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Cattle as a consistently resilient agricultural commodity

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Cattle as a consistently resilient agricultural commodity

This study compares a range of agricultural commodities over periods of varying economic circumstances. These commodities are examined over three categories, including returns, risk, and contribution to portfolio optimisation. Consistency in these categories is determined over four equal three-year stages which comprise pre-GFC (Global Financial Crisis), GFC, post-GFC and post-post GFC. To demonstrate resilience in the most extreme circumstances, the study uses Conditional Value at Risk (CVaR), which measures extreme risk in the tail of a distribution, as the risk measure and risk-return optimiser. The study thus provides a unique and comprehensive extreme-risk based focus which identifies and ranks the consistency of performance of agricultural commodities over a range of criteria and conditions. Cattle commodities consistently demonstrate the strongest overall performance in the categories examined.

Keywords: agricultural commodities; cattle; conditional value at risk; portfolio optimisation; economic cycles

Subject classification codes: G11; Q02

Introduction

Recent years have seen high volatility in commodity markets, commencing with a super-cycle boom in 2004, which was interrupted by the 2008 Global Financial Crisis (GFC) and its associated commodity and financial markets crash. Commodities rapidly recovered only to see another major downturn in 2014-2015.

This article seeks to provide a better understanding of the unique role of individual commodities within the overall agricultural commodity arena. It provides a new perspective on the dynamics of returns, volatility and diversification of agricultural commodities across a range of economic circumstances. Improved understanding of these dynamics is important in many ways. Volatility in agricultural markets can amplify poverty as it can impact on the amount people need to spend on food and lead to terms of trade shocks which can upset a country's internal and external balances and

impact on factors such as inflation, interest rates and unemployment (Algieri, 2014). Commodities have also become an increasingly important alternate investment asset to individuals and funds seeking to diversify their portfolios (Matesanz, Torgler et al. 2014). Commodity prices also impact on the food prices for the everyday consumer, and the prices received by farmers and others in the supply chain. Thus it is not surprising that a good understanding of the dynamics of agricultural commodity prices is noted by Brooks and Prokopczuk (2013) as being important to a wide range of stakeholders, including investors, producers, consumers, and policymakers.

As such, this study examines some of the core dynamics of agricultural commodity prices. In particular, the paper contributes to the understanding of the impact of extreme risk on the performance of agricultural commodities in that, not only is the GFC examined as a specific period, but CVaR (which focuses on extreme volatility), is used as both a risk measure and optimiser.

This article seeks to determine which commodities demonstrate consistent performance over the 12 year roller coaster experienced from 2004-2015 in three categories including returns, risk, and portfolio contribution (how well each commodity contributes to an optimal agricultural portfolio). While optimal portfolio contributions are often measured using a Markowitz (1952) return-variance framework, this article instead uses return-CVaR. While several studies measure the relationships between different commodities, they have predominantly focused on the overall distribution rather than the extreme tail risk. Geman (2005) and Fretheima and Kristiansena (2015) maintain that it is well known that commodities have high spikes with large deviations from the mean, which the literature generally fails to capture. Our use of CVaR addresses this problem for agricultural commodities by focussing on the tail.

To assess performance over a range of circumstances, each with its own challenges, the study takes place over four stages of three years' duration each. These are the 2004-2006 pre-GFC period, the 2007-2009 GFC period, the 2010-2012 post-GFC period and the 2013-2015 post-post-GFC period.

The commodities studied include agriculture and livestock products which form part of the S&P GSCI agricultural and livestock sub-indices (cocoa, coffee, corn, cotton, soybeans, sugar, wheat, feeder cattle, live cattle and lean hogs). The S&P GSCI is a production weighted investable index which is considered to be a leading indicator of commodity prices and general price movements in the economy. While the index has various formats, we use the S&P GSCI total return sub-indices which measure returns accrued from investing in fully-collateralised nearby commodity futures.

The overall aim of the paper is to ascertain the risk-return consistency of each commodity across a range of circumstances, as well as the contribution each commodity makes to an overall agricultural commodity index. In addition to assessing the overall performance of each commodity, this article assesses whether certain commodities have consistently high (low) risk (return) over each period, or whether the relative risk (return) rankings change significantly over time.

The study finds that cattle commodities (live cattle and feeder cattle) demonstrate the strongest overall performance, due to a combination of consistently low risk, higher than average returns and solid contribution to portfolio optimisation.

The next section discusses key drivers of agricultural risk and return. This is followed by a section on the methodology used, including the data, the four stages, and the measurement criteria for risk, return and optimisation. Thereafter the results of each of the four stages are presented followed by conclusions.

Drivers of agricultural risk and return

As background to our study, this section outlines some of the factors affecting agricultural risk and return, which could impact on the performance of the commodities in this study.

