Variance Risk Premia in Commodity Markets*

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Abstract

We use a large panel of commodity option prices to study the market price of variance risk. We construct synthetic variance swaps and find significantly negative variance risk premia in nearly all commodity markets. An equally-weighted portfolio of short commodity variance swaps earns an annualized Sharpe Ratio of around 40 %. We document increasing comovements across bonds, commodities and equity variance swap returns, suggesting that the variance swap markets are increasingly integrated. Finally, we show that commodity variance risk premia are distinct from price risk premia, indicating that variance risk is unspanned by commodity futures.

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I Introduction

Over the past decade, commodity markets have witnessed tremendous increases in volatility. Given their role as consumption goods, factors of production and financial assets, managing commodity volatility is crucial for a wide number of market participants such as commercial hedgers and investors. Arguably, these developments have motivated the successful launch of commodity related volatility derivatives such as oil and gold VIX futures contracts. The rapid proliferation of these derivatives raises several questions. Chief among them include: how large is the compensation required by investors to bear variance risk in commodity markets? To what degree are commodity variance risk premia time varying? Are there commonalities in commodity variance risk premia? How do commodity variance risk premia relate to bond and equity variance risk premia? What is the relationship between price and variance risk premia? These are some of the questions we seek to answer.

In this paper, we comprehensively analyze the market price of variance risk in 21 commodity markets between 1989 and 2011, a period which includes the recent financial crisis. In doing so, we make three important contributions to the literature. First, we use a large panel of futures and options data to construct synthetic commodity variance swaps. This is important as commodity variance swaps allow us to estimate the market price of variance risk in a model-free way. Variance swaps are made up of a fixed leg, the variance swap rate, and a floating leg, the realized variance. Each day, we combine static positions in option contracts to replicate the variance swap rate. Next, we estimate the floating leg by computing the realized variance of the underlying commodity over the maturity of the variance swap. We then estimate commodity variance risk premia as the sample average of the difference between the floating and fixed legs of variance swaps (Carr and Wu, 2009; Driessen et al., 2009). Analyzing variance swaps that mature in 60 and 90 days, we find significant variance risk premia in 18 out of 21 commodity markets.[1]

[1]Typically, commodity options have bimonthly or quarterly expiration cycles. As a result, we focus on variance swaps that mature in 60 and 90 days.

This is in contrast to the findings of Carr and Wu (2009) and Driessen et al. (2009), who find very limited evidence of variance risk premia in individual equities.[2] Typically, commodity variance risk premia are negative and economically large. An equally-weighted portfolio of short commodity variance swaps yields an annualized Sharpe Ratio of 40 %, which is of similar magnitude as that of a short position in the S&P 500 variance swap. Moreover, this Sharpe Ratio is four times larger than that of an equally-weighted portfolio of long commodity futures, underscoring the profitability of commodity variance swaps.

Our second novel contribution consists in providing the first analysis of commonalities in variance swap returns. Our investigation proceeds in three steps. First, we focus on comovements within commodity sectors. To achieve this goal, we group commodities into sectors, i.e. energy, grains, livestock, metals, tropical, and wood. For each sector, we compute the average pair-wise correlation of commodity variance swap returns. We find modest correlations between variance swap returns of similar commodities. For example, the average pair-wise correlation among energy commodity variance swap returns is around 30 %. Second, we investigate commonalities across sectors. For each commodity sector, we compute an equally-weighted portfolio of variance swap returns. We then study the comovement across distinct sectors and find correlation coefficients that are generally below 20 %. Third, we analyze how commodity variance swap returns correlate with bond (30-Year Treasury) and equity index (S&P 500) variance swap returns. Our results show modest (typically below 30 %) unconditional correlations across asset classes. Motivated by the literature on the financialization of commodity markets (Tang and Xiong, 2012), we partition our sample into two distinct subperiods. The first subperiod, which we label "pre-financialization", ends in November 2004. The "financialization" period, which captures the period of increased investor flows in commodity markets, runs from December 2004 until the end of our sample. We confirm that variance risk is significantly priced during each of these subperiods.

[2] Carr and Wu (2009) report significantly negative variance risk premia in 8 out of 35 individual equities only. Similarly, Driessen et al. (2009) find significant variance risk premia in 29 out of 127 individual stocks.

More importantly, we document increasing commonalities in variance swap returns across markets. The case of energy markets is particularly telling. Prior to December 2004, equity and energy variance swap returns are only weakly correlated, as evidenced by their low correlation coefficient (2.62 %). However, this correlation rises to around 48 % during the period of financialization. This finding indicates that the financialization of commodity markets affects not only the risk premia related to the first but also the second moment of commodity returns.

Our third contribution consists in investigating the relationship between commodity *variance* risk premia on the one hand and equity, bond and commodity *price* risk premia on the other. To do so, we follow a three-pronged approach. First, we examine the relationship between commodity variance risk premia and the determinants of equity risk premia. This is important because our findings of negative variance risk premia may be the result of a significantly negative correlation between innovations to commodity variance and equity risk factors. To investigate this, we regress commodity variance risk premia on the 3 factors of Fama and French (1993). We find that the slope estimates are not statistically distinguishable from zero, indicating that commodity variance risk premia are unrelated to equity risk factors, including the market risk premium. Furthermore, the regressions result in very low explanatory power, confirming that commodity variance risk premia are unrelated to the determinants of equity returns. Second, we analyze the relationship between commodity variance risk premia and bond risk premia. We use the Cochrane and Piazzesi (2005) and Ludvigson and Ng (2009) factors as determinants of bond risk premia and regress commodity variance swap returns on these factors, obtaining significantly large intercepts and very low explanatory power. Typically, the coefficient estimates of the independent variables are statistically insignificant. In short, our results suggest that commodity variance risk premia are independent of bond risk premia. Finally, we analyze the link between the variance risk premium of a commodity and its price risk premium by regressing the former on the latter. Generally, our regression model yields very low explanatory power and mainly insignificant slope estimates. These results indicate that variance risk premia

are largely orthogonal to price risk premia. In other words, commodity variance risk is not spanned by commodity futures, suggesting that options contracts are non-redundant securities.

We perform several checks to establish the robustness of our main results. First, we investigate whether expected (rather than realized) commodity variance risk premia are also significantly negative. To this end, we use historical variance as a proxy for expected variance to compute the floating leg of variance swaps and repeat our investigation. We show that expected commodity variance risk premia are significantly negative, confirming that our main findings remain unchanged. We then investigate the robustness of our variance swap rate estimates. To begin with, we use a cubic spline (rather than linear) interpolation technique. Again, we obtain similar results. We also use different truncation points and find that they do not materially affect our main findings. Additionally, we assess the effect of jumps on the variance risk premia estimates and demonstrate that they do not change our main conclusions: there are significantly negative variance risk premia in commodity markets. Moreover, we demonstrate that our synthetic swap rates are highly correlated with publicly available indices. Relatedly, we show that our results are robust to concerns related to the tradability of commodity options. We also analyze the impact of seasonality on our main results. In a first step, we regress variance swap returns on twelve monthly dummies to purge out potential seasonal fluctuations. We then repeat our main analyses and find little differences with our baseline results. Finally, we use non-overlapping samples of variance swaps and obtain similar results, demonstrating that our results are robust to overlapping observation concerns.

Our work is related to the literature on option trading returns. Coval and Shumway (2001), Bakshi and Kapadia (2003a), Bakshi and Kapadia (2003b), Carr and Wu (2009), Driessen et al. (2009), Trolle and Schwartz (2010), Wang et al. (2011) and Mueller et al. (2013), among others, study the market price of variance

risk in a variety of financial markets and reach conflicting findings.[3] This may be due to their fairly short sample periods and different methodologies, which make the results difficult to compare and interpret. In contrast to them, we use a model-free approach to analyze the market price of variance risk over a long sample period in a large number of commodity markets. Covering a long time series is crucial in order to draw robust inferences about the potentially time varying variance risk premia. Likewise, covering a large number of markets allows us to present the first study on commonalities in variance risk premia across assets.

Our paper is also connected to the literature on commodity futures risk premia. Gorton et al. (2013), Daskalaki et al. (2014) and Szymanowska et al. (2014), among others, study commodity futures risk premia. We analyze a different type of risk premium. Specifically, we focus on the compensation that investors require for bearing variance (rather than price) risk in commodity markets. We show that, contrary to price risk premia, commodity variance risk premia are significantly negative and economically large. More importantly, commodity variance risk premia are largely orthogonal to price risk premia. This important result implies that variance risk is unspanned by commodity futures, making options contracts non-redundant securities.

We also contribute to the growing literature on the integration of commodity markets with traditional asset classes. Recent works by Tang and Xiong (2012) and Singleton (2014) analyze the financialization of commodity markets and the effect of investor flows on the first moment of commodity returns. They show that commodity returns are increasingly integrated with returns on traditional asset classes. We complement this literature by documenting similar effects for the second moment of commodity returns: commodity variance swap returns are increasingly correlated with bond and equity variance swap returns. In short, our results provide direct and model-free evidence that the financialization of commodity markets is a pervasive

[3]For example, Bakshi and Kapadia (2003a) and Bakshi and Kapadia (2003b) use a delta-hedging approach and find significant volatility risk premia in individual equities. In contrast, Carr and Wu (2009) and Driessen et al. (2009) construct synthetic variance swaps and find little evidence of variance risk premia in individual equities.

phenomenon that affects both the futures and options markets.

This paper proceeds as follows. In Section II we introduce our methodology and describe the data set employed. In Section III we present and discuss our empirical results. Finally, Section IV concludes.

