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# Building a Better Commodities Portfolio

## Executive Summary

Institutional investment in commodities has been rising steadily for the past decade, in large part due to their portfolio diversification properties. The majority of assets invested in commodities are based on first-generation passive indices, the S&P GSCI and the Dow Jones-UBS Commodity Index, which suffer from two problems: over-concentration in volatile sectors such as energies, and a lack of risk management in adverse markets. Rather than relying on these passive indices, investors can potentially build a better commodities portfolio – one that is risk-balanced across sectors and targets a steady level of volatility through time. Investors may also benefit from employing tactical allocations based on commodity fundamentals, macroeconomic data, and price trends.

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Please read important disclosures at the end of this paper.

## Section 1: Introduction

As institutional and individual investors seek to diversify away from large concentrations in equity risk, they have added new asset classes to traditional 60/40 stock/bond portfolios. Simultaneously, many investors are worried about generating positive real returns in inflationary environments. These two trends have resulted in a rapid growth of capital invested in commodities, which historically have had only moderate correlations to stocks and bonds, and have performed well in periods of high inflation.

The vast majority of assets invested in commodities still track first-generation passive indices developed over a decade ago, the S&P GSCI (GSCI) and the Dow Jones-UBS (DJ-UBS). These standard indices provide exposure to a broad set of commodities, but their allocation is based on production quantities or market liquidity, resulting in a concentration of risk in commodity sectors that dominate global production, like energies. Given that commodity sectors have shown low correlations to one another, an allocation based on balancing risk across sectors provides better diversification and has delivered higher risk-adjusted returns than the standard first-generation indices. In addition, the standard commodities indices have historically exhibited large swings in realized volatility and suffered large drawdowns. Both can be mitigated – by targeting a stable level of portfolio volatility, and by systematically reducing risk exposure during prolonged bear markets in an effort to preserve wealth. Lastly, commodities portfolios can be enhanced through tactical adjustments based on supply-and-demand fundamentals, global macroeconomic data, roll yield, and price trends within commodity markets.

By incorporating all of these features – risk balancing, risk control, and tactical tilts – investors can make significant improvements in their commodity portfolios.

We analyze each of these components of a better commodities portfolio in turn. Section 2 summarizes the benefits of adding a long-biased commodities allocation to a traditional portfolio. Section 3 discusses how to build what we believe is a better *strategic* commodities portfolio using risk-balancing and drawdown control. Section 4 discusses the potential to improve expected returns through *tactical* commodity tilts overlaid on the strategic portfolio. Section 5 summarizes the main findings, and the Appendix contains details on data sources.

## Section 2: The Benefits of Adding Commodities to a Traditional Portfolio

Commodities offer investors three potential benefits: positive risk-adjusted returns, low correlations to stocks and bonds, and a hedge against inflationary pressures. In this section, we review some of the theoretical and empirical evidence supporting each.

First, an investment in commodity futures has historically provided significant positive risk-adjusted returns. Exhibit 1 compares the returns to an investment in the GSCI over the past four decades to an investment in the S&P 500 and U.S. Treasury Notes. Commodities have shown a similar level of both total and risk-adjusted returns relative to stocks and bonds. Because commodities have exhibited low correlations to stocks and bonds over this period, a portfolio comprised of all three has produced higher risk-adjusted returns than a 60/40 portfolio of stocks and bonds alone.

### Exhibit 1: Commodities Have Realized Similar Risk-Adjusted Returns to Stocks and Bonds

(January 1970-December 2011)

	S&P 500	Bonds	GSCI	60/40 Port	10% in GSCI, 90% in 60/40
Ann. Return	9.8%	8.1%	9.7%	9.5%	9.7%
Volatility	15.7%	5.2%	20.1%	9.9%	9.3%
Sharpe Ratio	0.30	0.39	0.27	0.37	0.41

Source: Bloomberg, AQR. The 60/40 portfolio represents the hypothetical returns to a monthly-rebalanced portfolio of 60% in S&P 500 and 40% in Bonds. For the specific time series and time periods used for each asset class, please see the Appendix

The theoretical argument for a risk premium to holding long commodity futures goes back at least to John Maynard Keynes (1923). Commodity producers tend to have concentrated businesses, reliant on only one or two crops, metals, or other products. To mitigate their risk, they hedge by short-selling commodity futures, creating a premium for investors who go long commodity futures. Said differently, hedgers are willing to pay an insurance premium to stabilize future revenues, and this premium can be earned by commodity investors who are willing to bear price risk.

