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About the Research

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Commodities Futures Returns: Reconciling history with expectations

By: Leola Ross, Senior Research Analyst

EXECUTIVE SUMMARY

Collateralized commodities futures (CCFs), as defined by the Dow Jones–UBS Commodity Index, exhibited a historical annualized return of 3.12% over cash for the 1991 through 2009 sample period.[1] This exercise is to examine whether there is a logical reason for this return.

- Many past attempts to explain the returns of CCFs were centered on the idea that "someone gets paid" for taking on another party's risk. Examples of various and sundry attempts at explanation are summarized in Till and Eagleeye (2007, Chapter 3).
- Erb and Harvey (2006, 69–97) take a different approach. Rather than trying to identify "who gets paid" for taking risk, they demonstrate that rebalancing a collection of lowly correlated risky assets—even if those risky assets have no expected positive returns of their own—can produce a positive return for the investor.
- Building on the work of Erb and Harvey, I adapt their analysis to fit the structure of the Dow Jones–UBS Commodity Index. Whereas Erb and Harvey used the components of another index and made a variety of simplifying assumptions, including equal weights of the underlying risky assets, I have generalized their analysis so as to handle non-equal weights, differences in variance and differences in correlations across assets. This generalization is well documented in Booth and Fama (1992, 26–32), Bernstein and Wilkinson (1997) and Bouchey (2009).
- The Dow Jones–UBS Commodity Index is reconstituted annually and does not rebalance between reconstitutions. I show, however, that even with this annual reconstitution, the practices of assuming monthly rebalancing and, in general, using monthly data are both suitable to the index and preferable to working with

[1] In the case of collateralized commodities futures, the futures return is distinct from the collateral return. Collateral is often called "cash" and may be invested in 3-month Treasury Bills or some other highly liquid short-term pool. For the purposes of this paper "cash" is in reference to invested collateral.

annual data. The results of my monthly rebalanced data correlate quite highly to realized index returns.

- With the simplified assumptions of Erb and Harvey, we observe an implied return of 4.29–7.19% over cash. Employing the generalized method in their study, we observe an implied return in our study ranging from 3.32–8.00% over cash. The lower end of these returns comes from an analysis of monthly rebalanced data, and the upper end from an analysis of annually rebalanced data. The lower end of the range very closely resembles the 3.12% observed from historical data. I present some arguments as to why the assumption of monthly rebalancing most closely resembles historical returns.

Introduction

Assets such as equities and bonds generate income. Because they do so, they are said to have intrinsic value. While parties may debate endlessly what the value of these assets is now, should be, and will be, it is naturally accepted that their values should be identifiable. Commodities futures, by contrast, do not generate income by virtue of intrinsic value. Instead, they offer the investor exposure to the market prices of futures of various physical commodities. Whether or not these futures have an obvious “value” to offer is a subject of much debate. Over time, many have observed, participating in commodities futures has generated a positive return even without generating income. Why is this so? In this paper, I seek an explanation for historical commodity returns. I do not presume to offer an *expectation* of future returns, but simply an *explanation* of past returns. The primary elements of this explanation are correlation, volatility and rebalancing.

Individual commodities futures, such as wheat and oil, are well known for low correlations to each other and, as a group, to other asset classes such as equities and bonds. As well, the documented returns of commodities futures have shown a tendency for close to “equity-like” return levels. While understanding the reasons for low correlations is rather straightforward, professional and academic observers have long struggled to understand the reasons for these near-equity returns. Commodities futures do not offer a yield, nor do they represent ownership in some sort of going concern. In fact, the most typical commodities investment option, collateralized commodities futures (CCFs), do not even give the investor claims on commodities themselves, but rather a derived return from the price performance of spot prices, the “rolling” of futures contracts and the performance of the underlying collateral. Ultimately, there is no conventional wisdom regarding the source of returns to CCFs.[2]

Many researchers over the years have attributed positive commodities futures returns to various market explanations—e.g., insurance and producer hedging (Keynes 1930; Hicks 1939; Cootner 1960, 396–404, and 1967, 65–106); inventory, storage and carry (Kaldor 1939, 1–27; Working 1948, 1–28; Brennan 1958, 50–72; Telser 1958, 233–55); volatility-based and convenience-yield arguments (Litzenberger and Rabinowitz 1995, 1517–45; Milonas and Thomadakis 1997, 1–15).[3] However, for all the sample periods where these explanations make sense, there are also sample periods where they do not.

[2] The purpose of this research is to offer an explanation for historical returns for collateralized commodities futures ex the collateral return.

[3] See Till and Eagleeye (Chapter 3) for an overview of these arguments.