II Methodology and Data

A. Methodology

Empirical studies on variance risk premia are usually anchored around one of the following three estimation approaches: parametric, semi-parametric or model-free. The parametric approach consists of specifying a data-generating process for the underlying. In this framework, the variance risk premium is usually a parameter to be estimated by exploiting information from the underlying and options prices. This approach is not only computationally intensive but also subject to specification errors since it explicitly assumes a specific data-generating process for the underlying. Consequently, parametric estimates of variance risk premia are joint tests of model specification and variance risk premia. Broadie et al. (2007) empirically examine the impact of model misspecification on risk premia. They conclude that the significance of variance risk premia depends crucially on assumptions about the presence of jumps in the data-generating process.[4]

Bakshi and Kapadia (2003a) propose to study variance risk premia in a semi-parametric manner by analyzing the profitability of delta-hedged at-the-money (ATM) straddles. This approach is motivated by financial theory, which posits that option prices are affected by changes in implied volatility and the underlying's price. Since delta-neutral ATM straddles are insensitive to small movements of the underlying's price, their profitability is mainly driven by changes in implied volatility. Hence, the profitability of delta-neutral ATM straddles may shed light on the existence of volatility risk premia. Though intuitive, this approach is still

[4]Pan (2002) reaches similar conclusions. She shows that once jumps are allowed for, the variance risk premium becomes insignificant in her data set.

vulnerable to the criticism that it relies on a specific hedging model.

To overcome these problems, the more recent model-free approach builds on variance swaps defined as swap contracts in which the floating leg corresponds to the realized variance of the underlying over a predetermined period. The underlying idea is that unconditional variance risk premia are equal to the sample averages of variance swap pay-offs which are the differences between the realized variance and the risk-neutral expectation of variance. No-arbitrage arguments imply that the rate of a variance swap, $SV_{t,T}$, must be equal to the risk-neutral expectation of variance, $\mathbb{E}_t^Q(V_{t,T})$, over the life of the swap. Thus, the unconditional variance risk premium can be estimated as the sample average of variance swap pay-offs. The pay-off to a variance swap contract (with a notional of 1) for the period ranging from t to T, $VRP_{t,T}$, is given by:

$$VRP_{t,T} = RV_{t,T} - SV_{t,T} \tag{1}$$

where $RV_{t,T}$ denotes the realized variance between t and T under the physical measure.

Consequently, quantifying variance risk premia reduces to estimating realized variance and variance swap rates. Whilst realized variance estimators have been extensively studied (see, e.g., Andersen et al. (2009) and the references therein), until recently, little has been known about the latter. In a seminal study, Britten-Jones and Neuberger (2000) elaborate a static replicating strategy to estimate the variance swap rate under the assumption that the underlying follows a continuous process.[5] More precisely, they derive the following relationship:

$$\mathbb{E}_t^Q(V_{t,T}) = MFIV_{t,T} = \frac{2e^{r_t(T-t)}}{T-t}\left[\int_0^{F_{t,T}} \frac{P(t,K,T)}{K^2}\,dK + \int_{F_{t,T}}^{+\infty} \frac{C(t,K,T)}{K^2}\,dK\right] \tag{2}$$

where $\mathbb{E}_t^Q(V_{t,T})$ and $MFIV_{t,T}$ refer to the risk-neutral expectation of variance and model-free implied variance between t and T, respectively. The annualized risk-free

[5]See Demeterfi et al. (1999) for an excellent treatment of the replicating strategy.

rate is denoted by r_t. $F_{t,T}$ denotes the futures contract observed at time t and expiring at T. $P(t,K,T)$ and $C(t,K,T)$ denote the price at time t of European put and call options struck at K and expiring at T.

Jiang and Tian (2005) extend this approach to a broader class of models by formally showing that Equation (2) holds for jump diffusion processes as well.[6] This result leads to the conclusion that the variance swap approach for estimating variance risk premia is essentially model-free in the sense that it holds for a general class of data-generating processes.

Therefore, we employ a methodology that is similar to that of Carr and Wu (2009). Assume we want to synthetically create a 60 day variance swap. On each trading day, we obtain and sort all out-of-the-money (OTM) options by time to maturity. We identify the two maturities T_1 and T_2 that are closest to and cover 60 days. We retain options of maturities T_1 and T_2 only. We require the existence of at least two OTM put and two OTM call options for each of the two maturities. We exclude from our sample all trading days that do not meet this requirement. As in Trolle and Schwartz (2010), we truncate the first and second integrals in Equation (2) at K_l and K_u respectively:

$$K_l = F_{t,T} \exp^{-10\sigma(T-t)} \tag{3}$$

$$K_u = F_{t,T} \exp^{10\sigma(T-t)} \tag{4}$$

where K_l and K_u refer to the lower and higher truncated strikes. $F_{t,T}$ refers to the futures contract observed at time t and expiring at T, σ is the average implied volatility of all OTM options and $T-t$ denotes the time to maturity of the option contract.[7] For each maturity, we linearly interpolate available Black (1976) implied volatilities across moneyness.[8] For strikes higher (lower) than the highest (lowest) listed strike price but lower (higher) than K_u (K_l), we assume constant implied

[6] Although jumps introduce errors in the replicating strategy, the numerical analysis of Carr and Wu (2009) indicates that these biases are negligible. We use a recent result by Rompolis and Tzavalis (2013) to analyze the effect of jumps on our main results. As Section *E.4* shows, our findings are robust to the impact of jumps.

[7] Our results are robust to the choice of truncation points. See Section *E.3* for further details.

[8] Section *E.2* shows that working with a spline interpolation approach yields very similar results.

volatility. Pursuing this approach, we obtain a grid of 1,000 equidistant implied volatilities for strikes between K_u and K_l.

We then convert implied volatilities back into European option prices using the Black (1976) option pricing formula. We evaluate the integrands at each of the 1,000 points and numerically approximate (trapezoidal rule) the integrals in Equation (2) to estimate the variance swap rate. Finally, we linearly interpolate between the two swap rates to obtain the 60 day variance swap rate. We repeat the above steps every day to obtain time series of 60 day variance swap rates.

As is common in empirical studies, we estimate realized variance as follows:

$$RV_{t,T} = \frac{252}{T-t} \sum_{i=t+1}^{T} \left(\log \frac{F_{i,T}}{F_{i-1,T}} \right)^2 \tag{5}$$

where T is the maturity date of the variance swap, $F_{i,T}$ denotes the futures contract observed at time i and expiring at time T.

Note that, contrary to individual equities, commodity options are written on futures contracts which life span is finite. As a result, the time series of the first nearby contract could exhibit spikes at rollover dates especially in markets characterized by steep term-structure of futures. Given that these spikes could bias our estimates of realized variance upward, we construct a constant maturity futures time series by linear interpolation of futures contracts maturing at T_1 and T_2.

B. Data

We obtain our futures and option data set from the Commodity Research Bureau (CRB). The data set contains information on the strike price, maturity and settlement price of individual commodity derivatives. Table 1 lists the 21 commodities included in our sample. To mitigate the effect of micro-structure related issues such as infrequent trading and stale prices, we only retain options with time-to-maturity of at least 12 days. We further delete options with prices lower than five times the minimum tick size reported in Table 1. Given that our data set comprises American options and that our estimation approach requires

European option prices, we convert the American option prices into European prices by following the standard approach of Barone-Adesi and Whaley (1987).

Table 1 also reports the annual average volume of individual commodity options for the years 2010 and 2011. We collect the volume data from the monthly volume reports published on the exchange's websites.[9] Generally, we see higher trading volume in some energy, grains and metal commodities than in other commodity sectors.

Our empirical analysis focuses on variance swaps with maturity of 60 and 90 days. This decision is motivated by the observation that, with the exception of energy markets, no other commodity exhibits a monthly expiration schedule (see Table 1). Since monthly variance swaps cannot be replicated, we focus on 60 and 90 day variance swaps. Therefore, we retain only OTM options on the first two futures contracts. For energy commodities, we retain OTM options on the second and third futures contracts.[10] Table 2 provides an overview of the final data set of option prices. It shows that our sample period spans more than 20 years including the recent financial crisis. The last two columns report the average number of OTM call and put options per trading day. On average across all commodities, there are 17 and 14 OTM call and put options with different strike prices per day, respectively. These numbers compare well with other studies such as those of Carr and Wu (2009) and Taylor et al. (2010).

III Empirical Results

Prior to discussing our empirical results, it is instructive to visualize the time series dynamics of realized variance (RV) and model-free implied variance (MFIV). Figure 1 plots these series for 6 commodities drawn from different sectors. This figure

[9]Ideally, one should report the average open interest and trading volume for the full sample period. Alas, the CRB does not provide such information. Fortunately, the exchanges provide volume data for the very recent years. We use the option trading volume for the period 2010–2011 as an indication of trading activity in commodity markets. Section *E.6* establishes the robustness of our findings to tradability concerns.

[10]The reason for selecting the second and third nearby futures contracts is that, unlike other commodities, energy commodities have a monthly expiration schedule.

highlights several interesting features. First, RV and MFIV trend together. Second, MFIV is usually higher than RV, suggesting that short variance swaps investments are profitable. However, by visually inspecting these plots, it is difficult to ascertain whether these profits are significantly different from zero or whether similar results are obtained for other commodities. Third, we can see that some commodities are more volatile than others, prompting us to explore the connection between variance risk premia and variance levels. We elaborate on each of the above observations in the ensuing paragraphs.

A. Is Variance Risk Priced in Commodity Markets?

We start our empirical analysis by ascertaining whether variance risk is priced in commodity markets. If variance risk is priced, we expect the average pay-off to variance swaps to be of economically large magnitude and statistically significant.

A.1 Variance Swap Payoffs

Table 3 presents summary statistics of the estimated commodity variance risk premia. The average 60 day variance risk premia reported in Panel A are mainly negative, suggesting that variance risk is negatively priced in commodity markets. To assess the significance of variance risk premia, we report Newey-West t-statistics in the fourth column of Table 3. The evidence for 60 day variance risk premia (Panel A) suggests that variance swaps generate significant pay-offs in virtually all markets. Unlike individual equities, we find clear evidence of significantly negative variance risk premia in 17 of the 21 markets.