Agricultural commodities in general

According to FAO (Food and Agriculture Organisation of the United Nations, 2013) and USDA (United States Department of Agriculture, 2018), there are a diverse range of factors impacting on commodity prices, including a growing global population, economic factors impacting on incomes and hence demand, water availability, climate change and global warming, price of inputs such as fertilizer, availability of machinery, new technology leading to improved production, and natural disasters. Since 2005, a series of unfavourable weather episodes in major producing countries, increases of grains in animal feed and in the fuel ethanol sector, and reduced levels of investment and stockholding have all combined to impact on prices.

There has been debate in the literature as to the extent to which agricultural commodities are correlated with, or impacted by, non-agricultural commodities, in particular energy (oil) prices. Weak association between energy and agriculture commodities was found by Zhang et al. (2010) and Chevallier and Ielpo (2013). Inconsistent relationships (depending on factors such as time period and product type) have been found by Ji and Fan, Nazlioglu, Erdem, and Soytas (2012), whereas strong long run linkages were found by Baek and Koo (2010) and Ohashi and Okimoto (2016). Increasing spillovers since the mid to late 2000's were found by Du, Yu and Hayes (2011) and Matesanz, Torgler et al. (2014).

In terms of return and volatility spillovers between agricultural products, differing degrees of relationships have been found depending on the product (Gardebroek, Hernandez, et al., 2016; Lahiani, Nguyen and Vo, 2013), with wheat and corn especially having important explanatory power on the volatility of the other commodities.

There have been mixed results on the association between agricultural commodities and equities with Marshall, Nguyen and Visaltanachot (2013) finding no consistent links, and Daskalaki and Skiadopoulos (2011) finding very little diversification benefits by including commodities in a more traditional asset portfolio. Belousova and Dorfleitner (2012) found agriculture and livestock as being two of the commodities that did contribute to the risk reduction of portfolio risk, but not to return improvement. Daigler, Dupoyet and You (2017) show that commodities futures portfolios generally outperform equity indexes for both risk and return and their study supports the use of commodity futures for diversification.

Speculation can also impact on commodity markets. Haase, Seiler and Zimmermann (2016, 2017), found that conclusions on impacts differ according to aspects such as the focus variable (e.g. price, volatility, spillovers and measure used) and the authors find greater spillovers from speculation to volatility than from speculation to returns. Will, Prehn, Pies and Glauben (2016) show that speculation mainly affects prices on commodity markets with lower liquidity, most notably soy oil and livestock products.

Powell, Vo and Pham (2018) find that the relative risk of individual commodities compared to other commodities in a portfolio changes over different economic cycles, and Ott (2014) finds that common macroeconomic factors (especially petrol prices and exchange rates) can significantly impact volatility.

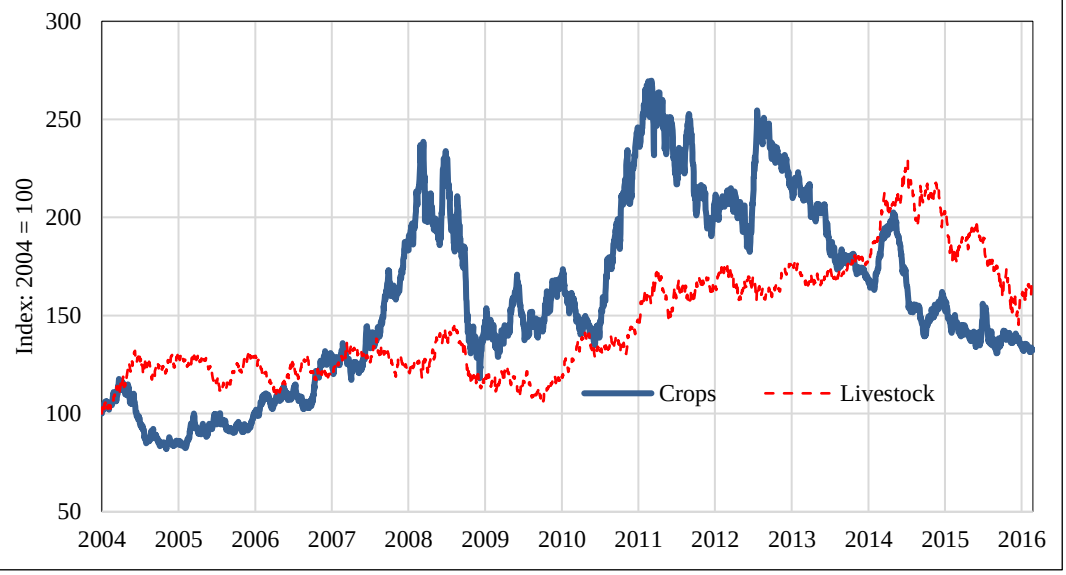
Specific agricultural commodity categories (non-grain crops, grains and livestock)

Non-grain grain crops such as coffee, cocoa, sugar and cotton can be highly volatile (although cotton generally to a lesser extent), and have their own set of impacting factors. Coffee and cocoa prices, as substitutes, have been found to be co-integrated (Traoréa and Badolob, 2016). Allocation of land use to farmers, weather, government strategies by large purchasers, and swings away from sugar to substitutes for health reasons all have an impact.