The second benefit of commodities has been portfolio diversification. Because commodity prices are heavily influenced by fundamental supply-and-demand dynamics, commodity returns have historically shown a low correlation to other asset classes, as seen in Exhibit 2. Other common inflation-protection assets – such as publicly traded real estate companies (REITs), natural resources equities, and inflation-protected bonds – have shown far higher correlations to either stocks or nominal bonds.

**Exhibit 2: Commodities Have Realized Low Correlations to Major Asset Classes**

**Correlations of Monthly Returns Across Traditional and Real Assets (January 1970-December 2011)**

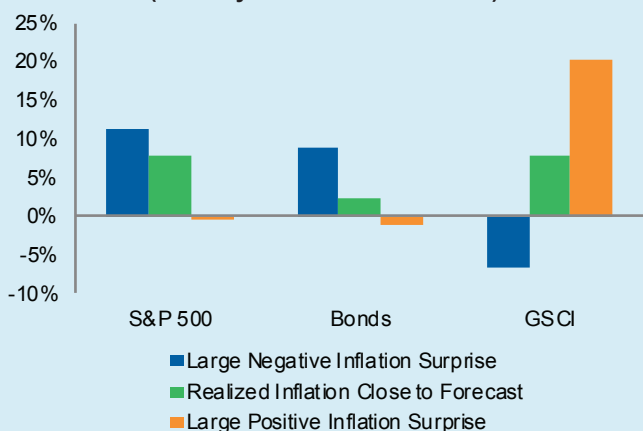
	S&P 500	Bonds	US TIPS	REITs	Natural Res Eq	GSCI
S&P500	1.00					
Bonds	0.14	1.00				
US TIPS	0.04	0.64	1.00			
REITs	0.59	0.01	0.19	1.00		
Natural Res Eq	0.75	-0.26	0.14	0.50	1.00	
GSCI	0.09	-0.07	0.26	0.15	0.59	1.00

Source: AQR, Bloomberg, Morningstar Direct. For the specific time series and time periods used for each asset class, please see the Appendix.

The third potential benefit is commodities’ historically strong performance during inflationary periods, when stocks and bonds typically suffer. While no financial asset is a perfect hedge against inflation, since commodities are real assets, they may protect a portfolio’s real purchasing power in inflationary environments, regardless of whether inflation is caused by scarcity (supply shocks) or monetary/fiscal expansion (demand shocks). Exhibit 3 shows the returns to stocks, bonds, and commodities in historical periods where realized inflation has surprised positively, surprised negatively, or been close to analyst forecasts. During periods of positive inflation surprises, stocks and bonds have historically generated negative real returns, while commodities have performed well.<sup>1</sup>

**Exhibit 3: Commodities Have Outperformed During Positive Inflation Surprises**

**Annualized Real Returns during Inflation Surprise Periods (January 1971-December 2011)**



Source: Datastream, Barclays Capital, AQR. We compute the “inflation surprise” as the realized 12-month inflation minus the average 12-month inflation forecast from a year prior, as reported by the Survey of Professional Forecasters. We compute this inflation surprise each month and group the months into thirds based on the size of the surprise. Finally, we compute the annual returns of S&P 500, Bonds, and GSCI in each of these groups of overlapping time periods. For the specific time series and time periods used for each asset class, please see the Appendix.

1 Additional analysis on inflation and asset returns can be found in AQR’s white paper on “Inflation in 2010 and Beyond?” by Katz and Palazzolo (2010), and in Dimson et al. (2012).

**Section 3: Building a Better Commodities Portfolio**

While most portfolios can benefit from the addition of a commodities allocation, there are different ways for investors to access the asset class. First-generation passive commodity indices such as the GSCI and DJ-UBS were developed over a decade ago and remain extremely popular with investors. Currently, nearly 80% of long-only investments in commodities are in funds that track these passive indices or in funds that hold physical precious metals.<sup>2</sup> However, as we explain below, these indices suffer from poor risk-diversification and a lack of risk management.

By building a better commodities portfolio, investors can seek a higher risk-adjusted return and a lower risk of large drawdowns. AQR’s approach to constructing what we believe is a better strategic commodities portfolio differs from the passive indices in two key ways:

- i. A risk-balanced allocation across sectors to take advantage of commodities’ inherent diversification benefits.
- ii. Dynamic management of portfolio exposures to target a stable level of volatility, and a systematic drawdown control process to manage risk during prolonged bear markets.