In 2006, Erb and Harvey offered an explanation for commodities futures ex of cash[4] return that is agnostic on yield, ownership of a going concern or an asset, inventory, producer hedging, or carry. Indeed, Erb and Harvey argued that a return expectation may be derived from a collection of lowly correlated risky assets that are held in a diversified portfolio and rebalanced regularly. Such a description fits commodities futures very well—in particular, it is well adapted to the diversified Dow Jones–UBS Commodity Index (DJ-UBS).

In the pages to follow, I discuss both the methodology used by Erb and Harvey and a more generalized form of that methodology, which has been documented by Bernstein and Wilkinson, Fernholz and Shay (1982, 615–24), and Booth and Fama, and expanded by Bouchey. The basic premise for both methodologies comes from a Taylor expansion of the growth process of a risk asset under a distribution that has some key properties of the normal distribution. Next I will describe the data used — a collection of excess returns from the various commodities futures comprising the DJ-UBS — and its shortcomings. Finally, I will argue a case for how to achieve the best statistical properties possible, within the constraints of available data, for use with this methodology.

The point of this exercise is not to calculate an expected ex of cash return for commodities futures, but rather to demonstrate that the return history we have observed is sensible, given the return patterns of individual commodities futures, their relationships with each other, and frequent rebalancing. Therefore, is it independent of an expected returns forecast. What is also of interest is the importance of using monthly data for explaining historical returns — despite the practice of annual rebalancing by the index provider, DJ-UBS. That monthly data explains annually rebalanced returns better than annual data does is an interesting anomaly that I explore in some detail below.

Methodology

The growth of a risky asset can be approximated by shortening a Taylor series expansion of the definition of geometric growth rates to the linear elements:

(1) $$g \approx \mu - \frac{\sigma^2}{2}$$ (see Bernstein and Wilkinson) (hereafter noted as B&W), and

(1a) $$\mu \approx g + \frac{\sigma^2}{2}$$,

where g denotes the geometric growth rate,[5] μ denotes the average arithmetic return and σ^2 denotes standard deviation. Such an approximation assumes that the growth of the asset is identically and independently distributed ("i.i.d."), that the data set has negligible higher moments (no material skewness or kurtosis), and that the investment has a modest arithmetic return. **N.B. While some of these are potentially strong assumptions for the commodities futures market, I will revisit them later and address the implications of relaxing them.**

[4] This return is called "excess return" in the commodities nomenclature; however, to avoid confusing ex of cash return with actively managed returns, I do not use the term "excess return" in this paper, but rather "ex of cash return."

[5] Christopherson, Cariño and Ferson (2009, pg. 23) highlight that g is a point estimate of median terminal wealth for a log-normal distribution. In the case of a log-normal distribution, the median is different from the mean.

It is important to note that the average arithmetic return is always higher than the median growth rate, as noted in Equation 1a. Moreover, Equation 1 implies that growth of an asset, relative to its average return, is penalized by approximately one-half its variance and highlights how volatility can be costly. By contrast, such volatility in the face of rebalancing and low correlations may be a benefit. For a collection of risky assets, each asset may be defined as:

(2) $$g_i \approx \mu_i - \frac{\sigma_i^2}{2} .$$

Following B&W and Bouchey, we can then redefine (1) as follows:

(3) $$g \approx \sum_i w_i g_i = \sum_i w_i \mu_i - \frac{1}{2} \sum_{i \neq j} w_i \sigma_{ij} w_j .$$

Replacing μ as defined by Equation 2 into the first term of Equation 3, we get:

(4) $$g \approx \sum_i w_i g_i + \frac{1}{2} \sum_i w_i \sigma_i^2 - \frac{1}{2} \sum_{i \neq j} w_i \sigma_{ij} w_j .$$

In other words, the growth rate of a portfolio of risky assets is approximately equal to:

the weighted average growth rate of the underlying assets,

+ ½ the weighted average component variance,

– ½ the weighted average portfolio variance.

Notice that the main driver of the growth rate may not be that the underlying risky assets grow, but rather that the volatile assets are lowly correlated and rebalanced; i.e., the relationship between the second and third terms may dominate the growth of the underlying components. **N.B. Ultimately, the terminal wealth of rebalanced risky assets can be materially different from the terminal wealth of risky assets that are not rebalanced.** In the pages to follow, I will demonstrate that in the case of collateralized commodities futures, the rebalanced CCFs will produce a greater terminal wealth and a higher average arithmetic return than they would have if they had not been rebalanced.

From Equation 4, we have an implied growth rate of a portfolio of risky assets; then, going back to Equation 1a, we can extrapolate the implied arithmetic average return of that same portfolio of risky assets.

