(0.155)	(-0.365)		(4.429)	(0.885)	(-0.253)	(-0.607)	(1.810)	(0.275)	(-0.783)
BCOM	-0.089	-0.103	-0.097	-	-0.064	-0.102	-0.116	-0.056	-0.071	-0.150
	(-1.528)	(-3.355)	(-4.429)		(-2.265)	(-4.907)	(-3.489)	(-2.827)	(-0.789)	(-2.101)
GSCI	-0.025	-0.039	-0.033	0.064**	-	-0.038	-0.052	0.008	-0.007	-0.086
	(-0.382)	(-0.877)	(-0.885)	(2.265)		(-1.241)	(-1.181)	(0.353)	(-0.079)	(-1.152)
GSEW	0.014	-0.001	0.006	0.102***	0.038	-	-0.013	0.047***	0.031	-0.048
	(0.237)	(-0.023)	(0.253)	(4.907)	(1.241)		(-0.419)	(2.517)	(0.342)	(-0.685)
GSRW	0.027	0.012	0.019	0.116***	0.052	0.013	-	0.060**	0.044	-0.034
	(0.598)	(0.451)	(0.607)	(3.489)	(1.181)	(0.419)		(2.106)	(0.492)	(-0.479)
GSLE	-0.033	-0.048	-0.041	0.056***	-0.008	-0.047	-0.060	-	-0.016	-0.094
	(-0.588)	(-1.576)	(-1.810)	(2.827)	(-0.353)	(-2.517)	(-2.106)		(-0.170)	(-1.324)
T10YR	-0.017	-0.032	-0.026	0.071	0.007	-0.031	-0.044	0.016	-	-0.079
	(-0.196)	(-0.344)	(-0.275)	(0.789)	(0.079)	(-0.342)	(-0.492)	(0.170)		(-0.824)
S&P500	0.061	0.047	0.053	0.150**	0.086	0.048	0.034	0.094*	0.079	-
	(0.789)	(0.683)	(0.783)	(2.101)	(1.152)	(0.685)	(0.479)	(1.324)	(0.824)	

Note: This table provides the difference of the row and the column indices' Sharpe ratio, with Z-value below. \*\*\*, \*\*, and \* indicate significance at the 1%, 5%, and 10% levels when the difference in the Sharpe ratios is positive. For example, the value of 0.097 with \*\*\* in the third row and fourth column means that the Sharpe ratio of EW is greater than that of BCOM and that this is significant at the 1% level. The sample period is March 1995 to August 2017.

Table 3: Comparison of volatilities

	GMV	ERC	EW	BCOM	GSCI	GSEW	GSRW	GSLE	T10YR	S&P500
GMV	-	0.798***	0.630***	0.563***	0.404***	0.556***	0.775***	0.558***	1.010	0.597***
	-	(6.225)	(10.169)	(11.879)	(18.896)	(12.170)	(6.166)	(12.378)	(0.167)	(8.987)
ERC	1.253***	-	0.789***	0.705***	0.506***	0.696***	0.970	0.699***	1.266***	0.748***
	(6.225)	-	(13.748)	(12.064)	(17.709)	(12.292)	(1.120)	(12.555)	(3.940)	(5.193)
EW	1.588***	1.268***	-	0.894***	0.641***	0.882***	1.230***	0.886***	1.604***	0.948
	(10.169)	(13.748)	-	(5.311)	(13.025)	(5.642)	(6.935)	(5.456)	(8.134)	(0.944)
BCOM	1.777***	1.418***	1.119***	-	0.717***	0.987	1.376***	0.991	1.795***	1.061
	(11.879)	(12.064)	(5.311)	-	(12.329)	(0.637)	(10.257)	(0.455)	(10.182)	(1.019)
GSCI	2.477***	1.977***	1.560***	1.394***	-	1.376***	1.919***	1.382***	2.502***	1.479***
	(18.896)	(17.709)	(13.025)	(12.329)	-	(10.847)	(17.122)	(14.233)	(17.369)	(6.791)
GSEW	1.800***	1.437***	1.133***	1.013	0.727***	-	1.394***	1.004	1.818***	1.074
	(12.170)	(12.292)	(5.642)	(0.637)	(10.847)	-	(11.143)	(0.222)	(10.456)	(1.259)
GSRW	1.291***	1.031	0.813***	0.727***	0.521***	0.717***	-	0.720***	1.304***	0.771***
	(6.166)	(1.120)	(6.935)	(10.257)	(17.122)	(11.143)	-	(12.109)	(4.419)	(4.536)
GSLE	1.792***	1.431***	1.129***	1.009	0.724***	0.996	1.388***	-	1.811***	1.070
	(12.378)	(12.555)	(5.456)	(0.455)	(14.233)	(0.222)	(12.109)	-	(10.397)	(1.172)
T10YR	0.990	0.790***	0.623***	0.557***	0.400***	0.550***	0.767***	0.552***	-	0.591***
	(0.167)	(3.940)	(8.134)	(10.182)	(17.369)	(10.456)	(4.419)	(10.397)	-	(9.257)
S&P500	1.675***	1.337***	1.055	0.943	0.676***	0.931	1.297***	0.934	1.692***	-
	(8.987)	(5.193)	(0.944)	(1.019)	(6.791)	(1.259)	(4.536)	(1.172)	(9.257)	-