The volatility of 60 day variance risk premia is generally low, with values usually below 7 %. However, natural gas and coffee variance risk premia exhibit volatilities that are an order of magnitude higher (15 % and 17 %, respectively). The high volatility of silver's variance risk premium could explain why its market price of variance risk is not statistically different from zero. Examining the higher moments of variance risk premia, we find evidence of positive skewness which contrasts with the negative skewness often found in returns. The positive skewness indicates

that, though short variance swap positions yield statistically and economically significant profits, these strategies could incur severe losses. Variance risk premia are leptokurtic with kurtosis as high as 24.48 in the soybeans market.

To gain insights into the term-structure of variance risk premia, we repeat the above analysis for 90 day variance risk premia and present the results in Panel B of Table 3. Generally, we observe significantly negative variance swap payoffs in 14 markets, indicating that variance risk is consistently negatively priced across both the bimonthly and quarterly maturities.

In summary, Table 3 unequivocally points to significantly negative variance risk premia in most commodity markets. Moreover, our evidence of significant variance risk premia for most commodities differs from that of individual equities reported in Carr and Wu (2009) and Driessen et al. (2009). This finding underscores the differences between the two asset classes.

A.2 Variance Swap Returns

To better appreciate the profitability of variance swap contracts, we compute the Log Variance Risk Premium (LVRP) defined as the continuously compounded excess return on a fully collateralized variance swap position. More formally, the variance swap return for the period from time t to T is computed as follows: $LVRP_{t,T} = \log\left[\frac{RV_{t,T}}{MFIV_{t,T}}\right]$.

Table 4 displays the results of the analysis for the LVRP. Again, we report results for 60 and 90 day variance swaps in Panels A and B, respectively. The LVRPs reported in Panel A of Table 4 are mostly negative.[11] The standard deviation of LVRPs is fairly homogeneous across commodities with values typically below 50 %.

To better appreciate the risk/reward characteristics of commodity variance swaps, we report absolute values of annualized, Newey-West corrected Sharpe Ratios (SR) in the penultimate column of Table 4. We present absolute values of SR because

[11] It is important to stress that under the null of zero variance risk premium, the average LVRP will be biased towards negative values due to Jensen's inequality. This observation explains the seemingly conflicting evidence, reported in Carr and Wu (2009), of significantly negative mean LVRP even though the average VRP, itself, is not statistically significant. Driessen et al. (2009) echo a similar concern in their footnote 13.

the negative returns on variance swaps complicate cross-market comparisons of SR. Table 4 demonstrates that 60 day commodity variance swaps yield sizable SR varying between 9.4 % and 63.4 %.[12] Clearly, these figures are higher than the 10 % that a long passive investment in commodity futures typically generates (Koijen et al., 2012). The variability in SR within and across sectors is striking. At 2 month horizons, SR fluctuate between 34 % and 47 % in energy markets. This variability carries over to grains and livestocks. For example, a short variance swap position in live cattle earns an annualized SR of 50.2 %, almost three times higher than the 17.4 % of lean hogs.

We further compare the performances of commodity variance swaps of different maturities. We repeat the above analysis for 90 day variance risk premia. Panel B of Table 4 reports SR that are higher than the reward to variability ratio of a passive investment in commodity futures. However, it is worth noticing that these SR are generally lower than those presented in Panel A, indicating a downward sloping term structure of SR.

B. Time Variation in Variance Risk Premia

In the following paragraphs, we analyze time variations in variance risk premia. First, we study the link between historical variance levels and variance risk premia. Second, we analyze the dynamics of commodity variance risk premia across different market regimes.

B.1 Affine Premia

We begin by investigating whether variance risk premia are linearly related to historical variance. This is important because most option pricing models assume that variance risk premia are affine functions of the variance of the underlying. Previous studies on variance risk premia, e.g. Carr and Wu (2009) and Trolle and

[12] In comparison, Carr and Wu (2009) report SR that vary between 0 % and 55 % for individual US equities.

Schwartz (2010), estimate a regression of the form:[13]

$$RV_{t,T} - MFIV_{t,T} = \alpha + \beta MFIV_{t,T} + \epsilon. \tag{6}$$

Although intuitive, this approach can be criticized on two grounds. First, the regression suffers from the issue of endogeneity, which biases the slope estimate. This problem arises because the variance risk premium affects the MFIV, which appears on both sides of the equation. Second, and more important, Equation (6) is likely to be an imbalanced regression since the order of integration of the variable on the left is much smaller than that of the independent variable.[14] To address these issues, we build on the arguments of Bollerslev et al. (2013) and run the following regression:[15]

$$RV_{t,T} - MFIV_{t,T} = \tilde{\alpha} + \tilde{\beta} HIST_t + \epsilon. \tag{7}$$

where $RV_{t,T}$ is the realized variance between times t and T. $MFIV_{t,T}$ is the model-free implied variance between times t and T. $HIST_t$ is the fractionally differenced historical variance. As is standard in the literature, we set the order of fractional integration at 0.40.

The first five columns of Table 5 report the results from Regression (7). Starting with 60 day variance risk premia, we find that the slope estimates are generally not statistically distinguishable from zero. This result suggests that commodity variance risk premia are unrelated to historical variance. We also assess whether variance swap returns are time varying by estimating the following regression:

$$\log(RV_{t,T}) - \log(MFIV_{t,T}) = \dot{\alpha} + \dot{\beta} \log(HIST_t) + \epsilon. \tag{8}$$

where $\log(RV_{t,T})$ is the log realized variance between times t and T. $\log(MFIV_{t,T})$ is the log model-free implied variance between times t and T. $\log(HIST_t)$ is the

[13] It is straightforward to rearrange the regression models presented in Carr and Wu (2009) and Trolle and Schwartz (2010) to obtain Equation (6).

[14] Note that the dependent variable is the difference of two series, making its order of integration smaller than that of the original series.

[15] We are grateful to Natalia Sizova for making this suggestion.

(fractionally) differenced logarithm of historical variance. The last five columns of Panel A report the coefficients, t-statistics and R^2 of the above regression. The main findings do not change. We cannot reject the null hypothesis at the 5 % level in most markets.

Panel B of Table 5 presents our findings for variance swaps that mature in 3 months. Our main conclusion is unaltered: the performance of short variance swaps positions is unrelated to historical variance.

Overall, our results suggest that the market price of commodity variance risk is not an affine function of variance. This result directly contradicts that of Carr and Wu (2009) and Trolle and Schwartz (2010). We attribute the difference in results to our more robust econometric approach that allows us to address the issues of endogeneity and imbalanced regressions.[16]

B.2 Market Regimes

In order to analyze the dynamics of commodity variance risk premia across different market regimes, we partition our sample into 2 distinct periods: the first period ends in November 2004, the second subsample runs from December 2004 onward.[17] These periods are selected because of their economic importance. The first subsample, which we refer to as "pre-financialization", corresponds to a period of low investor participation in commodity markets. The second period coincides with the financialization of commodity markets, a period characterized by increased investor flows into commodities. The results are presented in Table 6.

We confirm that variance risk is significantly priced in commodity markets during each of the two periods analyzed. Our results point to consistently negative variance risk premia for most markets. Moreover, for each commodity market, the variance risk premia estimates are of similar order of magnitude in each of the

[16] In an earlier draft of this paper, we follow the steps outlined in Carr and Wu (2009) and Trolle and Schwartz (2010). Their approach, which suffers from both endogeneity and imbalanced regression concerns, leads us to the conclusion that variance risk premia are affine functions of variance. The details of this analysis are not reported for brevity.

[17] In a recent study, Hamilton and Wu (2014) document a structural break in crude oil's futures risk premia in December 2004. Other studies suggest 2005 as a breakpoint. Considering 2005 as a breakpoint leads to very similar results. These results are not reported for brevity.

two subsamples. Collectively, these results show that variance risk premia are fairly consistent by commodity, and consistently negative overall, in both sample periods.[18]

C. Commonalities in Variance Swap Returns

We now investigate commonalities in variance swap returns. We follow a two-step approach. First, we analyze the correlations across commodities. Second, we study comovements across asset classes.

C.1 Evidence from Commodity Markets

Panel A of Table 7 presents the average correlation within each commodity sector. These figures are computed as follows. For each sector, e.g. energy, we compute pair-wise correlations between the variance swap returns of constituent commodities. We then average all pair-wise correlations to obtain the correlation within a sector. Note that we do not perform this analysis for the wood sector because it contains only one commodity (lumber). The estimated correlations vary between 5.68 % (tropical) and 33.42 % (energy) for 60 day variance swap returns, indicating mild comovements within individual sectors. Similarly, the average correlations of 90 day variance swap returns fluctuate between 11.48 % (tropical) and 33.05 % (metals). In general, these coefficients point to moderate commonalities within commodity sectors.

We now extend our analysis by studying commonalities across (rather than within) commodity sectors. Each trading day, we calculate the return on an equally-weighted portfolio of variance swaps of all commodities involved in a specific sector. By doing so, we obtain time series of variance swap returns for each sector. Next, we compute pair-wise correlations across different sectors. Panels B and C of Table 7

[18]These findings have a more profound implication. In particular, they suggest that liquidity effects are unlikely to drive our results. To understand this, remember that the second sample period relates to a period of high trading activity in commodity markets. If liquidity drove our results, one should observe marked differences across both sample periods. Clearly, our analysis suggests that the results for the two samples are broadly similar, making liquidity-based explanations difficult to reconcile with the data. Section *E.6* digs deeper into the issue of liquidity and presents a variety of analyses that further establish the robustness of our findings.

report the correlations of variance swap returns across sectors. We observe moderate correlations across sectors. The reported figures vary from 6.54 % (livestock and metals) to 24.65 %, (grains and tropicals) at the shorter horizon.[19]

The relatively moderate correlations across commodity variance swap returns suggest that a diversified portfolio of commodity variance swaps might have desirable features. We verify this by computing the, Newey-West corrected, annualized SR of a portfolio of variance swaps. On each day, we take an equally-weighted short position in all available variance swaps of a specific maturity. Since we do not have options data for most commodities in the year 1989, we construct the diversified portfolio from 1990 onward. On average, the diversified portfolio comprises 15 commodity markets. Focusing on the entries reported under "Diversified" in Table 4, we can see that a short equally-weighted portfolio of commodity variance swaps generates returns of 21.1 % and 19 % at the 60 and 90 day horizon, respectively. The diversified portfolio performs well compared to individual commodity variance swaps as its reward to variability ratio is equal to 37.9 % and 23.6 % for the shorter and longer maturities, respectively.