The Erb and Harvey (2006) Variation

A notable paper utilizing the ideas above is Erb and Harvey (hereafter noted as E&H). However, E&H illustrate return potential by using equal weights, though their results may be robust to alternative weighting schemes. E&H also assume identical correlations and identical covariances among those risky assets. By employing these simplifying assumptions, E&H are able to reduce Equation 4 to suggest that a diversification return (or what we called, above, a growth rate) is

(5) $$g = DR = \frac{1}{2}\left(1 - \frac{1}{K}\right)\overline{\sigma}^2\left(1 - \overline{\rho}\right),$$

where

DR = diversification return,

K = the number of risky assets,

$\overline{\sigma}^2$ = the average variance and

$\overline{\rho}^2$ = the average correlation between risky assets.

I will demonstrate below both the B&W/Bouchey results and the E&H results as applied to historical data.

Data

The current commodities futures benchmark endorsed by Russell Investments is the DJ-UBS (see Paris, 2010). It is useful at this juncture to recall some of the features of this index, and of commodities futures investing, that are relevant to the analysis to follow.

- The DJ-UBS is weighted by liquidity and production. These weights are restricted such that no single commodity may be more than 15% of the index and no commodity sector may be more than 34% of the index. The resulting weights are not equal, but they do create a diversified portfolio (see Exhibit 1).
- The DJ-UBS comprises 19 underlying commodities futures (see Exhibit 1).
- The DJ-UBS reconstitutes annually and does not rebalance within the calendar year; the new weights are announced in January each year.[6]
- The DJ-UBS is not a commodities index in the sense that physical commodities are traded, but is, rather, a simple strategy for rolling commodities futures contracts. As such, the DJ-UBS itself has only the returns of rolled futures. In practice, however, invested capital sits in a collateral account such that it equals the notional value of the futures; hence, the term “collateralized commodities futures,” or CCF. The index purveyors have this collateral account in 30-day Treasury bills. Therefore, a 30-day T-bill return is explicit in a CCF total return calculation.
- The pure futures return of the DJ-UBS (and other CCF indexes) is referred to as the “excess return” and is the foundation for the analysis below.

[6] Reconstitution is a form of rebalancing. The difference between an annual rebalance (a reconstitution) and a monthly rebalance is that new weights are assigned each year for the annual reconstitution. A monthly rebalance would imply that the weights determined in January are struck each month throughout the year.

In Exhibit 1, I show the components of the DJ-UBS and two different weighting schemes. The second column is the announced weights for the year 2010. (These weights were recently announced.) The third column is the average of the announced weights for every year since 1999. Prior weights are not available.[7]

Exhibit 1 / Components and weights for DJ-UBS[8]

Commodity	Jan 2010 Weights	Average Weights 1999–2009
Aluminum	5.75%	6.53%
Coffee	2.56%	2.90%
Copper	7.64%	6.52%
Corn	7.09%	6.07%
Cotton	2.00%	2.96%
Crude Oil	14.34%	13.78%
Gold	9.12%	7.46%
Heating Oil	3.58%	4.49%
Lean Hogs	2.10%	3.49%
Live Cattle	3.55%	5.61%
Natural Gas	11.55%	10.17%
Nickel	2.37%	2.38%
RBOB Gasoline	3.53%	4.42%
Silver	3.29%	2.80%
Soybean Oil	3.00%	2.44%
Soybeans	7.91%	8.15%
Sugar	2.89%	2.66%
Wheat	4.70%	4.72%
Zinc	3.02%	2.46%

Numbers may not add to 100% due to rounding

The Dow Jones–UBS Commodity Index launched in July 1998, and a back history of prices is available to January 1991 (reported at month end). Therefore, monthly returns for the index are available starting February 1991. Our data series starts in February 1991 and ends December 2009, providing 227 monthly observations, 75 quarterly data points (starting Q2 1991) and 19 annual observations (I have annualized the February through December returns from 1991 to create the 19th annual data point).

Summary of Data

Before illustrating the details of the methodology applied, let's review some historical DJ-UBS return and risk data. In Exhibit 2, I show the annualized arithmetic returns, geometric growth rate, variance and standard deviations for monthly, quarterly and annual data. As well, I include a "check" on the ability of the data to validate Equation 1 above—the number in the "Growth from Equation 1" row, below, is simply the realized arithmetic return less one-half the realized variance.

[7] In the analysis below, I assume 1999 announced weights for all pre-1999 data.

[8] The historical weights are moderately more diversified than the 2010 announced weights. The Herfindahl-Hirschman Index (HHI) for the average historical weights and the 2010 are 36 and 40, respectively. For comparison purposes, an equally weighted index with 19 components would produce an HHI of 28 and the June 2010 weights for the S&P Goldman Sachs Commodity Index produce an HHI of 72.