Grain commodities (corn, soybeans and wheat) can be highly volatile and prone to spikes (particularly wheat) and prices are driven by combination of factors such as weather, supply and demand fundamentals and speculation (Algierri, 2014; Janzen et al. 2014). Corn has several industrial uses, including use in ethanol, which can affect its price and price volatility (Gallagher, Wisner and Brubacker, 2005; Demirera, Kutanb and Shend, 2012; Wu et al., 2017).

Livestock in our study includes cattle, feeder cattle and lean hogs. The combination of cows' milk and beef, make cattle products the highest dollar value produced of any crop or livestock commodity in our study, with lean hogs as the source of pork meat being the second highest. Key factors affecting livestock prices include the price of inputs (corn is a major input into animal feeds), disease, and demand from leading importers (notably China). Figure 1 shows that livestock products have not been subject to the same high degree of volatility as crop products.

Figure 1: Crops and Livestock Price Indices



Source: Compiled from Datastream data

The above discussion shows that, while agriculture prices may be influenced by overall commodity and other financial markets, there are also unique agriculture specific factors. In terms of expectations for the results of this study, the discussion above indicates that the strongest returns performance could well arise from one of the crop products, while the livestock category could potentially show the lowest risk. The best overall performance will depend on which product has the optimal risk-return combination.

Methodology

Stages

The study covers a 12 year period, comprising four equal three-year stages. Stage 1 is the pre-GFC period from 2004-2006. Stage 2 is the GFC period from 2007-2009. Stage 3 is the post-GFC period from 2010-2012. Stage 4 is the post-post-GFC period from 2013-2015. The four stage format allows the assessment of each commodity over periods of different economic circumstances, including the pre-GFC financial markets

and commodities boom, the devastating GFC period, the post-GFC aftermath and its high commodities price growth, and the post-post-GFC period and its commodities slump.

Data

This article uses the S&P GSCI agriculture and livestock indices, which have ten further sub-indices for cocoa, coffee, corn, cotton, soybeans, sugar, wheat, feeder cattle, live cattle and lean hogs. The S&P GSCI is an investable index. The Total Returns Index (and its sub-indices) is appropriate to our study as it is considered a good indicator of returns for the different commodity categories and comparable to a regular investment in a stock index with dividend re-investment (as compared to the GSCI Excess Returns Index which is comparable to returns above cash and the spot index which is a measure of physical prices). Our modelling shows us that while the three types of indices (total, excess, spot) are not directly comparable on returns, they all yield significantly similar results on measures of volatility, including standard deviation and CVaR.

Risk, returns and optimisation

Returns in this study are measured as the average daily returns for each commodity in each of the four periods (in the same way as the GSCI measure their daily returns, being the daily percentage increase in the index over the prior day).

Risk is measured as the daily CVaR average for each commodity in each period. Unlike central measures of risk like standard deviation which fail to account for extreme losses (Allen & Powell, 2007; Kim et al., 2011), CVaR is a measure of the extreme risk in the tail of a distribution, and is conditional on returns exceeding a Value at Risk (VaR) threshold. Thus if VaR is measured at 95% level of confidence, CVaR is measured as the worst 5% of returns, which is the confidence level used in this study.

CVaR has been found to be an effective means for minimising losses in various portfolios, such as derivatives (Alexander, Coleman and Li, 2006), hedge funds (Giamouridis and Vrontos, 2007), equities (Quaranta and Zaffaroni, 2008), real estate (Stein, 2017), cryptocurrencies, (Lee, Chuen, Guo and Wang, 2018), and credit portfolios (Andersson et al., 2000, Powell and Allen, 2009, Allen and Powell et al., 2016).

Our optimisation methodology is rooted in the work of Markowitz (1952) and subsequent optimisation studies of others such as Roy (1952), Uryasev and Rockafellar (2000) and Allen and Powell (2011). The efficient frontier of a portfolio shows the maximum return that can be generated for each risk level (or minimum risk for each return level). Optimisation is most often based on variance-return. Assume *n* different assets in a portfolio with asset number *i* having the return r_i , the whole portfolio having the return r_p and the portfolio having the standard deviation σ with the variance σ^2. The covariance between r_i and r_k = $\sigma_{i,k.}$ The value invested in asset *i* is x_i .(i.e. the weighting of the asset). Thus the standard optimisation model, based on variance is as follows:

$$\sigma^2 = Var[r_p] = \sum_{i=1}^{n} \sum_{k=1}^{n} \sigma_{i,k} x_i x_k \quad (1)$$

$$E[r_p] = \sum_{i=1}^{n} x_i r_i \quad (2)$$

The optimisation objective for a given level of return is:

$$min \sum_{i=1}^{n} \sum_{k=1}^{n} \sigma_{i,k} x_i x_k \quad (3)$$

Subject to:

$$\sum_{i=1}^{n} x_i = 1 \quad (4)$$

$$0 \leq x_i \leq v_i,\ i = 1, 2, \ldots, n \tag{5}$$

Weighting for any portfolio cannot be negative, and can also be constrained to not exceed a specific weighting v (in order to ensure the portfolio is diversified).