C.2 Evidence from Equity and Bond Markets

We also analyze comovements between commodity variance swap returns and those observed in equity and fixed-income markets. To this end, we use options data on the S&P 500 index and the 30-Year US Treasury bond. Our data comes from OptionMetrics and covers the periods 1996–2011 and 1996–2010 for the equity and fixed-income market, respectively.[20] We follow the steps outlined in Section II to

[19] We also perform a principal component analysis (PCA). The results, not reported here for brevity, suggest that five factors are necessary to explain variations in variance swap returns across sectors with each factor capturing roughly 20 % of common variations.

[20] Our sample period for the S&P 500 and Treasury markets is determined by the availability of data from OptionMetrics. In general, the sample period for the bond and equity markets is shorter than that of most commodities. One should bear this in mind when interpreting our results.

estimate the variance risk premia of these markets.[21] We then compute the pair-wise correlations between the variance swap returns of individual commodity sectors and those of the stock and bond markets. Rows "S&P 500" and "Treasury" of Table 7 summarize our findings. We observe (at most) moderate comovements between bond and equity variance swap returns on the one hand and commodity variance swap returns on the other. For example, the correlation between energy and equity (bond) variance swap returns is 26.50 % (20.18 %) at the bimonthly horizon.

Motivated by the literature on the financialization of commodities, we analyze how the markets comove during different time periods. To this end, we repeat our analysis for each of the two regimes discussed in Section *B.2*. As Table 8 demonstrates, there are important differences between the two time periods. For example, the correlation between 60-day energy and equity variance risk premia is low (2.62 %) during the first sub period (see Panel A). However, it soars to 47.50 % in the second subsample (see Panel C). More generally, we can clearly see that variance swap returns are strongly correlated with each other during the "financialization" subsample. This stylized fact amounts to direct and model-free evidence that the financialization of commodity markets documented by Tang and Xiong (2012) affects not only the risk premia associated with the first but also the second moment of commodity returns.

Overall, we find some commonalities in variance swap returns across asset classes. Our results show that commodity variance swap returns are increasingly integrated with those of the bond and equity markets, indicating that the financialization of commodity markets is a general phenomenon that affects not only price risk premia but also variance risk premia.

[21] The last two entries of Tables 3 and 4 report summary statistics of bond and equity variance and log variance risk premia, respectively. Briefly, we can see that variance risk is negatively priced in both markets. This is true for both the short and long maturities. More interestingly, a short position in the S&P 500 yields an annual reward to variability ratio of around 37 %. This is important for two reasons. First, it indicates that a portfolio of commodity variance swaps performs as well as a short position in the S&P 500 variance swap. Moreover, the Sharpe Ratio of the short S&P 500 variance swap position is much smaller than the 0.98 documented by Carr and Wu (2009) at the monthly horizon. While this result may be due to a downward sloping term-structure of variance risk premia, it could also highlight the importance of analyzing variance swaps over a long period to draw robust inferences.

D. Price v.s. Variance Risk Premia

We now turn our attention to the relationship between *price* and *variance* risk premia. First, we examine the relationship between equity and bond risk premia on the one hand and commodity variance risk premia on the other. Second, we focus on the link between the variance swap returns of a commodity and its future returns.

D.1 Equity Risk Premia

It is natural to wonder whether variance swap returns are linked to the systematic factors that drive equity risk premia. After all, the negative sign of the market price of variance risk may be consistent with the Capital Asset Pricing Model (CAPM) and its extensions. Specifically, if an asset's volatility is negatively related to the market return, as is the case in equities, then one would expect a negative variance risk premium.

We analyze the relationship between variance swap returns and the 3 factors of Fama and French (1993). We obtain our data from French's website and estimate the following regression for each commodity:

$$LVRP_t = \alpha + \beta MKT_t + \gamma SMB_t + \delta HML_t + \epsilon_t. \tag{9}$$

where $LVRP$, MKT, SMB and HML denote the time series of variance swap returns, the market, small minus big and high minus low factors, respectively.

Tables 9–10 report our main results. We can see highly significant intercepts and, in most cases, statistically insignificant slope estimates, which indicate that commodity variance swap returns are largely orthogonal to the equity risk premium. Furthermore, the three factors typically account for less than 1 % of variations in commodity variance swap returns, leading us to conclude that commodity variance swap returns cannot be satisfactorily explained by the Fama and French (1993) factors.

D.2 Bond Risk Premia

We now investigate how commodity variance swap returns relate to the determinants of bond risk premia. We draw upon the work of Ludvigson and Ng (2009), who implement a dynamic factor analysis decomposition to extract 8 factors from a panel of 132 macroeconomic variables. We also use the Cochrane and Piazzesi (2005) factor, which has been shown to explain bond risk premia. All data are downloaded from Ludvigson's website.[22]

Table 11 presents the results of regressions of 60 day variance risk premia on these factors. On average, the regression yields significant intercepts of large magnitude and very low explanatory power, signaling that commodity variance swap returns are not affected by the drivers of bond risk premia. The coefficient estimates are of very low magnitude, with each factor exhibiting only 3 significant test statistics across all 21 markets. We obtain similar results for variance swaps of 90 day maturity (see Table 12). Clearly, the determinants of bond risk premia cannot explain movements in commodity LVRP satisfactorily.

D.3 Commodity Price Risk Premia

To analyze the relationship between commodity variance risk premia and commodity price risk premia, we regress variance swap returns on futures returns computed as follows

$$RET_{t,T} = \frac{252}{T-t} \sum_{i=t+1}^{T} \log \frac{F_{i,T}}{F_{i-1,T}} \tag{10}$$

where $F_{i,T}$ denotes the futures contract observed at time i and expiring at time T.[23,24] If price and variance risk premia are highly related, we expect to see a high

[22] Note that the monthly series of macro factors stops in December 2003. We restrict our sample of variance swap returns accordingly.

[23] Including the Goldman Sachs Commodity Index (GSCI) in our regression model does not materially affect our results. These are not reported for brevity.

[24] An alternative approach consists in identifying and using factors that explain variations in commodity futures returns. Alas, it is not entirely clear which factors (if any) successfully price commodity futures returns (Daskalaki et al., 2014; Szymanowska et al., 2014). Our direct approach, which broadly mirrors that of the literature on unspanned stochastic volatility, allows us to conveniently sidestep this fiercely debated issue by directly using commodity futures risk premia in the regression model.

explanatory power and significant slope estimates.

Table 13 displays statistically significant intercept estimates in all markets. More importantly, the intercepts are remarkably similar to the unconditional LVRP presented in Table 4. Of the 21 time series of commodity variance swap returns, only 6 exhibit a statistically significant relationship with futures returns. This suggests that there is a weak relationship between price and variance risk premia. This result is further corroborated by the low explanatory power (typically lower than 7 %).

Summarizing, we provide model-free evidence of unspanned stochastic variance in commodity markets: stochastic variance is not spanned by a long position in a single futures contract. A direct implication of this result is that term structure models of commodity futures must allow for both spanned and unspanned stochastic variance. In future work, it would be interesting to dig deeper into this class of models. Trolle and Schwartz (2009) provide an interesting starting point.

E. Robustness Analysis

In this section, we establish the robustness of our findings. To begin with, we demonstrate that our main results hold when we analyze the expected (as opposed to realized) market price of variance risk. Next, we show that our findings are robust to the interpolation technique. We then confirm that the choice of truncation points does not materially affect our main results. Subsequently, we demonstrate that our approach yields implied volatility indices that correlate very well with (the handful of) publicly available volatility indices. We also show that our main findings are robust to liquidity-based explanations. Additionally, we analyze the impact of seasonality on our main results. Lastly, we repeat our analysis using non-overlapping data and confirm that our main results hold.

E.1 Expected Variance Risk Premia

Although consistent with the market definition of variance swap payoffs, it is important to acknowledge that our estimates of variance risk premia implicitly assume that realized variance is equal to the physical expectation of variance.

Strictly speaking the variance risk premium is equal to the difference between the physical and risk-neutral expectations of variance. Viewing realized variance as the sum of the physical expectation of variance plus a forecasting error, our finding of negative variance risk premia could be taken as evidence that the mean forecasting error is negative. Thus, it appears important to also analyze the *expected* market price of variance risk.

Following Bollerslev et al. (2009), we use historical (rather than realized) variance as the floating leg of our variance swap and repeat our analysis. Before discussing the results of this exercise, it is important to stress that the analysis assumes that investors use historical variance to form their expectation about future variance, making the results somewhat model dependent.[25] In a recent study, Bekaert and Hoerova (2014) provide a detailed discussion of this issue and warn that findings based on expected (as opposed to realized) variance risk premia must be interpreted cautiously.

Tables 14 and 15 present the results of this analysis. Typically, expected and realized variance swap returns display a correlation coefficient that is lower than 40 %. More important, investors expect significantly negative variance risk premia in most commodity markets. This result holds for both the bimonthly and quarterly maturities, strengthening our main conclusions.

E.2 Interpolation Technique

We evaluate the robustness of our results to the interpolation technique. To this end, we follow the procedure outlined in Section II with one difference: we use a cubic spline (rather than linear) interpolation technique to obtain a fine grid of implied volatilities. Tables 16 and 17 demonstrate that our results are robust to the interpolation technique. In particular, Column "Corr" shows that the variance risk premia estimated using the spline interpolation technique and those obtained using the linear interpolation are highly correlated. Typically, this correlation coefficient

[25] It is outside of the scope of this paper to identify the best forecasting model of variance. See Andersen et al. (2009) for a recent survey of the literature on variance forecasting.

is greater than 99.9 %. Our main conclusions are unchanged: commodity variance risk premia are significantly negative and of economically large magnitude.