Exhibit 2 / Return history for DJ-UBS (All data is annualized)

	Monthly Data Feb. 1991–Dec. 2009	Quarterly Data Q2 1991–Q4 2009	Annual Data 1991–2009*
Arithmetic Returns	3.12%	3.34%	3.77%
Geometric Growth	2.07%	1.99%	2.04%
Variance	2.10%	2.57%	3.33%
Standard Deviation	14.48%	16.02%	18.24%
Growth from Equation 1	2.07%	2.05%	2.11%

*1991 is annualized utilizing February through December returns.

Several observations from Exhibit 2 are worth highlighting.

1. The entries in the “Geometric Growth” and “Growth from Equation 1” rows are slightly different. This difference results from the DJ-UBS trading methodology. Because portfolios are traded mid-month, the weights and monthly returns do not align.
2. The geometric growth rates vary by frequency, and this should not be true for samples from identical return series. However, the samples for the monthly, quarterly and annual data are slightly different from each other due to the February start of available returns.
3. The average arithmetic returns increase as frequency decreases. This is a direct result of trending in commodities markets.[9] This point will come back into our discussion several times.
4. The variance increases as data frequency decreases. This, again, is the result of trending in commodities markets. An i.i.d. sample would not show this monotonic relationship.

From the observations above, the reader will note that there is already some indication that using quarterly or annual data for this analysis may present some issues. Thus before going further, it is appropriate to reflect back on the properties of the DJ-UBS noted in the previous section and, in particular, to recall that the DJ-UBS is rebalanced annually. **N.B. I encourage the reader to keep the DJ-UBS annual rebalancing practice in mind as I present more detailed results. Ultimately, I will argue that working with monthly rebalanced returns data is sensible.**

Analysis

To implement Equation 4, I must make an assumption regarding the weights of the portfolio. Doing so is necessary because DJ-UBS publishes weights for its index only on an annual basis. Yet in practice, the weights are eased into the index from the 5th to the 9th business day of each month when DJ-UBS rolls its contracts. On each day of this period, 20% of the contracts are rolled, and thus the effective application of the weights is far more complex than anything annual data (or even monthly) can illustrate.[10] The weights for each commodity in the index as published annually are not accurate representations of actual weights at regular calendar dates, such as a beginning or end of year.

[9] Trending is a form of autocorrelation.

[10] See the DJ-UBS Handbook for details.

In light of the complexity of the index weighting, I demonstrate results by use of two weighting assumptions, which I show in Exhibit 1—the recently published 2010 weights, and the historical average of published weights from 1999 to 2009—as well as three rebalancing schemes (monthly, quarterly and annually). To reduce the complexity of the calculations, I apply these weights to the entire history of the DJ-UBS data, which includes both the index returns and the returns of the underlying commodities. Again, all returns are rolled futures contracts and ex of cash.

In Exhibit 3, I exhibit the application of Equation 4 and also of Equation 5. All variances are calculated with sample methodology, as are all covariances. All returns are stated in excess of cash. Implied growth is the *g* that solves Equation 4, where all other variables are calculated from the data.

Exhibit 3 / Application of Equation 4 and Equation 5 to historical DJ-UBS data (Monthly and quarterly growth rates [geometric returns] are annualized. Growth rates are weighted by 2010 DJ-UBS industry weights and DJ-UBS average historical weights.)

	Monthly Data Feb. 1991–Dec. 2009		Quarterly Data Q2 1991–Q4 2009		Annual Data 1991–2009*	
Weight Scheme	2010	Average	2010	Average	2010	Average
Equation 4—B&W						
Average Growth	–0.95%	–1.08%	–1.03%	–1.18%	–0.99%	–1.11%
½ Average Variance	4.51%	4.39%	5.09%	4.94%	9.37%	8.87%
½ Portfolio Variance	1.10%	1.04%	0.89%	0.90%	2.05%	1.99%
Implied Growth	2.46%	2.27%	3.17%	2.86%	6.34%	5.77%
Implied Returns†	3.51%	3.32%	4.45%	4.15%	8.00%	7.43%
Equation 5—E&H						
Implied Growth		3.25%		3.44%		5.53%
Implied Return		4.29%		4.72%		7.19%

*1991 is annualized utilizing February through December returns.
† ex of cash.