**The Global Commodities Market**

Although commodity futures may be new to many investors, they are one of the world’s oldest financial instruments. Trade in raw materials dates back as far as written records of civilization, and centrally traded agreements for future delivery already existed in the early 1700s at the Dojima Rice Exchange in Osaka, Japan.<sup>3</sup> Modern futures contracts began in 1865 when the Chicago Board of Trade published the first regulations standardizing delivery and margin requirements for corn, wheat, and oats futures.<sup>4</sup>

Today, the global commodity market is enormous. Global annual copper production exceeds \$120 billion, global annual wheat production exceeds \$170 billion, and global annual crude oil production is worth approximately \$2.5 trillion as of May 2012.<sup>5</sup> Much of this is bought and sold through private agreements, rather than public futures agreements, but private agreements often reference the publicly traded futures contract prices, and smaller producers and consumers often find that centrally cleared and more liquid futures provide easier access to the market. The commodities derivatives market totals around \$2.3 trillion.<sup>6</sup>

2 Cooper et al. (2012).

3 Schaefer (1989).

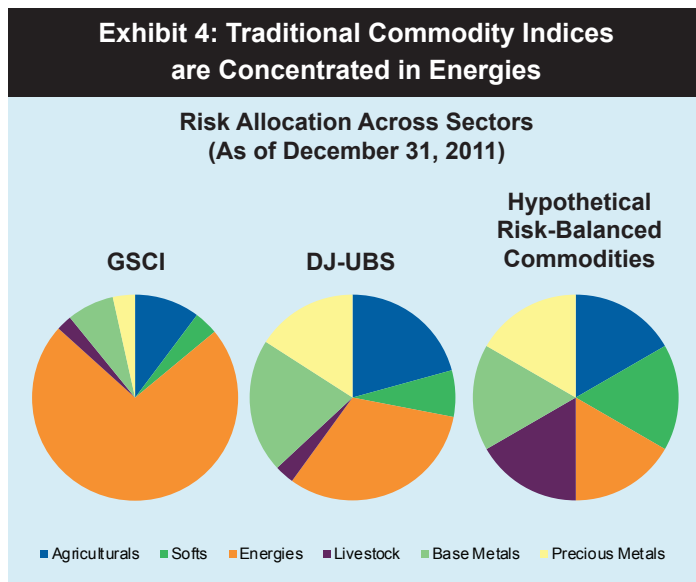
4 Taylor (1917).

5 Sources: May 2012 spot prices from Bloomberg; 2011 Copper Production from Copper Bulletin, International Copper Study Group; 2011/12 Wheat production from World Agricultural Supply and Demand Estimates, World Agricultural Board; 2009 Crude Oil production from International Petroleum Monthly, U.S. Energy Information Administration.

6 Pêtre and Von Kleist (2011).

## Balance Risk Across Commodity Sectors

As seen in Exhibit 4, the traditional commodity indices (GSCI and DJ-UBS) have large risk allocations to energy commodities, especially crude oil, a risk that has historically not been rewarded with a commensurately higher return. We believe investors can increase their risk-adjusted returns through improved diversification by risk-balancing across commodity sectors.



Source: Bloomberg, AQR. Volatility estimates for each sector are estimated using the methodology detailed in the Appendix.