E.3 Truncation Points

We also investigate the sensitivity of our variance swap estimates to the truncation points. We work with tighter truncation points, K_l and K_u, defined as follows:

$$K_l = F_{t,T} \exp^{-8\sigma(T-t)} \quad (11)$$

$$K_u = F_{t,T} \exp^{8\sigma(T-t)} \quad (12)$$

where K_l and K_u refer to the lower and higher truncation points. $F_{t,T}$ refers to the futures contract observed at time t and expiring at T, σ is the average implied volatility of all OTM options and $T-t$ denotes the time to maturity of the option contract.

As Tables 18 and 19 clearly show, our findings are not materially affected by this change. In fact, the numbers reported under "Corr" show that the correlation between the newly estimated variance risk premia and our benchmark estimates is typically greater than 99.9 %. In short, our results are robust to the choice of truncation points.

E.4 The Role of Jumps

We now examine the robustness of our results to the presence of jumps. This is important because jumps could affect the replication of variance swap rates. In a recent study, Rompolis and Tzavalis (2013) show how to gauge the bias induced by jumps. They formally prove that the bias due to jumps (JB) is related to the

model-free skewness (MFS) and kurtosis (MFK):

$$JB_{t,T} = \frac{-2e^{r_t(T-t)}}{T-t}\left[\frac{1}{3!}MFS_{t,T} + \frac{1}{4!}MFK_{t,T}\right] \quad (13)$$

$$MFS_{t,T} = \int_{F_{t,T}}^{+\infty} \frac{6\log[\frac{K}{F_{t,T}}] - 3\ (\log[\frac{K}{F_{t,T}}])^2}{K^2} C(t,K,T)\,dK \quad (14)$$

$$- \int_{0}^{F_{t,T}} \frac{6\log[\frac{K}{F_{t,T}}] + 3(\log[\frac{K}{F_{t,T}}])^2}{K^2} P(t,K,T)\,dK \quad (15)$$

$$MFK_{t,T} = \int_{F_{t,T}}^{+\infty} \frac{12(\log[\frac{K}{F_{t,T}}])^2 - 4\ (\log[\frac{K}{F_{t,T}}])^3}{K^2} C(t,K,T)\,dK \quad (16)$$

$$- \int_{0}^{F_{t,T}} \frac{12(\log[\frac{K}{F_{t,T}}])^2 + 4(\log[\frac{K}{F_{t,T}}])^3}{K^2} P(t,K,T)\,dK \quad (17)$$

where $JB_{t,T}$ refers to the bias due to jumps. The annualized risk-free rate is denoted by r_t. $F_{t,T}$ denotes the futures contract observed at time t and expiring at T. $MFS_{t,T}$ and $MFK_{t,T}$ denote the model-free skewness and kurtosis, respectively. $P(t,K,T)$ and $C(t,K,T)$ denote the price at time t of European put and call options struck at K and expiring at T.

Following Rompolis and Tzavalis, we add together the MFIV and the JB to obtain a jump robust estimate of the risk-neutral expectation of variance. We then repeat our analysis of variance risk premia and variance swap returns. Tables 20 and 21 demonstrate that accounting for the role of jumps does not change our main findings. We still observe significantly negative variance risk premia in most commodity markets, strengthening the conclusion that short variance swap positions are highly profitable in commodity markets.

E.5 Synthetic v.s. Public Volatility Indices

We compare our synthetic swap rates to publicly available volatility indices. Since our methodology broadly mirrors that of the exchange, we expect the synthetic and publicly available variance swap rates to be highly correlated. Although there are volatility indices for the corn, soybeans and wheat markets, these indices were only recently introduced. Hence, we focus only on the crude oil and gold markets. There

are, however, 2 issues that need to be highlighted. First, the crude oil volatility index reported by the exchange is based on a 30 day horizon. In contrast, our synthetic variance swap rates are available for horizons of both 60 and 90 days. To ensure a valid comparison, we create synthetic variance swaps of 30 days for the crude oil market.[26] These variance swaps are used solely for comparison purposes and are not discussed further in the paper. Second, the exchange lists the model-free implied volatility rather than variance. As a result, we square the volatility indices in order to make them comparable to our variance swap rates.

The comparison period extends from May 11, 2007 to September 2, 2011 for crude oil. Similarly, the period of interest starts from September 13, 2010 to August 10, 2011 for gold. Overall, the overlapping periods comprise 1078 and 227 days for the crude oil and gold markets, respectively. We proceed in two steps. First, we compute the correlation between our synthetic variance swap rates and the CME series. As expected, we observe a high correlation between the two series. The correlation coefficients are equal to 97.38 % and 98.04 % for the crude oil and gold markets, respectively. Second, we analyze the mean difference. On average, our synthetic variance swap rate is very close to its CME counterpart. For example, the synthetic swap rate of gold differs from that of the exchange by an average of 11 basis points. In summary, this analysis gives us confidence in our empirical methodology.

E.6 Tradability of Commodity Variance Swaps

Studies on variance risk premia, including those of Carr and Wu (2009) and Driessen et al. (2009), are invariably criticized on the grounds that option contracts may not be actively traded and this may significantly drive the results. We argue that this is unlikely to be true in our case for several reasons. First, the evidence of significantly negative variance risk premia is not specific to a limited number of commodity markets. Rather this finding holds for virtually all commodity markets, making a liquidity-based explanation of our results very challenging. Second, if the lack

[26] Note that the construction of monthly variance swaps is not possible for non-energy commodities. This is due to the fact that non-energy commodity options do not have monthly expiration cycles.

of liquidity significantly drove our results, one would observe large differences in the magnitude, sign, and statistical significance of the variance risk premia during the"financialization" period, where commodities grew in popularity. However, as Table 6 clearly shows, the sign and magnitude of commodity variance risk premia is stable across both the "pre-financialization" and "financialization" samples, making our results difficult to reconcile with a liquidity-based argument.

Another potential concern is that the performance of the diversified portfolio of commodity variance swaps is difficult to achieve in practice because it includes less actively traded commodity markets. To address this concern, we construct an equally-weighted portfolio of commodity variance swaps that includes only the 7 most actively traded commodities. To identify these actively traded commodities, we use the yearly average option trading volume reported in Table 1.[27] The seven markets include corn, crude oil, gold, natural gas, soybeans, sugar and wheat.[28] Our unreported analysis indicates that the newly constructed portfolio yields SR equal to 36.01 % and 17.04 % for the shorter and longer horizons, respectively. Overall, these reward-to-variability ratios are very similar to those reported for the unrestricted portfolio of commodity variance swaps (see Table 4). The upshot of this is that our main findings are robust to liquidity concerns.

One may also wonder about the impact of transaction costs on our variance risk premia estimates. It may be that our synthetic variance swap rate are the sum of the true variance swap rate and transaction costs. It is therefore possible that the variance risk premia estimates presented in Table 3 are biased downwards, i.e. more negative than the true variance risk premia, owing to the influence of transaction costs. To investigate this, we incorporate transaction costs in our analysis. We

[27]To a large extent, the decision to look at the option trading volume for the period 2010–2011 is forced upon us, as the CRB data set does not contain information on the trading volume of individual options. As a further robustness check, we obtain the yearly average futures trading volume for the period 1989–2011 from Bloomberg. We then create another portfolio that includes the 7 commodities with the highest average futures (rather than option) trading volume and obtain very similar results. This is hardly surprising because 6 (of the 7) commodity markets with the highest average option volume are also among the 7 markets with the highest average futures trading volume.

[28]It is worth pointing out that corn, crude oil, gold, soybeans and wheat now have publicly available volatility indices. This highlights the importance of these markets from a trading perspective.

follow two approaches. First, we assume that transaction costs represent 5 % of the synthetic variance swap rate. This implies that the true variance swap rate corresponds to 95 % of the synthetic variance swap rate. For example, if the synthetic variance swap rate is 10% the true variance swap rate is 9.5 %. Second, we allow for fixed transaction costs in the spirit of Duarte et al. (2007), by assuming that the true model-free implied volatility (not variance) is 1 % less than the synthetic model-free implied volatility. This means that if the synthetic model-free implied volatility is 10 %, then the true implied volatility is 9 %, leading to a true variance swap rate of 0.81 %. It is worth noticing that this approach is generally more stringent than the proportional approach, thus yielding very conservative variance risk premia estimates. Tables 22–23 summarize our main results. Although we observe slightly less negative variance risk premia for most commodity markets, we can see that most variance risk premia remain significantly negative. This is true regardless of whether we assume proportional or fixed transaction costs.[29] Collectively, these analyses indicate that our results are not driven by the effect of transaction costs.

E.7 Seasonality in Commodity Variance Swap Returns

Many commodities exhibit seasonal patterns. Suenaga et al. (2008) document the seasonality of realized variance in the natural gas market. More recently, Back et al. (2013) find evidence of seasonality in implied volatilities. One may wonder how this salient feature of commodity markets affects our analysis of commonalities.

To address this concern, we deseasonalize variance swap returns by regressing individual series on twelve monthly dummies. We then use the deseasonalized series to repeat all our analyses. Focusing on our investigation of commonalities across markets, Table 24 reports similar results to our baseline estimates (see Table 7). Clearly, accounting for calendar variations in commodity variance swap returns does

[29] We go a step further and assume that the manager of a portfolio of short variance swaps charges performance fees equal to 20 % of the payoff to variance swaps. This implies that the net-of-fees variance risk premia correspond to 80 % of the figures reported under Tables 22–23. More importantly, the t-statistics of the net-of-performance-fees variance risk premia correspond to approximately $0.9(\sqrt{0.8})$ of those shown in Tables 22–23. Clearly, the significance of our main findings is robust to this.

not materially affect our results.