Note: This table provides the ratio of row index to column index volatility, with t-value below. \*\*\*, \*\*, and \* indicate significance at the 1%, 5%, and 10% levels. For example, the ratio 0.798 with \*\*\* in the first row, second column means that the ratio of volatilities between GMV and ERC is different from 1 and that this is significant at the 1% level; in other words, the volatility of GMV is significantly lower than that of ERC. The sample period is March 1995 to August 2017.

Table 4: Comparison of coefficients of correlation with S&amp;P 500

	GMV	ERC	EW	BCOM	GSCI	GSEW	GSRW	GSLE
GMV	-	-0.181***	-0.192***	-0.128**	-0.064	-0.165***	-0.122***	-0.131***
	-	(-4.916)	(-3.878)	(-2.294)	(-1.013)	(-2.981)	(-2.797)	(-2.424)
ERC	0.181	-	-0.011	0.053	0.118	0.016	0.059	0.050
	(4.916)	-	(-0.692)	(1.852)	(2.787)	(0.541)	(2.290)	(1.783)
EW	0.192	0.011	-	0.064	0.129	0.027	0.071	0.061
	(3.878)	(0.692)	-	(3.190)	(3.684)	(1.283)	(2.428)	(2.904)
BCOM	0.128	-0.053**	-0.064***	-	0.065	-0.037**	0.006	-0.003
	(2.294)	(-1.852)	(-3.190)	-	(2.389)	(-1.934)	(0.206)	(-0.148)
GSCI	0.064	-0.118***	-0.129***	-0.065***	-	-0.102***	-0.058*	-0.067***
	(1.013)	(-2.787)	(-3.684)	(-2.389)	-	(-3.458)	(-1.392)	(-2.981)
GSEW	0.165	-0.016	-0.027*	0.037	0.102	-	0.044	0.035
	(2.981)	(-0.541)	(-1.283)	(1.934)	(3.458)	-	(1.479)	(1.984)
GSRW	0.122	-0.059**	-0.071***	-0.006	0.058	-0.044*	-	-0.009
	(2.797)	(-2.290)	(-2.428)	(-0.206)	(1.392)	(-1.479)	-	(-0.341)
GSLE	0.131	-0.050**	-0.061***	0.003	0.067	-0.035**	0.009	-
	(2.424)	(-1.783)	(-2.904)	(0.148)	(2.981)	(-1.984)	(0.341)	-

Note: This table provides the difference, between the row and column indices, of the mean of the coefficient of correlation with the S&P 500, with Z-value below. \*\*\*, \*\*, and \* indicate significance at the 1%, 5%, and 10% levels in a 1-tailed test. For example, the figure -0.181 with \*\*\* in the first row, second column means that the coefficient of correlation of GMV with the S&P 500 is lower than that of ERC with the S&P 500 and that this is significant at the 1% level. The sample period is March 1995 to August 2017.