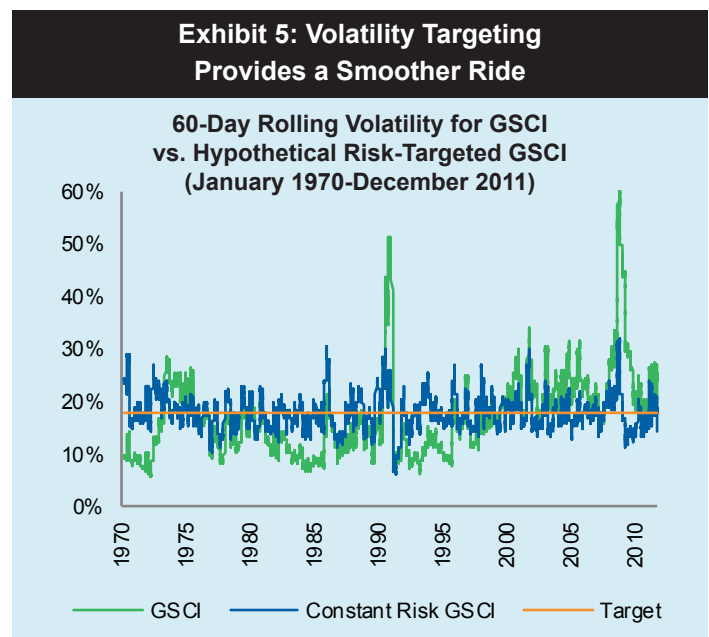
In the risk-balanced portfolio (depicted on the right), every sector contributes equally to the volatility of the total portfolio. Said differently, no one sector dominates the returns. High-risk sectors, notably energies, are given smaller notional allocations; low-risk sectors, such as precious metals, are given higher allocations. While more diversified, this approach will be lower capacity than the traditional approach of allocating by liquidity or global production. As with all techniques requiring estimation of volatility, the methodology can vary, in particular based on how quickly volatility estimates respond to the market-place. We have found that volatility levels in commodity markets can change quickly and tend to be persistent in the short-term. As a result, we use relatively short-term volatility estimates to construct a risk-balanced portfolio, an approach that requires constant monitoring and rebalancing.

The benefits, however, are significant. Because each commodity has unique supply-and-demand characteristics, commodities feature lower correlations across individual sectors than do traditional asset classes. For instance, using monthly returns from January 1990 to December 2011, the average pair-wise correlation

across ten of the most traded commodity futures contracts was 0.22, compared to 0.62 across ten developed country equity index futures and 0.53 for the G6 10-year bond futures.<sup>7</sup> If diversifying across global markets is valuable with equities, diversifying across sectors is even more valuable with commodities.

## Target Steady Volatility and Control Drawdowns

Just as concentrating risk in one or two *sectors* is suboptimal, concentrating risk in one or two *time periods* may also potentially hurt long-term returns. Historically, commodity bear markets, such as the one in 2008, have usually happened gradually over months or years, and have generally been accompanied by higher volatility within commodity markets and higher correlations across commodity markets. These significant spikes in risk can be managed by targeting a pre-specified level of volatility. Exhibit 5 shows the realized volatility of a volatility-managed commodity portfolio with similar weights to the GSCI. Instead of an inflexible 100% notional exposure to commodities, the notional exposure to commodities is adjusted daily to target an annualized volatility of 18%,<sup>8</sup> using a simple short-term volatility estimate. The realized volatility of the risk-managed portfolio stays much closer



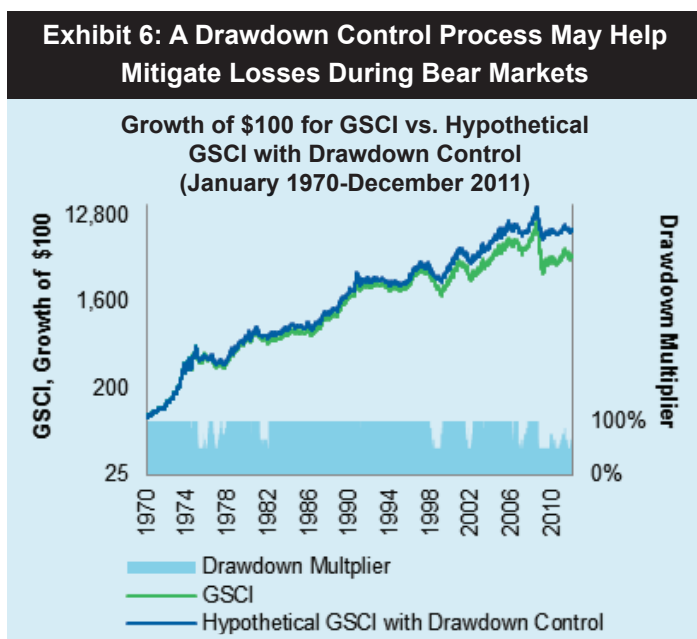
Source: AQR. Risk targeted portfolio is rebalanced daily to target 18% annualized volatility. For more details on the volatility estimation methodology, as well as important information regarding hypothetical performance, please see the Appendix.

<sup>7</sup> Source: AQR calculations. Commodities used: Aluminum, Brent Crude Oil, Coffee, Copper, Corn, Gold, Silver, Soybeans, Sugar, WTI Crude Oil; Country equity index futures used: Australia, Canada, France, Germany, Hong Kong, Japan, Netherlands, Spain, U.K., U.S.; 10-Year Bond futures used: Australia, Canada, Germany, Japan, U.K., U.S.