E.8 Non-Overlapping Samples

Although the various statistics displayed in Table 3 are compelling, they are subject to a potential problem: we estimate realized variance on a rolling window basis. It could be argued that because of the substantial amount of overlap in sampling periods, our results may not be particularly informative. To address such concern, we present summary statistics of non-overlapping variance risk premia in Table 25. Overall, the results are quite similar to those reported in Table 3. The reduction in the autocorrelation of variance risk premia is noteworthy. For example, the autocorrelation of gold's 60 day variance risk premium falls from 0.97 to 0.21. This is not surprising, given that there is no overlap between consecutive variance swap contracts. The results are generally quite similar to those reported in Table 3. In short, variance risk is significantly priced in commodity markets.

IV Conclusion

This paper investigates the market price of variance risk in 21 commodity markets from 1989 to 2011. Using synthetically constructed variance swaps, we present model-free evidence of variance risk premia in commodity markets. More specifically, we show that variance risk is negatively priced in most commodity markets. A portfolio of short commodity variance swaps significantly outperforms that of long commodity futures, highlighting the potential benefits of investing in variance derivatives. Our results hold for variance swap contracts that mature in either 60 or 90 days and we confirm that variance risk is priced during both the "pre-financialization" and "financialization" sample periods.

We find some evidence of commonalities in variance swap returns both within and across commodity sectors. More important, we document increasing comovements between commodity variance swap returns on the one hand and bond and equity variance swap returns on the other. In short, our findings suggest that

the financialization of commodity markets is not restricted to futures markets: it also affects the market for variance swaps.

Finally, we show that commodity variance risk premia are distinct from traditional risk premia. In particular, we establish that the Fama and French (1993) and the Ludvigson and Ng (2009) factors, which successfully capture equity and bond risk premia, cannot explain commodity variance swap returns satisfactorily. Moreover, regressing commodity variance risk premia on price risk premia, we find that the two risk premia are distinct, i.e. variance risk is unspanned by commodity futures.

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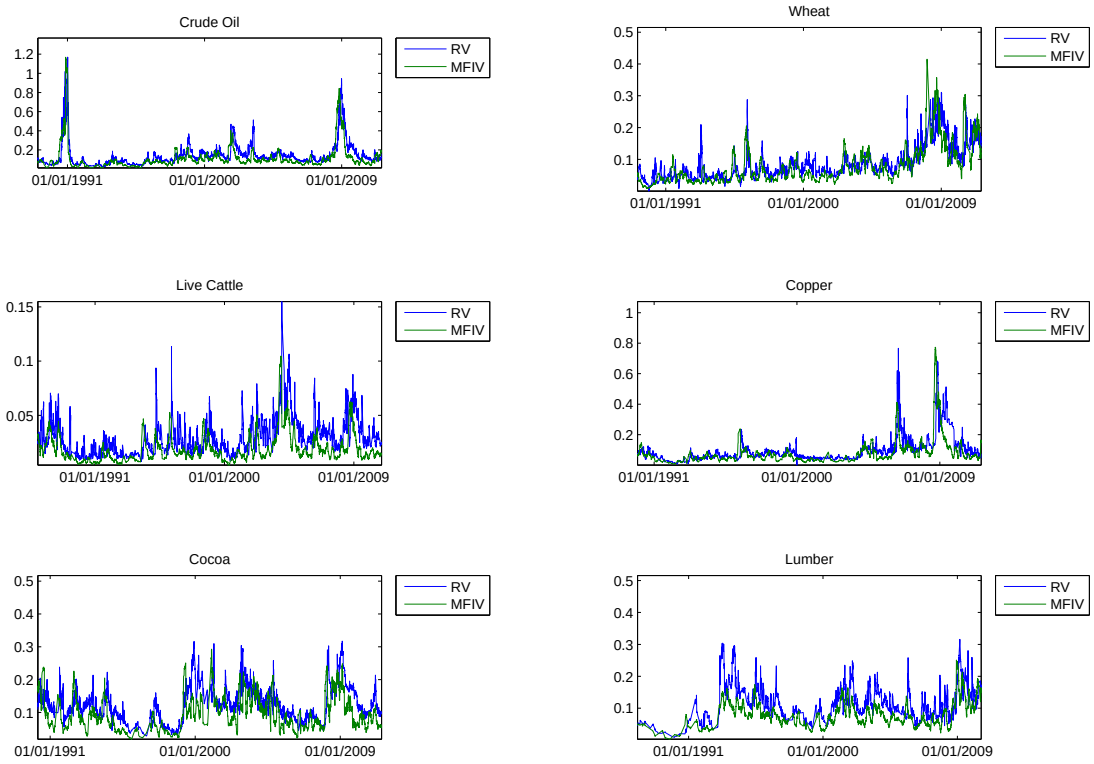

Figure 1: **Time Series of Realized Variance and Model-Free Implied Variance**

This figure displays time series of realized and model-free implied variances for crude oil, wheat, live cattle, copper, cocoa and lumber over a 60 day horizon. The blue and green lines represent model-free implied and realized variances, respectively. The difference between realized and implied variances is the variance risk premium.

Table 1: **Overview of Commodities**

This table lists all commodities considered. The first two columns report the sector and name of specific commodities. The third column displays the exchange where the futures and options contracts of the commodity are traded. The fourth and fifth columns report the available maturity months and minimum tick sizes of the options contracts as reported by the relevant exchange. The sixth column displays the average yearly option volume (based on the years 2010 and 2011). We extract the volume data from the monthly volume reports published on the exchange's websites.

Sector	Commodity	Exchange	Maturity Months	Tick Size	Volume
Energy	Crude Oil	NYMEX	January-December	0.01	35,901,515
	Heating Oil	CME	January-December	0.0001	891,918
	Natural Gas	NYMEX	January-December	0.001	25,995,473
Grains	Corn	CBOT	January, March, May, July, September, November, December	0.25	28,650,380
	Cotton	ICE	March, May, July, October, December	0.01	2,853,173
	Soybeans	CBOT	January, March, May, July, August, September, November	0.25	11,641,356
	Soybean Meal	CBOT	January, March, May, July, August, September, October, December	0.1	984,277
	Soybean Oil	CBOT	January, March, May, July, August, September, October, December	0.01	2,102,072
	Sugar	ICE	March, May, July, October, December	0.01	7,713,957
	Wheat	CBOT	March, May, July, September, December	0.25	4,588,187
Livestock	Lean Hogs	CME	Febuary, April, June, July, August, October, December	0.025	861,942
	Live Cattle	CME	Febuary, April, June, August, October, December	0.025	2,551,210
Metals	Copper	COMEX	Febuary, April, June, August, October, December	0.0005	12,203
	Gold	COMEX	March, May, July, September, December	0.1	8,905,621
	Silver	COMEX	March, May, July, September, December	0.5	1,882,170
Tropical	Cocoa	ICE	March, May, July, September, December	1	487,270
	Colombian Coffee	ICE	March, May, July, September, December	0.05	2,464,992
	Oats	CBOT	March, May, July, September, December	0.25	19,020
	Orange Juice	ICE	January, March, May, July, September, November	0.05	195,483
	Rough Rice	CBOT	January, March, May, July, September, November	0.05	37,770
Wood	Lumber	CME	January, March, May, July, September, November	0.1	8,033

Table 2: **Description of Options Data**

This table summarizes information about the OTM options data. For each commodity, we only retain OTM options that mature between 30 and 120 calendar days. The first two columns report the sector and name of specific commodities. Columns "Starting Date" and "Ending Date" indicate the beginning and end of the sample, respectively. "Days" reports the number of observation days in the sample. The last two columns show the average number of OTM calls and puts with different strike prices on each trading day, respectively.

Sector	Commodity	Starting Date	Ending Date	Days	Calls	Puts
Energy	Crude Oil	January 16, 1989	September 2, 2011	5640	27	22
	Heating Oil	January 11, 1989	September 14, 2011	5660	29	24
	Natural Gas	October 2, 1992	September 14, 2011	4740	51	27
Grains	Corn	February 24, 1989	October 7, 2011	5691	19	13
	Cotton	January 30, 1990	November 16, 2007	4449	20	15
	Soybeans	February 24, 1989	October 7, 2011	5692	20	14
	Soybean Meal	February 24, 1989	October 14, 2011	5686	8	5
	Soybean Oil	February 24, 1989	October 7, 2011	5651	13	11
	Sugar	March 6, 1990	October 4, 2011	5372	26	17
	Wheat	February 24, 1989	October 7, 2011	5692	18	13
Livestock	Lean Hogs	February 1, 1985	May 13, 2011	6612	7	12
	Live Cattle	October 30, 1984	February 28, 2011	6630	9	11
Metals	Copper	December 12, 1989	October 11, 2011	5461	12	14
	Gold	January 3, 1989	October 11, 2011	5704	16	13
	Silver	March 3, 1989	October 26, 2011	5673	24	32
Tropical	Cocoa	March 6, 1990	September 23, 2011	5384	10	6
	Colombian Coffee	March 5, 1990	September 30, 2011	5390	5	19
	Oats	May 1, 1990	August 12, 2011	5344	7	5
	Orange Juice	March 2, 1990	October 7, 2011	5370	8	4
	Rough Rice	April 10, 1992	July 14 2011	4832	9	6
Wood	Lumber	June 5, 1987	November 15, 2010	5680	10	7

Table 3: **Variance Risk Premia**

This table presents summary statistics of the estimated commodity variance risk premia. Columns entitled Mean, T-Stat, Median, AR(1), Min and Max report the average, Newey-West corrected t-statistic (same lag length as the maturity of the swap), median, first order auto-correlation, minimum and maximum variance risk premia. The last four columns display the standard deviation, skewness, kurtosis and number of observations, respectively. Panel A presents the results for a horizon of 60 days, Panel B for a horizon of 90 days.