Using CVaR as opposed to variance in equations 1 - 5, we construct a variance-covariance matrix to account for correlations between commodity returns, from which we then calculate portfolio return and portfolio CVaR. We then optimise the portfolio to generate a portfolio of assets which minimises CVaR for selected return levels. To ensure that our portfolio is not overweight in any asset, we impose a constraint of a maximum 33% weighting in the portfolio for any single commodity. We select our maximum return point as the highest achievable return that can be generated by the portfolio subject to our weighting constraint. The minimum return point is the return that can be achieved with the lowest possible CVaR. We then use 8 equidistant return points between the highest and lowest return points, giving us a total of 10 return points and we calculate the optimal (most efficient) portfolio for each of these return points as being the mix of commodities yielding the lowest portfolio CVaR at each point. These CVaR-return combinations make up the efficient frontier.

Let x be a commodity within the set of available commodities X and let ϕ be CVaR:

$$\min_x\ \phi(x),\ R(x) \geq \rho,\ x \in X \tag{6}$$

The selected level of return is ρ, which the reward function $R(x)$ must meet or exceed. We have constrained the minimum portfolio weight for each commodity to 0 with 33% upper bound in order to ensure diversification. Varying ρ traces the efficient frontier. We have constrained ρ to a minimum of 0. This does not necessarily exclude

all negative return industry sectors, as an industry sector with a slightly negative return could combine with industry sectors with positive returns to provide an overall portfolio return > 0. Our optimum CVaR portfolio shows the combination of assets that yield the minimum portfolio CVaR for each selected level of return.

Discussion and results

Each of the four stages are separately discussed, including the circumstances and results of each stage.

Stage 1. The pre-GFC period: 2004 -2006

Crotty (2009) saw this as period as one of 'perfect calm' in financial markets, with low interest rates, risk spreads, volatility and corporate default rates, and high levels of corporate profitability and market liquidity.

In this stage, commodities entered a super-cycle of extreme price growth (Erten and Ocampo, 2013; Huellen and Nissanke, 2012), rising by more than 50%, led largely by Energy products, with overall commodity growth fuelled by factors such as demand (particularly from China), and increased use of commodities as an investment tool and as a mechanism to hedge financial market risk. Agriculture had more moderate growth with crops increasing by 26% and Livestock by 20%. Erten and Ocampo (2013) found that, historically, tropical agriculture (such as sugar, coffee and cocoa) exhibits super cycles with much larger amplitude relative to non-tropical agriculture. This period also saw increased grain demand for industrial uses, such as corn and sugar for biofuels (Rosegrant et al., 2008; Zulauf, 2016). Livestock products remained very steady in comparison to crop products during this period with a lower level of growth and volatility.

Table 1. Results. Pre-GFC Period: 2004-2006

	Daily CVaR	CVaR Rank	Daily Return	Return Rank	Optimal Portfolio	Optimal Portfolio Rank	Average Rank	Combined Rank
Wheat	0.0321	5	-0.00008	9	3.5%	6	7	6
Corn	0.0313	4	-0.00004	8	0.1%	8	7	6
Soybeans	0.0372	6	0.00007	7	0.0%	10	8	9
Cotton	0.0393	7	-0.00075	10	0.1%	9	9	10
Sugar	0.0412	8	0.00059	1	22.7%	3	4	3
Coffee	0.0421	10	0.00055	3	12.0%	4	6	5
Cocoa	0.0420	9	0.00010	6	0.3%	7	7	8
Feeder Cattle	0.0210	2	0.00057	2	33.0%	1	2	1
Live Cattle	0.0209	1	0.00029	4	23.2%	2	2	2
Lean Hogs	0.0280	3	0.00027	5	5.0%	5	4	4
Average Agriculture	0.03353		0.00016					
Total Commodities	0.02872		0.00039					

Note: In the results tables for each stage, Daily CVaR is the average of the worst 5% of returns in the three year period, with a higher CVaR indicating a higher risk. Daily return is the average daily returns over the period. The optimal portfolio is based on the average optimal percentage holding of each commodity in the agricultural portfolio as per Appendix 1, with a higher percentage representing greater efficiency. Rankings are from 1 (best) to 10 (worst). The "average rank" is the average of the CVaR, return, and optimal portfolio rankings. The final column ranks the average rank, where a ranking of 1 is awarded to the best (lowest) average rank in the prior column. The "Average Agriculture" figures at the bottom of the table show the average of the CVaR and return figures for the 10 commodities in the table. The "Total Commodities" figure is for comparison purposes and is based on the total S&P GSCI index for all commodities (including agricultural and non-agricultural commodities).