<sup>8</sup> The volatility-managed portfolio targets 18% annualized volatility to match the long-term level of realized volatility of the GSCI.

to the target, whereas the volatility of the GSCI spikes above 50% or 60%, especially during bear markets, while realizing a low volatility at other times. By maintaining a steadier level of volatility, a dynamically managed portfolio may experience a smoother ride and realize less severe negative tail events.

Since commodity bear markets tend to occur gradually, commodity investors may benefit from a drawdown control policy, a systematic process that seeks to reduce risk when the portfolio experiences meaningful losses. A drawdown control policy specifies how portfolio risk and exposure levels should be reduced when portfolio losses reach predetermined thresholds, in an attempt to mitigate the magnitude of drawdowns in prolonged bear markets. Importantly, the policy also specifies how risk should be gradually increased back to normal levels as portfolio returns improve. Exhibit 6 shows the hypothetical results of applying drawdown control to the GSCI from 1970 to 2011. Although the process only kicked in on a number of occasions during this period, it added long-term value by mitigating losses in the largest bear markets.



Source: AQR. The hypothetical GSCI with Drawdown Control holds commodities contracts in identical relative weightings to the GSCI index, but the systematic drawdown control steadily scales down the notional sizes of all commodities if the portfolio losses over multiple trailing time periods approach 20%, with a minimum exposure of 50% of the portfolio value. The Drawdown Multiplier represents the amount by which portfolio has been scaled down due to Drawdown Control. Please see the Appendix for more details on the methodology used, and for important information regarding hypothetical performance.

## A Better Strategic Commodities Portfolio: Putting the Pieces Together

We create the Hypothetical Strategic Commodities Portfolio by putting all the pieces together. This hypothetical strategic portfolio is risk-balanced across sectors (agriculturals, softs, energies, livestock, base metals, precious metals), targets a steady volatility over time, and uses systematic drawdown control. Our portfolio is based on relatively simple, intuitive concepts that seek to improve performance by adding diversification and by limiting the risk of a severe loss of capital. Exhibit 7 shows that the Hypothetical Strategic Commodities Portfolio has realized higher risk-adjusted returns and less severe drawdowns than both the GSCI and DJ-UBS passive indices over the historical time periods where the standard indices are defined.

**Exhibit 7: Putting It All Together**

**Hypothetical Strategic Commodities Portfolio vs. Passive Indices (January 1970-December 2011)**

	(January 1970-December 2011)	(February 1991-December 2011)		
	GSCI	Hypo. Strategic Commodities Portfolio	DJ-UBS	Hypo. Strategic Commodities Portfolio
Average Return	9.7%	16.0%	5.4%	7.2%
Std. Dev.	20.1%	20.2%	15.0%	16.7%
Sharpe Ratio	0.27	0.54	0.21	0.30
Maximum Drawdown	-67.6%	-47.9%	-54.3%	-47.9%

Source: AQR. The Hypothetical Strategic Commodities Portfolio is rebalanced each month so that each sector contributes equally to the constant volatility target of 18%. A systematic drawdown control process is applied to reduce the target volatility of the portfolio as the average drawdown over multiple trailing periods approaches 20%. Please see the Appendix for important information regarding hypothetical performance.

We note that our improvements do not come without a cost. This portfolio requires much more frequent rebalancing of positions as risk levels change, and it allocates relatively larger portfolio weights to less liquid futures contracts compared to passive indices. These features lead to lower capacity and higher transaction costs for the Strategic portfolio. In addition, the Strategic portfolio will have significant tracking error to passive indices due to non-trivial differences between the Strategic portfolio and passive indices, as well as the high volatility of this asset class. Indeed, the month-to-month and year-to-year performance of the Strategic portfolio and a less-diversified, non-risk-managed passive index will vary widely, with the traditional approach outperforming significantly at times. Nevertheless, we believe the benefits to holding a risk-balanced, risk-targeted commodities portfolio outweigh these costs in the long term.

### Section 4: Commodity Fundamentals and Tactical Allocations

Beyond this *strategic* commodities portfolio, there can be considerable benefits to utilizing *tactical* commodity management, which involves overweighting commodities with strong current fundamentals, rising trends, and positive carry. Performance may be further improved through efficient trading implementation, including the selection of futures contract and roll management.