Panel A: 60 Day Variance risk premia

Sector	Commodity	Mean	T-Stat	Median	AR(1)	Min	Max	Std Dev	Skew	Kurt	Obs
	Crude Oil	-3.4%	-5.96	-3.2%	0.96	-0.62	0.71	0.08	1.28	18.72	5025
Energy	Heating Oil	-3.0%	-7.48	-2.6%	0.94	-0.63	0.63	0.07	0.50	19.75	5210
	Natural Gas	-10.2%	-9.24	-7.3%	0.94	-1.66	0.30	0.15	-1.61	9.72	4394
	Corn	-2.3%	-8.20	-1.9%	0.94	-0.25	0.22	0.04	-0.07	9.19	5024
	Cotton	2.6%	11.10	2.4%	0.94	-0.18	0.16	0.03	0.06	7.41	4149
	Soybeans	-0.8%	-2.06	-1.2%	0.97	-0.19	0.46	0.05	3.01	24.48	5011
Grains	Soybean Meal	0.0%	0.06	-0.6%	0.96	-0.16	0.34	0.05	2.20	13.61	3621
	Soybean Oil	-1.0%	-3.50	-0.9%	0.96	-0.14	0.25	0.04	1.46	12.46	3667
	Sugar	-2.6%	-5.78	-2.3%	0.94	-0.65	0.25	0.06	-0.99	12.31	5225
	Wheat	-0.7%	-2.53	-1.1%	0.94	-0.22	0.26	0.04	0.88	8.82	4340
Livestock	Lean Hogs	-1.2%	-3.01	-1.1%	0.94	-0.30	0.27	0.05	0.15	8.40	3231
	Live Cattle	-1.0%	-11.06	-0.8%	0.93	-0.11	0.05	0.01	-0.46	5.99	4642
	Copper	-2.4%	-3.55	-1.9%	0.97	-0.53	0.62	0.08	1.79	24.21	4220
Metals	Gold	-1.0%	-4.41	-0.9%	0.97	-0.16	0.13	0.03	0.33	10.96	3631
	Silver	-0.2%	-0.83	0.2%	0.98	-0.29	0.13	0.03	-1.40	14.82	5150
	Cocoa	-3.0%	-8.48	-3.1%	0.94	-0.23	0.16	0.05	0.27	4.72	4004
	Colombian Coffee	-1.7%	-0.73	-3.2%	0.97	-0.51	1.04	0.17	3.01	16.51	1794
Tropical	Oats	-6.2%	-7.68	-6.2%	0.95	-0.52	0.41	0.07	0.52	9.40	2095
	Orange Juice	-2.3%	-3.31	-2.3%	0.97	-0.53	0.30	0.08	-0.33	10.43	3303
	Rough Rice	-3.0%	-8.28	-2.7%	0.92	-0.30	0.20	0.04	-0.11	6.67	2835
Wood	Lumber	-3.5%	-10.36	-3.0%	0.95	-0.22	0.13	0.04	-0.86	5.51	3660
	Diversified	-2.1%	-10.61	-2.0%	0.94	-0.24	0.13	0.04	0.37	7.59	5454
Other	S&P 500	-1.5%	-3.01	-1.8%	0.98	-0.35	0.52	0.06	4.66	41.38	3998
	Treasury	-2.8%	-3.28	-1.3%	0.93	-0.44	0.09	0.07	-3.47	14.81	2981

Panel B: 90 Day Variance risk premia

Sector	Commodity	Mean	T-Stat	Median	AR(1)	Min	Max	Std Dev	Skew	Kurt	Obs
	Crude Oil	-3.6%	-5.40	-3.1%	0.97	-0.77	0.47	0.07	0.17	17.63	5477
Energy	Heating Oil	-3.2%	-6.29	-2.7%	0.96	-0.72	0.30	0.06	-0.92	13.84	5190
	Natural Gas	-9.1%	-8.86	-6.6%	0.95	-1.79	0.24	0.12	-2.16	17.14	4374
	Corn	-1.8%	-5.21	-1.6%	0.96	-0.20	0.22	0.04	0.79	9.69	5004
	Cotton	1.5%	6.91	1.3%	0.97	-0.09	0.10	0.02	0.57	4.91	4134
	Soybeans	1.8%	1.22	-0.8%	0.99	-0.19	1.29	0.15	6.06	44.89	4991
Grains	Soybean Meal	4.2%	2.14	0.3%	0.99	-0.15	1.47	0.18	5.54	38.11	3601
	Soybean Oil	-0.7%	-2.26	-0.8%	0.96	-0.13	0.19	0.03	1.35	10.23	3647
	Sugar	-2.2%	-4.36	-2.0%	0.92	-0.85	0.34	0.07	-2.52	33.45	5191
	Wheat	-0.6%	-1.77	-0.9%	0.96	-0.22	0.21	0.04	1.21	8.61	4325
Livestock	Lean Hogs	4.3%	3.68	1.2%	0.98	-0.26	0.42	0.10	1.28	4.44	3210
	Live Cattle	-0.5%	-4.97	-0.5%	0.96	-0.09	0.04	0.01	-0.08	6.66	4622
	Copper	-2.4%	-3.06	-2.0%	0.97	-0.63	0.49	0.08	1.00	17.09	4189
Metals	Gold	-1.1%	-3.83	-1.0%	0.97	-0.18	0.12	0.03	-0.33	10.10	3611
	Silver	-1.2%	-2.76	-0.1%	0.99	-0.27	0.10	0.04	-1.60	8.58	5239
	Cocoa	-3.1%	-7.71	-3.1%	0.95	-0.24	0.12	0.04	-0.03	4.97	3984
	Colombian Coffee	-1.3%	-0.48	-3.0%	0.98	-0.45	0.81	0.16	2.63	12.50	1774
Tropical	Oats	-2.0%	-0.91	-5.1%	0.98	-0.27	1.24	0.17	5.05	31.91	2075
	Orange Juice	-3.0%	-4.99	-2.4%	0.96	-0.36	0.13	0.06	-1.00	5.93	3283
	Rough Rice	-2.3%	-5.34	-2.2%	0.95	-0.29	0.15	0.04	-0.27	5.60	2815
Wood	Lumber	-2.3%	-5.29	-2.3%	0.97	-0.21	0.12	0.04	-1.03	7.31	3640
	Diversified	-1.5%	-5.58	-1.6%	0.94	-0.31	0.20	0.03	1.31	11.37	5434
Other	S&P 500	-1.5%	-2.60	-1.8%	0.99	-0.31	0.48	0.06	4.53	36.32	3958
	Treasury	-1.5%	-2.73	-1.1%	0.94	-0.24	0.13	0.04	-2.66	14.52	2074

Table 4: **Log Variance Risk Premia**

This table presents summary statistics of the estimated log variance risk premia. Columns entitled Mean, T-Stat, Median, AR(1), Min and Max report the average, Newey-West corrected t-statistic (same lag length as the maturity of variance swaps) , median, first order auto-correlation, minimum and maximum values of log variance risk premia. The last five columns report the standard deviation, skewness, kurtosis, Newey-West adjusted Sharpe Ratios (annualized) and number of observations, respectively. Panel A presents the results for a horizon of 60 days, Panel B for a horizon of 90 days.

Panel A: 60 Day Log Variance Risk Premia

Sector	Commodity	Mean	T-Stat	Median	AR(1)	Min	Max	Std Dev	Skew	Kurt	SR	Obs
	Crude Oil	-33.9%	-10.64	-38.0%	0.97	-1.52	1.63	0.43	0.57	3.58	36.8%	5025
Energy	Heating Oil	-29.5%	-10.04	-32.1%	0.95	-1.80	2.01	0.42	0.41	4.40	34.1%	5210
	Natural Gas	-43.0%	-12.71	-43.1%	0.95	-1.96	1.26	0.47	0.06	3.22	47.0%	4394
	Corn	-44.2%	-12.66	-44.0%	0.95	-2.17	1.22	0.47	0.00	3.00	43.7%	5024
	Cotton	66.9%	16.68	69.9%	0.91	-1.30	5.52	0.57	0.14	5.20	63.4%	4149
	Soybeans	-25.6%	-6.55	-29.9%	0.97	-1.65	1.82	0.53	0.50	3.62	22.7%	5011
Grains	Soybean Meal	-8.5%	-2.31	-12.2%	0.95	-1.90	2.11	0.50	0.37	3.67	9.4%	3621
	Soybean Oil	-21.6%	-5.75	-20.6%	0.96	-1.77	1.32	0.47	-0.02	3.09	23.3%	3667
	Sugar	-22.8%	-7.20	-24.1%	0.95	-1.95	1.27	0.43	0.31	3.28	24.4%	5225
	Wheat	-16.1%	-4.94	-18.7%	0.93	-2.19	4.99	0.47	0.43	7.10	18.4%	4340
Livestock	Lean Hogs	-18.3%	-4.04	-18.3%	0.95	-1.92	1.44	0.50	0.04	3.23	17.4%	3231
	Live Cattle	-46.0%	-13.95	-49.5%	0.95	-1.95	1.45	0.46	0.42	3.61	50.2%	4642
	Copper	-29.9%	-7.65	-32.5%	0.94	-1.73	4.66	0.50	0.75	6.37	28.8%	4220
Metals	Gold	-34.6%	-8.32	-37.9%	0.96	-1.79	2.09	0.54	0.50	3.88	33.8%	3631
	Silver	44.1%	3.89	24.6%	0.90	-2.58	5.96	1.21	0.81	3.78	13.3%	5150
	Cocoa	-32.3%	-10.26	-32.3%	0.95	-1.66	1.09	0.40	0.09	3.39	39.7%	4004
	Colombian Cofee	-22.6%	-2.47	-31.1%	0.97	-2.22	2.87	0.68	1.31	6.15	14.3%	1794
Tropical	Oats	-86.5%	-9.97	-85.8%	0.97	-2.33	1.25	0.67	0.48	3.09	53.4%	2095
	Orange Juice	-23.3%	-4.39	-27.7%	0.96	-2.54	2.46	0.61	0.40	4.79	18.7%	3303
	Rough Rice	-45.3%	-9.41	-47.1%	0.93	-1.92	1.85	0.53	0.31	3.25	43.3%	2835
Wood	Lumber	-37.0%	-13.58	-38.6%	0.95	-1.93	1.20	0.36	0.20	3.75	55.0%	3660
	Diversified	-21.1%	-11.44	-23.0%	0.93	-1.18	0.90	0.24	0.66	4.15	37.9%	5454
Other	S&P 500	-53.7%	-9.57	-62.9%	0.98	-2.04	2.32	0.60	1.12	5.36	37.1%	3998
	Treasury	-55.4%	-10.47	-58.7%	0.95	-2.60	1.13	0.48	0.08	4.49	47.0%	2981