Table 1 reveals that the stage 1 best risk performance is shown by live cattle. The returns of sugar and coffee, both tropical products, exceed those of the other grain products. Sugar's prices, further impacted by its use in biofuels, has demonstrated the best returns, followed by feeder cattle. First in the optimisation category is feeder cattle, which also achieves the overall best rank, just above live cattle and sugar, due to its strong performance in both the risk and return categories.

Stage 2. The GFC: 2007 - 2009

This was a period of extreme volatility. Total commodity prices grew strongly in 2007, then fell 65% in 2008, climbing again strongly in 2009 to finish 19% up for the total GFC period. Crop products grew 41% in 2007, lost most of the growth in 2008, and then rebounded in 2009 to achieve overall growth for the three-year period of 26%. Livestock had lesser growth and falls than the crop products and achieved a small 2%

decline in prices over the period.

The price rises and falls of wheat stand out in this period, growing 77% in 2007 and falling 67% in 2008. Soybeans also had high rises and falls, but to a lesser extent than wheat. Sugar had a very different experience, with small growth and falls in 2007 and 2008, but then had astonishing price growth of 129% in 2009, fuelled by the broader commodity boom and global shortages in sugar caused by poor weather in Brazil (excess rain) and India (drought), and the diversion of sugar supplies to ethanol. Cocoa also had high price growth in this period (70%) among poor harvests in the Ivory Coast, increased demand for chocolate, and futures speculation. Resulting from these events, cocoa, soybeans and sugar head the returns category.

Table 2. Results. GFC Period: 2007-2009.

	Daily CVaR	CVaR Rank	Daily Return	Return Rank	Optimal Portfolio	Optimal Portfolio Rank	Average Rank	Combined Rank
Wheat	0.0562	10	-0.00010	4	1.5%	6	7	8
Corn	0.0513	9	-0.00015	6	0.0%	8	8	10
Soybeans	0.0467	6	0.00078	2	21.3%	3	4	1
Cotton	0.0460	5	-0.00018	7	0.2%	7	6	6
Sugar	0.0489	7	0.00059	3	24.2%	1	4	1
Coffee	0.0427	4	-0.00012	5	0.0%	10	6	6
Cocoa	0.0512	8	0.00098	1	24.2%	2	4	1
Feeder Cattle	0.0224	2	-0.00025	8	20.1%	4	5	4
Live Cattle	0.0219	1	-0.00050	9	8.5%	5	5	5
Lean Hogs	0.0364	3	-0.00108	10	0.0%	8	7	9
Average Agriculture	0.0424		0.00000					
Total Commodities	0.0482		-0.00007					

Note: See note to Table 1 for an explanation of the figures in the above table.

The best ranking commodity in the stage 2 risk category is live cattle, and the optimisation category is sugar. The overall best rank for this stage is a three-way tie between sugar, cocoa and soybeans with cocoa slightly ahead of the other two on

returns but behind on risk. The cattle products have not featured too well overall in this stage, because although doing well on risk, they achieved a negative return.

Stage 3. The post-GFC period: 2010 - 2012

2010 was year of strong growth for commodities. Total commodities grew by 20%, but agricultural commodities outpaced overall commodity growth, with a 44% growth for crops and 25% for livestock. The surge was led by cotton at 92% for the year and coffee at 77% amidst poor weather in China and Pakistan (cotton) and in South America and Vietnam (coffee), as well as replenishing of run down stocks of cotton in importing countries. Corn had strong price growth of 55%, fuelled by lower supply estimates from the U.S. and increasing demand from developing countries. The other crops experienced more moderate price growth in 2010, with cocoa having a small fall over the year.

Over the next two years (2011 -2012), crop prices fell back to achieve overall growth for the three year period of 24%. The prices of cotton and cocoa, in particular, fell back strongly amidst improved supply, while corn prices continued on their growth path. Livestock, led by cattle product prices, continued to increase to 38% for the period, amidst increasing demand for cattle products from developing countries, while still maintaining low volatility relative to other commodities.

Table 3. Results. Post-GFC Period: 2010-2012.

	Daily CVaR	CVaR Rank	Daily Return	Return Rank	Optimal Portfolio	Optimal Portfolio Rank	Average Rank	Combined Rank
Wheat	0.0476	9	0.00008	7	1.0%	8	8	8
Corn	0.0408	7	0.00077	1	19.4%	3	4	3
Soybeans	0.0311	4	0.00052	3	22.4%	1	3	2

Cotton	0.0414	8	0.00058	2	16.9%	4	5	5
Sugar	0.0558	10	0.00022	5	1.7%	7	7	7
Coffee	0.0402	6	-0.00001	8	0.0%	10	8	8
Cocoa	0.0387	5	-0.00041	10	0.4%	9	8	8
Feeder Cattle	0.0181	1	0.00029	4	21.7%	2	2	1
Live Cattle	0.0185	2	0.00015	6	13.8%	5	4	4
Lean Hogs	0.0267	3	-0.00002	9	2.6%	6	6	6
Average Agriculture	0.0359		0.00022					
Total Commodities	0.0302		0.00018					

Note: See note to Table 1 for an explanation of the figures in the above table.