#### An Overview of Commodity Fundamentals

As mentioned, every commodity has its own unique supply and demand characteristics. Understanding the fundamental drivers within each commodity market offers investors the opportunity to tilt a portfolio toward commodities with a higher likelihood of outperforming in the short-term. For instance, high or rising inventories in a commodity may indicate excess supply, and lead to falling prices. Falling inventories may indicate strengthening demand, and lead to rising prices.

Seasonal patterns also influence commodity prices in predictable ways. Agricultural commodities with a dominant growing season have a large supply entering the market during northern hemisphere harvest seasons, which tends to lower futures prices and increase hedging demands for those months. The wintertime surge in demand for natural gas and heating oil has the opposite effect, pushing up futures prices for those months. To the extent these seasonal effects lead to changes in commodity risk premia, investors may benefit from incorporating them within their commodity allocation process.

Macroeconomic data can provide insight into commodity demand, since global economic growth and exchange rates are important drivers of commodity prices. By analyzing each commodity's global consumption profile, investors may be able to discern which commodities will benefit or suffer most from changes in the economic health of major commodity-consuming countries. For example, since Europe accounts for over 40% of global coffee consumption, but only 7% of global corn consumption, a slowing European economy and falling Euro are likely to have a larger negative impact on coffee prices than on corn prices.<sup>9</sup> On the other hand, since China is a major user of base metals, a slowdown in China's economy may have a larger impact on aluminum prices than on gold prices.

Certain commodities have close economic links that give rise to relative-value bets. For example, there is a fundamental relationship

<sup>9</sup> Corn consumption data from USDA. Coffee consumption data from International Coffee Council.

between the prices of crude oil, heating oil, and gasoline. This relationship is known as the “crack spread,” in reference to the process of refining or “cracking” crude oil into products such as gasoline and heating oil. If the spread between crude oil and product prices narrows too much, refineries will slow production and schedule maintenance in order to protect their profit margins. Their actions reduce the *demand* for crude oil and the *supply* of products, which should eventually push their relative prices back toward an equilibrium level. On the other hand, if the spread grows too wide, refineries tend to expand production to capitalize on the larger refining margins, which ultimately pushes relative prices back toward equilibrium. An investor can potentially profit from this dynamic relationship by trading on the relative prices of crude vs. the distillates, overweighting crude when its relative price is low and underweighting it otherwise.

#### Two Simple, yet Powerful, Commodity Indicators

There are two additional indicators that can be used to make tactical shifts among commodities: *carry* (closely related to “roll yield”) and *trend* (also called “price momentum”).

There is strong empirical and theoretical evidence supporting the power of “carry” and “trends” to predict future returns in a variety of asset classes, including currencies, equities, fixed income, and commodity markets. Indeed, many investors are familiar with the concept of “carry” from its application in currency trading. A trader borrows in a low-yielding currency to buy a high-yielding currency, and if the exchange rate does not change, the trade earns the “carry” or yield differential between the two currencies. More broadly, any security position's carry is its return earned assuming market conditions do not change.

The concept of carry naturally applies to commodity futures: a commodity futures contract has a high positive carry if the futures price is far below the current “spot” price of the commodity. In this case, the owner of the futures contract earns the carry as the futures contract increases towards the spot price over time. Of course, there is no guarantee that the expected carry will be earned; the spot price can change over time. But, as we document in Exhibit 8, commodities with high carry have historically produced higher expected returns than commodities with low carry.

Trading on trends is another powerful predictor of commodity returns. Commodities that have been increasing (declining) in price over the past year have historically tended to continue appreciating (depreciating) in the future. We believe price momentum works in commodity futures for the same reason it

works in other asset classes: Investors tend to anchor on prior prices in the near-term and do not fully adjust prices to reflect news, leading to initial under-reaction. In some cases, investors tend to over-react to price moves due to herding tendencies, also leading to price trends. Investors can benefit from these trends by tactically overweighting commodities with positive price trends, and underweighting commodities with negative price trends.

Carry and price momentum are simple concepts, but they have been helpful in tactical allocation strategies in commodities and other asset classes.<sup>10</sup> Exhibit 8 reports the returns to hypothetical commodity portfolios sorted by carry and momentum since 1980, and shows a significant outperformance of high-carry and high-momentum commodities.