As in reviewing Exhibit 2, the reader will immediately notice several points in Exhibit 3:

1. The weighted average historical growth rate of the individual commodities futures in the DJ-UBS is negative, while the growth rate of the DJ-UBS itself (see Exhibit 2) is clearly positive. This is our first demonstration that, indeed, rebalancing risky assets with low correlations does create a diversification return. **N.B. In simpler language, a positive growth rate for individual commodities futures is not a necessary condition for a rebalanced portfolio of commodities futures to provide a positive growth rate**. This insight applies not just to commodities; it may be generalized to all liquid assets where regular rebalancing is possible and correlations are low.
2. When moving from monthly to quarterly to annual data analysis, the most dramatic change, regarding the terms in Equation 4, is in the variance. Indeed, the variance of annual return data is roughly double that of monthly data annualized. This difference in variance is the result of dramatic trending in two commodities futures—natural gas and nickel. The pattern is also observed in the intermediate quarterly data, though it does not appear to be an issue with

monthly data.[11] The result of these dramatically higher variances is a materially higher implied growth rate and implied return. However, these implied growth rates and returns are not observed in practice. The DJ-UBS growth rate is more closely aligned with that implied by monthly rebalancing, as is the average return.

3. The implied growth rate from the monthly data in Equation 4 most closely resembles the realized growth rate of the DJ-UBS (2.07%), but still overshoots a bit.
4. Similarly to Equation 4, the E&H (Equation 5) results exhibit implied growth rates and implied returns ex of cash, which are materially higher than for Equation 4 when periodicity is higher.

The B&W method vs. E&H

While the simplicity of the E&H formula is appealing, the implied growth rates that fall out of it are out of range from historically realized growth for all three periodicities. In examining the E&H equation and its implications, I find that the assumption of identical variances, covariances and correlations is largely immaterial. The material point from the E&H formula is that equal weighting is central. The DJ-UBS is highly diversified (as compared with other commodities futures indexes, such as the Standard and Poors Goldman Sachs Commodity Index (S&P GSCI)), but is not equally weighted.[12] The most material differences between realized growth and the E&H implied growth stems from the equal weighting assumption. Therefore, the more generalized B&W methodology is more appropriate to the DJ-UBS than is the E&H.

The Case for Using a Monthly Rebalancing Assumption

As noted above, the approximation illustrated in Equation 1 has implicitly assumed i.i.d. and immaterial higher moments. I promised to address these points in the context of commodities futures data. Moreover, I noted that while the DJ-UBS is (technically) reconstituted annually without intermediate rebalancing, an assumption of monthly rebalancing produces results more consistent with historical data. Since this evidence leads me to prefer assuming monthly rebalancing in the face of an un-rebalanced index, I will now devote some time to making a case for that assumption.

It is well accepted that commodities markets may trend for months at a time.[13] Rebalancing in the face of an upward-trending market results in lower returns—that is, until the trend reverses. A closer examination of individual commodities futures return series illustrates that trending may occur in commodities futures. This is most readily observed via the annualized volatilities of monthly and quarterly returns, along with the variances of annual returns as shown in Exhibit 4.

[11] Monthly data seems to be better behaved, with moments more reflective of normal distribution, than quarterly and annual data.

[12] See footnote 5.

[13] See Shen, Szakmary & Sharma (2007, 25–27), Erb & Harvey, Miffre & Rallis, Pirrong, Gorton et al., Schneeweis et al..

Exhibit 4 / Comparison of variances of returns by frequency

	Variances			Autocorrelation P-Values
	Annualized Monthly	Annualized Quarterly	Annual	Quarterly
DJ-UBS	2.10%	2.57%	3.33%	0.17
Aluminum	3.52%	4.20%	**6.91%**	**0.00**
Coffee	15.83%	21.12%	22.82%	0.42
Copper	6.80%	8.82%	**17.70%**	**0.04**
Corn	6.02%	7.42%	4.91%	0.73
Cotton	6.63%	4.78%	6.53%	**0.03**
Crude	9.79%	11.64%	**20.59%**	0.38
Gold	2.28%	1.34%	1.90%	0.49
Heating Oil	9.64%	10.69%	15.82%	0.48
Lean Hogs	6.18%	5.14%	5.99%	0.94
Live Cattle	1.82%	1.98%	1.47%	0.33
Natural Gas	25.05%	29.70%	**74.13%**	0.74
Nickel	11.81%	14.83%	**36.96%**	**0.07**
RBOB Gasoline	10.94%	11.79%	16.58%	0.30
Silver	7.09%	5.10%	4.29%	0.50
Soybean Oil	6.46%	5.11%	6.16%	0.82
Soybeans	5.62%	5.65%	6.09%	0.21
Sugar	8.94%	8.93%	10.80%	0.67
Wheat	6.53%	6.72%	6.66%	0.29
Zinc	6.08%	7.16%	**19.61%**	**0.00**

To identify trending in commodities markets, I test the existence of first-order autocorrelation in commodities futures returns. Trending may express itself through autocorrelation. In Exhibit 4, I show the p-value of the regression coefficient. A statistically significant regression coefficient is indicative of first-degree autocorrelation. It is typical of trending data that variances will increase as frequency decreases.