The stage 3 best ranked commodity in the risk category is feeder cattle followed by live cattle. The return category has corn with the best ranking, followed by cotton and soybeans. The optimisation category is led by soybeans and the overall category by feeder cattle.

Stage 4. The post-post-GFC period: 2013-2015

Stage 4 saw a substantial drop in global commodity prices. The total commodity S&P GSCI fell 72% over this period, led largely by a fall in energy prices. Saggu and Anukoonwattaka (2015) attribute these global commodity falls to a range of demand, supply and monetary factors. This included lower growth in China, continued Eurozone stagnation, commodity exporting countries experiencing lower growth, the United States experiencing a shale-energy boom, a price targeting strategy by OPEC to maintain market share, certain minerals experiencing export bans, record agricultural harvests, an increase in the U.S. dollar leading to lower prices for dollar denominated commodities, and interest rate tightening expectations in the U.S.

Agriculture fell to a lesser extent, with crops falling 46%. Cocoa, through strong demand for cocoa butter used in the production of chocolate, was the only crop not to record an overall fall for the three year period. Livestock initially bucked the falling trend, with strong demand from emerging countries. However, in the latter half of this

period, livestock prices succumbed, recording an overall fall of 7% for the three years (a combination of a drop in lean hogs and a small increase in cattle prices), which was much lower overall than most other commodities.

Table 4 shows that the stage 4 best ranked commodity in the risk category is live cattle, the return category is cocoa and the optimisation category is feeder cattle. The best overall ranking is achieved by feeder cattle, with live cattle second and cocoa third.

Table 4. Results. Post-post-GFC Period: 2013-2015.

	Daily CVaR	CVaR Rank	Daily Return	Return Rank	Optimal Portfolio	Optimal Portfolio Rank	Average Rank	Combined Rank
Wheat	0.0331	9	-0.00073	9	1.1%	7	8	9
Corn	0.0322	8	-0.00081	10	0.0%	10	9	10
Soybeans	0.0254	4	-0.00007	4	1.5%	6	5	4
Cotton	0.0264	5	-0.00009	5	3.2%	4	5	4
Sugar	0.0307	7	-0.00071	8	3.1%	5	7	6
Coffee	0.0459	10	-0.00030	6	0.0%	8	8	8
Cocoa	0.0235	3	0.00047	1	29.9%	3	2	3
Feeder Cattle	0.0204	2	0.00009	2	30.8%	1	2	1
Live Cattle	0.0192	1	0.00003	3	30.5%	2	2	2
Lean Hogs	0.0305	6	-0.00038	7	0.0%	8	7	7
Average Agriculture	0.0287		-0.00025					
Total Commodities	0.0268		-0.00098					

Note: See note to Table 1 for an explanation of the figures in the above table.

Overall performance

Table 5 averages the scores from each of the four stages to determine the overall best ranking over the 12 years.

Table 5. Final results

Total Period	Average CVaR Rank	CVaR Rank	Average Return Rank	Return Rank	Average Optimal Portfolio Rank	Optimal Portfolio Rank	Average Rank	Combined Rank
Wheat	8.3	10	7.3	9	6.8	7	7.8	10
Corn	7.0	7	6.3	8	7.3	9	7.3	9
Soybeans	5.0	4	4.0	1	5.0	4	4.0	3
Cotton	6.3	5	6.0	7	6.0	6	6.3	6
Sugar	8.0	9	4.3	3	4.0	3	4.3	4

Coffee	7.5	8	5.5	5	8.0	10	6.8	8
Cocoa	6.3	5	4.5	4	5.3	5	5.0	5
Feeder Cattle	1.8	2	4.0	1	2.0	1	1.8	1
Live Cattle	1.3	1	5.5	5	3.5	2	3.3	2
Lean Hogs	3.8	3	7.8	10	6.8	7	6.5	7

Note: The CVaR, return and optimal portfolio figures are the average of the figures in Tables 1 – 4 for each stage. The ranking columns are then obtained as per the note to Table 1.

The combined stages joint best ranking commodities in the risk category are live cattle and feeder cattle, in the return category is soybeans equal with feeder cattle and in the optimisation category is feeder cattle. The combined stage best overall ranking is achieved by feeder cattle, then live cattle, then soybeans, then sugar. Overall, non-cattle prices have been more susceptible over the studied period to some of the volatility driving factors that we have discussed in each of the stages, such as weather, supply, and demand for alternate uses like ethanol. The strong performance of the cattle products is consistent with what we previously saw in Figure 1, which shows the lower overall volatility of livestock products, but which ended the 12 year period at a slightly higher price index level than the crop products. High volatility coupled with lower than average returns has resulted in wheat achieving the lowest ranking.