### Exhibit 8: Tactical Tilts May Add Value to a Commodities Portfolio

#### Returns to Hypothetical Commodity Portfolios Sorted by Carry and Momentum (February 1980-December 2011)

	High Carry	Low Carry	High Momentum	Low Momentum
Ann. Total Returns	13.2%	1.6%	14.7%	2.8%
Volatility	18.2%	16.9%	20.3%	18.2%
Sharpe Ratio	0.39	-0.24	0.44	-0.15

Source: AQR. Each month, 24 of the most liquid commodities are sorted by either their carry (defined as their annualized percentage price differential between the first- and second-month contracts) or their time-series momentum (defined as the twelve-month return to a rolling position in the second-month contract). The "High Carry" portfolio is rebalanced each month to hold an equal-weighted portfolio of the top third highest carry commodities, while the "Low Carry" holds the bottom third. Similarly, the momentum portfolios hold the top and bottom third commodities by momentum. Please see the Appendix for important information regarding hypothetical performance.

## Smarter Contract Selection and Flexible Trading

A passive index in equities is a "buy-and-hold" portfolio of companies. In contrast, a "passive" commodity futures investment must trade regularly. A commodity futures investment must exit each futures contract before it expires – or accept physical delivery of the commodity. In order to maintain exposure to each commodity market without taking physical delivery, the manager must "roll" the futures position, that is, exit the futures contract that is about to expire and enter a later-maturity contract in its place. Standard commodity indices roll on a fixed schedule. They are vulnerable to traders who position themselves ahead of this predictable flow of billions in trading volume – buying the

<sup>10</sup> For more details and evidence of momentum and carry in commodity futures, see Erb and Harvey (2006), Gorton and Rouwenhorst (2006), and Gorton, Hayashi, and Rouwenhorst (2007). Trends and time-series momentum have historically been prevalent in nearly all markets ranging from commodities to currencies, equities, and fixed income (Hurst, Ooi, and Pedersen (2010), and Moskowitz, Ooi, and Pedersen (2012)) and carry has been equally consistent across markets (Kojien, Moskowitz, Pedersen, and Vrugt (2012)).

longer futures contracts ahead of time and selling them to passive index holders during the standard roll period at a higher price. This predictable roll can lead to significant costs for investors in standard commodities indices.

Exhibit 9 shows the historical benefits of investing in contracts with later expiration dates than those held by passive indices, since the mid-1990s. As market participants and regulation continue to evolve, commodity investors may benefit from the flexibility to select futures contracts with different maturities, and may choose to roll contracts using a different methodology than the passive indices.

### Exhibit 9: Contract Selection Matters

#### Returns to the GSCI in Front-Month vs. Deferred-Month Contracts (January 1995-December 2011)



Source: AQR, Standard & Poor's. The hypothetical GSCI in Deferred Contract holds identical commodity weights to the standard S&P GSCI, but always holds the next contract further out on the futures curve. Please see the Appendix for important information regarding hypothetical performance.

## Section 5: Conclusion

A long-biased investment in commodity futures may improve the risk-adjusted returns of a traditional asset portfolio by adding diversification and helping preserve real value in periods of high inflation. This paper shows how investors can build a better strategic commodities portfolio – by risk-balancing across sectors, by targeting a steady volatility through time, and by having a plan for reducing risk in bear markets. Performance may be further improved by tactical allocations based on commodity fundamentals, macroeconomic data, price trends, and roll management. Although there can be significant random variation month-to-month and year-to-year, these commodities investment techniques have historically led to significantly improved performance relative to standard first-generation passive indices.

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### Appendix: Data and Methodology

The data used in exhibits are from the following sources:

- The S&P 500 Index Total Return data is from Bloomberg, and starts in January 1970.
- The S&P GSCI data is from Bloomberg and starts in January 1970.
- The DJ-UBS commodities index data is from Bloomberg and starts in January 1991.
- Bond returns are represented by the Barclays Capital US Government Index from January 1973, and the Ibbotson Intermediate Government Index prior to 1973.
- US TIPS returns are represented by the Barclays Capital US TIPS Index starting in March 1997.
- REITs returns are represented by the FTSE EPRA/NAREIT US Index starting in January 1990.
- Natural Resources Equities returns are represented by the MSCI World Energy and Materials Sectors Net Return Index starting in January 1999.
- Data on inflation forecasts from the Survey of Professional Forecasters is provided by the Federal Reserve Bank of Philadelphia and starts in January 1971.
- The individual commodities data cover 25 commodity futures. Our data on Aluminum, Copper, Nickel, Zinc, and Lead are from the London Metal Exchange (LME), Brent Crude, Gas Oil, Cotton, Coffee, Cocoa, and Sugar are from the Intercontinental Exchange (ICE), Live Cattle, Lean Hogs, and Feeder Cattle are from the Chicago Mercantile Exchange (CME), Corn, Soybeans, Soybean Meal, Soybean Oil, and Wheat are from Chicago Board of Trade (CBOT), WTI Crude, RBOB Gasoline spliced with Unleaded Gasoline, Heating Oil, and Natural Gas are from the New York Mercantile Exchange (NYMEX), and Gold and Silver are from New York Commodities Exchange (COMEX).