We can observe in Exhibit 4 that the autocorrelation of quarterly returns data closely aligns with the exacerbation of variances as frequency decreases. Nickel and zinc almost triple in volatility as frequency decreases from monthly to annually and are also exhibiting first-degree autocorrelations. Aluminum, also exhibiting first degree autocorrelation, almost doubles. With the exception of two cases, crude oil and natural gas, dramatic increases in variances are consistent with first-degree autocorrelation. Autocorrelation is a violation of the i.i.d. assumption behind Equation 1.

The exceptions of crude oil and natural gas are very curious. For natural gas (already a highly volatile commodity future), as periodicity is reduced to annual, the variances go from 25.05% to 74.13%. As well, crude oil variance doubles when moving from monthly to annual returns. These increases in variance are material, but they are not explained by first-degree autocorrelation. For these, the most volatile of commodities futures, we look more closely at the annual returns in Exhibit 5.

Exhibit 5 / Geometrically linked annual returns for DJ-UBS and high variance commodities futures.

Year	DJ UBS	Coffee	Copper	Crude	Heating Oil	Natural Gas	Nickel	Unleaded Gas	Zinc
1991	–6%	–23%	0%	4%	–7%	–26%	–18%	11%	0%
1992	0%	–18%	6%	3%	4%	49%	–21%	–5%	4%
1993	–4%	–25%	–23%	–34%	–31%	6%	–15%	–34%	–11%
1994	12%	**118%**	**71%**	25%	14%	–36%	60%	13%	4%
1995	9%	–44%	2%	22%	8%	–1%	–16%	29%	–20%
1996	17%	51%	–5%	**98%**	**70%**	47%	–23%	52%	–5%
1997	–8%	**115%**	–14%	–32%	–31%	–12%	–11%	–16%	9%
1998	**–31%**	–16%	–18%	–50%	–51%	–43%	–37%	–46%	–22%
1999	19%	–3%	20%	**111%**	**68%**	–1%	101%	**78**%	27%
2000	24%	–58%	–7%	33%	65%	**323%**	–8%	52%	–17%
2001	–22%	–47%	–26%	–25%	–34%	**–79%**	–13%	–19%	–30%
2002	24%	–1%	2%	55%	43%	37%	30%	49%	–11%
2003	23%	–13%	45%	33%	29%	26%	**136%**	33%	24%
2004	8%	34%	42%	47%	45%	–26%	–6%	24%	17%
2005	18%	–12%	56%	22%	32%	53%	–8%	36%	45%
2006	–3%	1%	45%	–17%	–26%	–72%	**167%**	–27%	**127%**
2007	11%	–6%	4%	40%	47%	–23%	–17%	46%	–43%
2008	**–37%**	–27%	–54%	–54%	–48%	–38%	–57%	–62%	–52%
2009	19%	10%	**130%**	4%	20%	–52%	55%	**74%**	**98%**
Variance	3%	23%	18%	21%	16%	74%	37%	17%	20%

In Exhibit 5 we find the annual returns (monthly returns geometrically linked) of the eight most volatile commodities futures, along with their variances in the bottom row. In each column, the two largest absolute returns are **bold**. Note that the largest absolute returns for the DJ-UBS are negative. By contrast, the majority of large individual commodities futures returns are positive. Moreover, while those boldface positive returns for individual commodities are often triple-digit, the highest return for the DJ-UBS is 24% in 2002.[14] Now let's drill down into the monthly returns of crude and natural gas in their most volatile years.

[14] It is also notable that in 1999, crude, heating oil, nickel and unleaded gas showed very extreme returns. These four components represented 27% of the DJ-UBS that year, but could not even move the return of the aggregate index past 20%. This observation, in and of itself, is an excellent example of the diversification of commodities futures within the index.

Exhibit 6 / Monthly returns for crude oil and natural gas in their two most volatile years

	Crude Oil		Natural Gas	
	1996	1999	2000	2001
January	–6.93%	4.59%	14.35%	–35.08%
February	9.86%	–4.95%	5.45%	–0.99%
March	14.69%	35.16%	6.28%	–4.90%
April	11.07%	9.29%	6.06%	–6.96%
May	–2.42%	–8.18%	37.93%	–17.86%
June	8.79%	14.44%	2.99%	–21.70%
July	1.59%	6.37%	–15.04%	3.91%
August	11.86%	7.45%	27.40%	–25.15%
September	12.30%	11.06%	7.15%	–17.20%
October	–1.51%	–10.46%	–13.58%	23.77%
November	4.68%	13.01%	45.42%	–21.21%
December	9.09%	6.65%	50.19%	–7.98%

While there is no apparent pattern in the returns, only a few extreme positives and negatives scattered throughout each year can make for some very extreme annual returns. Therefore, in the case of crude oil and natural gas, the reason for the dramatic increase in volatility is a more randomly occurring collection of outliers. When going from 227 monthly observations (where there are many data points to “smooth” a distribution) to 19 annual observations, we create extreme values that make the assumption of an i.i.d., normal distribution inappropriate. We will return to this point below.