Table 5: Comparison of coefficients of correlation with 10-year U.S. T-bond

	GMV	ERC	EW	BCOM	GSCI	GSEW	GSRW	GSLE
GMV	-	0.090	0.092	0.032	0.067	0.053	0.027	0.067
	-	(2.358)	(1.767)	(0.555)	(1.034)	(0.909)	(0.599)	(1.205)
ERC	-0.090***	-	0.001	-0.058**	-0.024	-0.038	-0.063**	-0.023
	(-2.358)	-	(0.075)	(-1.917)	(-0.536)	(-1.217)	(-2.307)	(-0.768)
EW	-0.092**	-0.001	-	-0.059***	-0.025	-0.039**	-0.065**	-0.024
	(-1.767)	(-0.075)	-	(-2.781)	(-0.682)	(-1.734)	(-2.091)	(-1.079)
BCOM	-0.032	0.058	0.059	-	0.034	0.021	-0.005	0.035
	(-0.555)	(1.917)	(2.781)	-	(1.228)	(1.006)	(-0.159)	(1.806)
GSCI	-0.067	0.024	0.025	-0.034	-	-0.014	-0.040	0.001
	(-1.034)	(0.536)	(0.682)	(-1.228)	-	(-0.453)	(-0.913)	(0.034)
GSEW	-0.053	0.038	0.039	-0.021	0.014	-	-0.026	0.015
	(-0.909)	(1.217)	(1.734)	(-1.006)	(0.453)	-	(-0.822)	(0.802)
GSRW	-0.027	0.063	0.065	0.005	0.040	0.026	-	0.040
	(-0.599)	(2.307)	(2.091)	(0.159)	(0.913)	(0.822)	-	(1.433)
GSLE	-0.067	0.023	0.024	-0.035**	-0.001	-0.015	-0.040*	-
	(-1.205)	(0.768)	(1.079)	(-1.806)	(-0.034)	(-0.802)	(-1.433)	-

Note: This table provides the mean of the difference between the row and columns indices of their coefficients of correlation with the 10-year U.S. T-bond, with the Z-value below. \*\*\*, \*\*, and \* indicate significance at the 1%, 5%, and 10% levels in a 1-tailed test. For example, the value of -0.090 with \*\*\* in the second row and first column means that the coefficient of correlation of ERC with the 10-year U.S. T-bond is lower than that of GMV with the 10-year U.S. T-bond and that this is significant at the 1% level. The sample period is March 1995 to August 2017.

## Appendix: Commodity contracts list

Commodity	Bloomberg Ticker	Futures Exchange	Sector	GSCI	BCOM	Start Date
WTI Crude Oil	CL	NYM / ICE	Energy	Yes	Yes	30-Mar-1983
Heating Oil	HO	NYM	Energy	Yes	Yes	01-Jul-1986
RBOB Gasoline	XB	NYM	Energy	Yes	Yes	03-Oct-2005
Brent Crude Oil	CO	ICE - UK	Energy	Yes	Yes	23-Jun-1988
Gasoil	QS	ICE - UK	Energy	Yes	No	03-Jul-1989
Natural Gas	NG	NYM / ICE	Energy	Yes	Yes	03-Apr-1990
Gold	GC	CMX	Precious metal	Yes	Yes	02-Jan-1975
Silver	SI	CMX	Precious metal	Yes	Yes	02-Jan-1975
Aluminum	LA	LME	Industrial metal	Yes	Yes	23-Jul-1997
Copper	LP	LME	Industrial metal	Yes	No	27-Jun-1997
Lead	LL	LME	Industrial metal	Yes	No	23-Jul-1997
Nickel	LN	LME	Industrial metal	Yes	Yes	23-Jul-1997
Zinc	LX	LME	Industrial metal	Yes	Yes	23-Jul-1997
Copper	HG	CME	Industrial metal	No	Yes	06-Dec-1988
Chicago Wheat	W	CBT	Grains	Yes	Yes	05-Jan-1970
Kansas Wheat	KW	KBT	Grains	Yes	Yes	05-Jan-1970
Corn	C	CBT	Grains	Yes	Yes	05-Jan-1970
Soybeans	S	CBT	Grains	Yes	Yes	05-Jan-1970
Soybean Oil	BO	CBT	Grains	No	Yes	05-Jan-1970
Soybean Meal	SM	CBT	Grains	No	Yes	05-Jan-1970
Coffee	KC	ICE - US	Soft	Yes	Yes	16-Aug-1972
Sugar	SB	ICE - US	Soft	Yes	Yes	05-Jan-1970
Cocoa	CC	ICE - US	Soft	Yes	No	05-Jan-1970
Cotton	CT	ICE - US	Soft	Yes	Yes	05-Jan-1970
Lean Hogs	LH	CME	Livestock	Yes	Yes	01-Apr-1986
Live Cattle	LC	CME	Livestock	Yes	Yes	05-Jan-1970
Feeder Cattle	FC	CME	Livestock	Yes	No	30-Nov-1971

Note: This table lists all the commodity futures contracts included in either the GSCI or BCOM indices. The column GSCI (BCOM) indicates whether the contract is included in the GSCI index (BCOM respectively).