Stage correlation significance checks

In order to determine whether there has been highly significant correlation in the return, risk and optimisation rankings over time, we undertook pairwise Spearman ranking correlations between the periods at a 99% and 95% levels of confidence (i.e. pre-GFC v GFC, pre-GFC v post-GFC and so on for each period versus every other period, yielding 6 pairs of periods in total). For nonparametric results (rankings), the Spearman ranking correlation coefficient is a widely used measure of correlation significance which has been found to have high efficiency and robustness (Croux and Devon, 2010).

We found no significant correlation in return (99% confidence), risk or optimisation rankings between any of the pairs. We found correlation at a lower level (95% confidence) for only one pair of optimisation rankings (2010-2012 with 2013-2015) and for only two pairs of risk rankings (2007-2009 with 2010-2012; 2010-2012 with 2013-2015). This means that the relative return, risk and optimisation rankings are not consistent over time, and that a commodity having a good return, risk or optimisation ranking in one period can have a poor ranking in another. Examples are cocoa going from the worst return in the post-GFC period to the best return in the post-post GFC period and corn doing practically the opposite. On the risk side, some of the rankings have remained more consistent, with feeder cattle and live cattle having consistently held the top two rankings, but with shifting rankings displayed by most of the other commodities.

Conclusions

The study assessed commodities over four stages of varying boom and bust circumstances, across three criteria including risk, return and portfolio efficiency. Risk was measured by CVaR as opposed to a central risk measure. The crop products such as soybeans and sugar, tended to demonstrate better return performance than risk performance, with the livestock products dominating risk performance. There was no consistency in return rankings from one period to another, with individual commodities shifting from having among the best returns in one period to having among the worst in others. There was found to be a slightly higher level of consistency in relative risk, particularly with the cattle products which displayed low risk across periods. The overall strong performance of cattle commodities was achieved on the back of their low volatility, coupled with higher than average agricultural commodity returns.

As with any study on financial markets, there are limitations to the transferability of results into the future. However, having a sound understanding of the risk and return dynamics of agricultural products over several periods of different economic circumstances can help stakeholders such as including investors, producers, consumers, and policy makers make informed decisions and choices.

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Appendix 1. Optimal Portfolios

2004-2006

Return	Wheat	Corn	Soy-beans	Cotton	Sugar	Coffee	Cocoa Index	Feeder Cattle	Live Cattle	Lean Hogs
16.62%	0.00%	0.00%	0.00%	0.00%	33.00%	33.00%	0.00%	33.00%	1.00%	0.00%
15.82%	0.00%	0.00%	0.00%	0.00%	33.00%	32.41%	0.00%	33.00%	1.59%	0.00%
15.02%	0.00%	0.00%	0.00%	0.00%	33.00%	21.72%	0.00%	33.00%	12.28%	0.00%
14.23%	0.00%	0.00%	0.00%	0.00%	29.33%	15.39%	0.00%	33.00%	22.28%	0.00%
13.43%	0.00%	0.00%	0.00%	0.00%	24.75%	10.27%	0.00%	33.00%	30.36%	1.63%
12.63%	0.00%	0.00%	0.00%	0.00%	20.56%	5.10%	0.00%	33.00%	33.00%	8.34%
11.83%	3.00%	0.00%	0.00%	0.00%	17.76%	1.91%	0.00%	33.00%	33.00%	11.33%
11.03%	7.22%	0.00%	0.00%	0.00%	15.10%	0.00%	0.12%	33.00%	33.00%	11.56%
10.23%	11.60%	0.00%	0.00%	0.00%	11.45%	0.00%	1.25%	33.00%	33.00%	9.70%
9.43%	13.44%	1.46%	0.00%	1.14%	9.13%	0.00%	1.45%	33.00%	32.88%	7.50%
Average	3.5%	0.1%	0.0%	0.1%	22.7%	12.0%	0.3%	33.0%	23.2%	5.0%

2007-2009

Return	Wheat	Corn	Soy-beans	Cotton	Sugar	Coffee	Cocoa Index	Feeder Cattle	Live Cattle	Lean Hogs
28.93%	1.00%	0.00%	33.00%	0.00%	33.00%	0.00%	33.00%	0.00%	0.00%	0.00%
25.71%	1.00%	0.00%	33.00%	0.00%	33.00%	0.00%	33.00%	0.00%	0.00%	0.00%
22.50%	1.00%	0.00%	33.00%	0.00%	33.00%	0.00%	33.00%	0.00%	0.00%	0.00%
19.28%	0.00%	0.00%	28.20%	0.00%	26.91%	0.00%	32.06%	12.83%	0.00%	0.00%
16.07%	0.00%	0.00%	24.06%	0.00%	24.67%	0.00%	27.75%	23.52%	0.00%	0.00%
12.86%	1.37%	0.00%	19.75%	0.00%	22.46%	0.00%	23.42%	33.00%	0.00%	0.00%
9.64%	1.93%	0.00%	16.08%	0.00%	20.42%	0.00%	19.99%	33.00%	8.58%	0.00%
6.43%	2.39%	0.00%	12.42%	0.00%	18.34%	0.00%	16.60%	33.00%	17.25%	0.00%
3.21%	2.87%	0.00%	8.74%	0.00%	16.29%	0.00%	13.20%	33.00%	25.90%	0.00%
0.00%	3.73%	0.00%	4.93%	1.57%	14.20%	0.00%	9.57%	33.00%	33.00%	0.00%
Average	1.5%	0.0%	21.3%	0.2%	24.2%	0.0%	24.2%	20.1%	8.5%	0.0%