Exhibit 7 / Comparison of realized and implied growth rates per Equation 1 and Equation 2. Sample period February 1991 through December 2009.

	Annual Monthly Growth		Annual Quarterly Growth		Annual Growth	
	Realized	Implied	Realized	Implied	Realized	Implied
DJ-UBS	2.07%	2.07%	1.99%	2.06%	2.04%	2.11%
Aluminum	–2.88%	–2.93%	–2.65%	–2.60%	–3.03%	–3.38%
Coffee	–6.68%	–7.38%	**–7.27%**	**–10.06%**	**–6.76%**	**–9.54%**
Copper	7.82%	7.57%	7.76%	7.72%	7.78%	5.68%
Corn	–9.98%	–10.44%	–10.06%	–10.50%	–9.98%	–10.22%
Cotton	–9.00%	–9.41%	–9.33%	–9.65%	–9.03%	–8.74%
Crude	6.21%	6.05%	6.12%	6.36%	**6.21%**	**4.77%**
Gold	2.23%	2.20%	2.43%	2.40%	2.18%	2.11%
Heating Oil	3.97%	3.86%	3.60%	3.90%	3.92%	3.49%
Lean Hogs	–11.56%	–12.17%	–11.98%	–12.47%	–11.56%	–11.43%
Live Cattle	–2.40%	–2.42%	–2.65%	–2.69%	–2.42%	–2.43%
Natural Gas	–13.76%	–14.95%	**–13.83%**	**–15.73%**	**–13.82%**	**–30.24%**
Nickel	3.84%	3.67%	3.56%	2.73%	**3.73%**	**–2.79%**
RBOB Gasoline	6.88%	6.73%	6.54%	6.91%	6.90%	6.83%
Silver	3.88%	3.80%	3.96%	3.86%	3.83%	3.56%
Soybean Oil	–2.09%	–2.11%	–1.93%	–1.91%	–2.19%	–2.40%
Soybeans	2.52%	2.50%	2.60%	2.56%	2.46%	1.96%
Sugar	4.28%	4.14%	4.27%	4.01%	4.33%	3.41%
Wheat	–7.97%	–8.29%	–8.27%	–8.80%	–7.80%	–8.03%

In Exhibit 7, we observe two very interesting points:

First, we note that when applying Equation 1 to the DJ-UBS, as noted above, monthly data has a zero basis point discrepancy, whereas we see a slight discrepancy going to quarterly and annual data. Indeed, these discrepancies are so small that we can appeal to the B&W argument that the approximation in Equation 1 is robust to minor deviations from the assumptions that higher moments are immaterial and that the returns are i.i.d.[15]

Second, we notice that the differences between realized and implied growth rates for individual commodities futures are also within the same order of magnitude for monthly rebalanced data. However, for quarterly and annual rebalanced data, we observe some material differences in magnitude for several commodities futures. In the case of the quarterly data, we see that coffee and, to a lesser extent, natural gas have implied growth rates that are higher than the realized growth rates. As well, for annual data, we observe material differences in magnitude for coffee, crude, natural gas and nickel. These are precisely the commodities futures for which we noted dramatic changes in variance as we reduced frequency from monthly to quarterly to annually. **Apparently, the trending of individual commodities futures represents a statistically meaningful violation of the assumptions necessary to approximate the Taylor series as in Equation 2.**

I suspect that the contrast between the first and second observation is central to the breakdown of our ability to apply the sequence of Equations 2–4 to trending data. Whereas the DJ-UBS itself does trend a small amount, the underlying components trend quite dramatically and render ineffectual our effort to use quarterly or annual data in the approximation.

Q: Given that the DJ-UBS rebalances annually, why is it more appropriate to use an assumption of monthly rebalancing to estimate growth rates?

A: Here are some facts and three conjectures:

First, the ability to use the approximation in Equation 2 (which is necessary for Equation 4 to be appropriate) is compromised by severe assumption violations in quarterly and annually rebalanced returns. Monthly rebalanced data and index-level data suffer only from mild assumption violations.