The Hypothetical Strategic Commodities Portfolio rebalances monthly. It is risk-balanced across the following 24 commodities in 6 sectors: Agriculturals (Corn, Soybeans, Wheat, Soybean Meal, Soybean Oil), Softs (Coffee, Cocoa, Cotton, Sugar), Energies (WTI Crude, Brent Crude, Gas Oil, Gasoline, Heating Oil, Natural Gas), Livestock (Live Cattle, Lean Hogs), Precious Metals (Gold, Silver), Base Metals (Aluminum, Copper, Nickel, Zinc, Lead). It gives equal notional weight to commodities within each sector.

The Hypothetical Strategic Commodities Portfolio targets a constant volatility of 18% at each monthly rebalance, subject to a drawdown control process. The portfolio volatility is estimated using a combination of individual volatilities and pair-wise correlations. The individual volatilities are calculated using historical daily returns, weighted exponentially with a 60 day center of mass. Correlation estimates are calculated using 5-day overlapping returns (to account for different market close times), exponentially weighted with a 150 day center of mass.

For the drawdown control system we estimate the current drawdown using an average of: (a) portfolio drawdown from the trailing twelve month peak; (b) portfolio drawdown from the average trailing twelve month return index level; (c) portfolio return since the beginning of the month; and (d) portfolio return since the beginning of year. We then estimate VaR as the 95% ten-day historical simulation value-at-risk (VaR) using the returns of current positions projected back over the three years prior to the VaR estimation date. When the current drawdown is less than two VaR units from the drawdown floor of 20%, a drawdown is triggered, and risk is reduced by 13%. Should that cut not decrease portfolio VaR enough for the drawdown to now be more than two VaR units from the floor, another 13% cut is added, and so on. The drawdown control system is symmetric; as returns improve and the measure of drawdown decreases, we begin to raise portfolio volatility back toward full target levels. But, to avoid excessive trading, we begin making incremental 15% increases to risk only when the drawdown gets above three VaR amounts away from the floor. Risk cannot go below 50% of the target.

### Disclosures

The views and opinions expressed herein are those of the author and do not necessarily reflect the views of AQR Capital Management, LLC its affiliates, or its employees.

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Hypothetical performance results (e.g., quantitative backtests) have many inherent limitations, some of which, but not all, are described herein. No representation is being made that any fund or account will or is likely to achieve profits or losses similar to those shown herein. In fact, there are frequently sharp differences between hypothetical performance results and the actual results subsequently realized by any particular trading program. One of the limitations of hypothetical performance results is that they are generally prepared with the benefit of hindsight. In addition, hypothetical trading does not involve financial risk, and no hypothetical trading record can completely account for the impact of financial risk in actual trading. For example, the ability to withstand losses or adhere to a particular trading program in spite of trading losses are material points which can adversely affect actual trading results. The hypothetical performance results contained herein represent the application of the quantitative models as currently in effect on the date first written above and there can be no assurance that the models will remain the same in the future or that an application of the current models in the future will produce similar results because the relevant market and economic conditions that prevailed during the hypothetical performance period will not necessarily recur. There are numerous other factors related to the markets in general or to the implementation of any specific trading program which cannot be fully accounted for in the preparation of hypothetical performance results, all of which can adversely affect actual trading results. Discounting factors may be applied to reduce suspected anomalies. This backtest's return, for this period, may vary depending on the date it is run.

Diversification and inflation hedging does not eliminate the risk of experiencing investment losses.

***Past performance is not an indication of future performance.***

The Drawdown Control System described herein will not always be successful at controlling a fund's risk or limiting portfolio losses. This process may be subject to revision.

There is a risk of substantial loss associated with trading commodities, futures, options, derivatives and other financial instruments. Before trading, investors should carefully consider their financial position.