2010-2012

Return	Wheat	Corn	Soy-beans	Cotton	Sugar	Coffee	Cocoa Index	Feeder Cattle	Live Cattle	Lean Hogs
22.13%	0.00%	33.00%	33.00%	33.00%	0.00%	0.00%	0.00%	1.00%	0.00%	0.00%
20.20%	0.00%	33.00%	33.00%	33.00%	0.00%	0.00%	0.00%	1.00%	0.00%	0.00%
18.26%	0.00%	33.00%	33.00%	33.00%	0.00%	0.00%	0.00%	1.00%	0.00%	0.00%
16.33%	0.00%	33.00%	30.99%	19.73%	0.00%	0.00%	0.00%	16.28%	0.00%	0.00%
14.40%	0.00%	24.38%	26.47%	15.39%	0.21%	0.00%	0.00%	33.00%	0.54%	0.00%
12.46%	0.00%	18.33%	21.77%	12.53%	1.23%	0.00%	0.00%	33.00%	13.14%	0.00%
10.53%	0.00%	12.27%	17.08%	9.68%	2.24%	0.00%	0.00%	33.00%	25.74%	0.00%
8.59%	2.07%	5.84%	13.59%	7.07%	3.91%	0.00%	0.00%	33.00%	33.00%	1.52%
6.66%	3.51%	1.15%	10.04%	4.55%	4.56%	0.00%	0.00%	33.00%	33.00%	10.18%
4.73%	4.34%	0.00%	4.85%	1.53%	4.76%	0.00%	4.29%	33.00%	33.00%	14.24%
Average	1.0%	19.4%	22.4%	16.9%	1.7%	0.0%	0.4%	21.7%	13.8%	2.6%

Appendix 1 continued.

2013-2015

Return	Wheat	Corn	Soy-beans	Cotton	Sugar	Coffee	Cocoa Index	Feeder Cattle	Live Cattle	Lean Hogs
11.75%	0.00%	0.00%	0.00%	0.00%	0.00%	1.00%	33.00%	33.00%	33.00%	0.00%
10.59%	0.00%	0.00%	0.00%	0.00%	0.00%	1.00%	33.00%	33.00%	33.00%	0.00%
9.43%	0.00%	0.00%	0.00%	0.00%	0.00%	1.00%	33.00%	33.00%	33.00%	0.00%
8.27%	0.00%	0.00%	0.00%	0.00%	0.00%	1.00%	33.00%	33.00%	33.00%	0.00%
7.11%	0.00%	0.00%	0.00%	0.00%	0.00%	1.00%	33.00%	33.00%	33.00%	0.00%
5.95%	0.00%	0.00%	0.00%	0.00%	0.00%	1.00%	33.00%	33.00%	33.00%	0.00%
4.79%	0.00%	0.00%	0.00%	0.00%	0.00%	1.00%	33.00%	33.00%	33.00%	0.00%
3.63%	0.00%	0.00%	0.00%	1.35%	5.66%	0.00%	28.40%	31.97%	32.63%	0.00%
2.47%	0.06%	0.00%	0.00%	4.90%	8.25%	0.00%	21.93%	31.86%	33.00%	0.00%
1.31%	2.75%	0.00%	0.00%	6.64%	9.56%	0.00%	17.55%	30.93%	32.58%	0.00%
Average	0.28%	0.00%	0.00%	1.29%	2.35%	0.70%	29.89%	32.58%	32.92%	0.00%

Note: As explained in the methodology section, the maximum return in each table in this appendix (top row, column 1) is the maximum return that can be obtained from the portfolio. The minimum return (bottom row, column 1 is the return associated with the lowest possible risk (CVaR) of the diversified portfolio. Eight equidistant return points have been selected between the minimum and maximum returns (giving a total of 10 return points), and the percentage in columns 2 onwards is the proportion of each commodity that should be held to minimise CVaR at each return level (with each commodity restrained to a maximum 33% holding). The average of each column is the figure that is shown in the "Optimal Portfolio" columns of Tables 1-4 of the main body of this article. For example, to achieve a 14.23% return in the 2004-2006 period, the optimal proportion of commodities (that which minimises CVaR) is 29.33% sugar, 15.39% coffee, 33% feeder cattle, 22.28% live cattle and 0% of the remaining commodities.