Conjecture 1: Monthly data is, in some cases, a “de-trending” of the annual data, which allows us to demonstrate the diversification return effect illustrated by Equation 4.

Second, to some extent, annual rebalancing of the DJ-UBS is not fully accurate. As noted above, the DJ-UBS weights are published every January. They are then applied to February trading, which occurs prior to contract expiry mid-month. The contracts are rolled on the 5th to 9th business days of the month in 20% tranches. Because futures contracts converge to spot prices as they near expiry, there may be material differences between the weights implied by calendar-month returns and actual returns as of the date of trade. These differences will be exacerbated by some contracts being in backwardation and others being in contango. Therefore, building quarterly and annual weights off of monthly returns may not well replicate the weights of commodities relative to each other throughout the year—and, in particular, when trading takes place. In other words, we cannot, from monthly returns data, understand well how the weights of commodities evolve within an index throughout the year in a way that allows us to construct sensible quarterly and annual returns.

[15] For the DJ-UBS index, the skewness is modest for all three transformations of the data, but excess kurtosis of approximately 3 is apparent in both monthly and quarterly data.

To further illustrate the plausibility of a monthly rebalancing assumption, I calculated a weighted average of monthly commodity returns to estimate the DJ-UBS with the assumption of monthly rebalancing (i.e., holding the weights constant within a calendar year) and with the assumption of annual rebalancing. The returns weighted under the annual rebalancing assumption were correlated to the DJ-UBS returns at 0.98. The returns weighted under the monthly rebalancing assumption were correlated to the DJ-UBS returns at 0.99. These are both very high correlations. I do not argue that the 0.98 correlation between the weighted average of commodities futures returns achieved by an assumption of annual rebalancing negates the validity of an annual rebalancing practice or assumption. However, I do argue that the very similar 0.99 correlation of weighted average returns, assuming monthly rebalancing, is sufficiently high that such an assumption is sensible for making calculations within the context of the above methodology.[16]

Conjecture 2: The DJ-UBS behaves like a monthly rebalanced index; therefore, it is sensible to use monthly rebalanced data to estimate growth rates.

Finally, let's consider another aspect of statistical analysis that was noted in reference to Exhibit 6. Our DJ-UBS index and component data dates only from February 1991. By annualizing the 11 available months of 1991, we have 19 observations of annual data. By using monthly data, we have 227 observations. Having 227 observations provides more opportunities for a sample period to exhibit the traits of a normal distribution. However, producing only 19 observations is quite likely to result in the exhibition of non-normal traits. If we accept that a monthly rebalancing assumption is valid due to its potential de-trending of the data and/or its high correlation to actual returns, then we would favor monthly data as well on its ability to improve the variance of the sample distribution.

Conjecture 3: The assumption of monthly rebalancing improves the statistical properties of the sample by increasing *N* from 19 to 227.

Conclusion and Recommendation

Rebalancing diversified and lowly correlated risky assets can generate a growth rate that is greater than the growth rates of its underlying risky assets. Under certain assumptions, such an ability to derive growth from rebalancing is formulaic and reliable. This formula is robust to mild violations of those assumptions, but not to severe violations. In applying this truism to the DJ-UBS, I find that monthly rebalanced data is more consistent with the necessary assumptions than is quarterly or annually rebalanced data. Moreover, weighted monthly returns of underlying commodities futures, under the assumption of rebalanced data, have a high correlation to actual index returns. Finally, monthly returns give a more robust sample size and thereby improve the variance around forward-looking estimates. As well, the use of the more flexible B&W method is more appropriate to the DJ-UBS than is the simplified E&H method, due to the unequal weights of the DJ-UBS. Ultimately, this technology explains well how an index of dissimilar assets outperforms the sum of its parts.

[16] All correlation analysis is from 1999 through 2009. The shorter sample period is appropriate, because weights prior to 1999 are not available.

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Standard Deviation: A statistical measure of the degree to which an individual value in a probability distribution tends to vary from the mean of the distribution. The greater the degree of dispersion, the greater the risk.

Realized Growth: Compound annual growth rate for the number of full fiscal years shown.

Implied Growth: The implied growth rate is the value determined by inserting calculated values into the right hand side of Equation 4.

Autocorrelation: In statistics, the autocorrelation of a random process describes the correlation between values of the process at different points in time, as a function of the two times or of the time difference. Let X be some repeatable process, and i be some point in time after the start of that process. (i may be an integer for a discrete-time process or a real number for a continuous-time process.) Then Xi is the value (or realization) produced by a given run of the process at time i. Suppose that the process is further known to have defined values for mean μi and variance σi2 for all times i. Then the definition of the autocorrelation between any two time s and t is

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