Panel B: 90 Day Log Variance Risk Premia

Sector	Commodity	Mean	T-Stat	Median	AR(1)	Min	Max	Std Dev	Skew	Kurt	SR	Obs
	Crude Oil	-39.3%	-9.31	-42.0%	0.98	-1.52	1.71	0.45	0.61	3.83	25.2%	5477
Energy	Heating Oil	-32.2%	-8.17	-31.6%	0.97	-1.65	1.74	0.43	0.55	4.76	22.7%	5190
	Natural Gas	-43.6%	-11.55	-44.1%	0.97	-2.04	1.48	0.45	-0.11	3.05	34.9%	4374
	Corn	-37.4%	-9.08	-38.0%	0.96	-1.88	1.13	0.46	0.19	3.30	25.7%	5004
	Cotton	31.4%	7.94	31.3%	0.97	-0.88	1.51	0.39	-0.06	2.70	24.7%	4134
	Soybeans	-12.0%	-1.99	-20.6%	0.98	-1.82	3.06	0.63	1.22	5.94	5.6%	4991
Grains	Soybean Meal	13.4%	2.26	6.1%	0.97	-1.37	2.40	0.59	0.92	4.44	7.5%	3601
	Soybean Oil	-15.4%	-3.67	-17.0%	0.96	-1.73	1.29	0.44	0.18	3.39	12.1%	3647
	Sugar	-19.8%	-5.17	-23.1%	0.92	-2.40	3.03	0.47	0.64	5.14	14.3%	5191
	Wheat	-15.1%	-3.82	-18.5%	0.97	-1.41	1.24	0.41	0.34	3.36	11.6%	4325
Livestock	Lean Hogs	28.1%	3.34	18.5%	0.98	-1.11	4.46	0.71	0.70	3.47	11.8%	3210
	Live Cattle	-22.9%	-6.65	-28.0%	0.97	-1.32	1.38	0.41	0.67	3.73	19.6%	4622
	Copper	-29.3%	-6.41	-32.7%	0.96	-1.55	1.85	0.49	0.81	4.68	19.8%	4189
Metals	Gold	-34.7%	-6.67	-37.5%	0.97	-1.86	1.67	0.53	0.33	3.48	22.2%	3611
	Silver	9.8%	0.72	-9.1%	0.98	-2.86	3.80	1.12	0.56	2.83	2.0%	5239
	Cocoa	-31.9%	-8.91	-33.2%	0.96	-1.35	1.05	0.38	0.39	3.67	28.2%	3984
	Colombian Cofee	-18.6%	-1.70	-28.8%	0.98	-1.54	2.68	0.68	1.63	7.04	8.1%	1774
Tropical	Oats	-65.5%	-5.73	-73.2%	0.98	-2.19	2.43	0.78	1.29	5.79	25.2%	2075
	Orange Juice	-26.5%	-4.55	-31.5%	0.97	-2.39	1.43	0.55	-0.09	3.74	15.9%	3283
	Rough Rice	-35.4%	-6.37	-37.4%	0.96	-1.65	1.62	0.52	0.08	2.84	24.0%	2815
Wood	Lumber	-25.8%	-7.32	-29.3%	0.97	-1.50	1.25	0.40	0.26	3.31	24.3%	3640
	Diversified	-19.1%	-8.70	-22.3%	0.96	-1.01	0.77	0.23	0.61	3.60	23.6%	5434
Other	S&P 500	-51.5%	-8.03	-64.3%	0.99	-1.77	2.34	0.61	1.22	5.42	31.3%	3958
	Treasury	-42.1%	-7.37	-51.6%	0.96	-1.88	1.20	0.45	0.84	3.75	39.7%	2074

Table 5: **Time Variation in Variance Risk Premia**

This table reports results from the regressions of variance risk premia on fractionally differenced historical variance. $\tilde{\alpha}$ reports the intercept estimates and the corresponding t-statistics (in brackets). The t-statistics are adjusted following the method of Newey-West with lag length equal to the maturity of the variance swap. $\tilde{\beta}$ reports the slope estimate and the corresponding t-statistic (in brackets). Columns $\dot{\alpha}$ and $\dot{\beta}$ present the analogous regression results for log variance risk premia.

Panel A: 60 Day Variance Risk Premia

Sector	**Commodity**	$\tilde{\alpha}$		$\tilde{\beta}$		*Adj* R^2	$\dot{\alpha}$		$\dot{\beta}$		*Adj* R^2
	Crude Oil	-0.03	(-6.11)	-0.05	(-0.35)	0.0%	-0.33	(-9.47)	0.10	(0.59)	0.1%
Energy	Heating Oil	-0.03	(-7.36)	-0.31	(-1.88)	1.3%	-0.34	(-11.51)	-0.46	(-3.32)	3.2%
	Natural Gas	-0.10	(-9.56)	-1.07	(-4.24)	5.6%	-0.48	(-13.8)	-0.65	(-3.44)	5.6%
	Corn	-0.02	(-9.69)	-0.09	(-0.22)	0.0%	-0.42	(-10.64)	0.24	(1.36)	1.1%
	Cotton	0.03	(11.13)	0.43	(2.12)	1.3%	0.63	(14.56)	-0.31	(-1.9)	0.8%
	Soybeans	-0.01	(-2.13)	0.04	(0.31)	0.0%	-0.26	(-6.44)	0.01	(0.06)	0.0%
Grains	Soybean Meal	0.00	(0.14)	-0.07	(-0.48)	0.0%	-0.09	(-2.41)	-0.09	(-0.73)	0.1%
	Soybean Oil	-0.01	(-3.84)	0.17	(0.8)	0.2%	-0.24	(-5.38)	-0.16	(-1.16)	0.4%
	Sugar	-0.02	(-5.69)	-0.47	(-2.2)	1.3%	-0.24	(-7.43)	-0.13	(-0.79)	0.2%
	Wheat	-0.01	(-2.23)	-0.17	(-0.63)	0.3%	-0.13	(-3.98)	0.25	(1.53)	1.0%
Livestock	Lean Hogs	-0.01	(-3.16)	-0.06	(-0.21)	0.0%	-0.19	(-3.68)	-0.08	(-0.53)	0.1%
	Live Cattle	-0.01	(-10.58)	-0.41	(-2.26)	1.0%	-0.50	(-13.4)	-0.27	(-2.01)	1.1%
	Copper	-0.02	(-3.45)	-0.08	(-0.21)	0.0%	-0.31	(-6.88)	-0.04	(-0.33)	0.0%
Metals	Gold	-0.01	(-4.45)	-0.59	(-1.17)	2.5%	-0.36	(-7.17)	-0.10	(-0.6)	0.2%
	Silver	0.00	(-0.7)	-0.71	(-0.91)	1.8%	0.28	(2.26)	-0.98	(-2.93)	3.3%
	Cocoa	-0.03	(-8.68)	-0.20	(-1.01)	0.4%	-0.33	(-9.94)	-0.05	(-0.37)	0.0%
	Colombian Coffee	-0.02	(-0.96)	0.56	(1.48)	2.7%	-0.22	(-2.02)	0.05	(0.16)	0.0%
Tropical	Oats	-0.06	(-7.51)	0.21	(1.72)	0.3%	-0.78	(-8.54)	0.42	(3.09)	3.1%
	Orange Juice	-0.02	(-3.11)	-0.50	(-2.84)	2.0%	-0.26	(-4.73)	-0.18	(-1.16)	0.4%
	Rough Rice	-0.03	(-8.23)	-0.09	(-0.4)	0.0%	-0.46	(-8.38)	-0.09	(-0.35)	0.1%
Wood	Lumber	-0.03	(-10.43)	-0.66	(-2.23)	2.1%	-0.40	(-12.93)	-0.28	(-2.36)	1.8%

Panel B: 90 Day Variance Risk Premia

Sector	**Commodity**	$\tilde{\alpha}$		$\tilde{\beta}$		*Adj* R^2	$\dot{\alpha}$		$\dot{\beta}$		*Adj* R^2
	Crude Oil	-0.03	(-5.22)	-0.72	(-2.26)	4.19%	-0.40	(-8.63)	-0.10	(-0.45)	0.10%
Energy	Heating Oil	-0.03	(-7.08)	-0.37	(-1.15)	1.24%	-0.35	(-8.51)	-0.20	(-1.37)	0.51%
	Natural Gas	-0.09	(-8.83)	-0.51	(-1.61)	0.97%	-0.44	(-10.59)	0.01	(0.03)	-0.02%
	Corn	-0.02	(-5.39)	-0.38	(-1.36)	1.24%	-0.36	(-8.11)	0.12	(0.62)	0.22%
	Cotton	0.01	(6.76)	0.37	(0.91)	0.84%	0.31	(6.92)	-0.04	(-0.25)	0.00%
	Soybeans	0.02	(1.14)	-0.01	(-0.21)	-0.02%	-0.14	(-2.13)	-0.06	(-0.41)	0.03%
Grains	Soybean Meal	0.04	(2.11)	-0.19	(-1.86)	0.30%	0.12	(2.05)	-0.12	(-1.13)	0.21%
	Soybean Oil	-0.01	(-3.09)	0.48	(1.31)	1.67%	-0.14	(-2.84)	0.17	(1.01)	0.40%
	Sugar	-0.02	(-3.73)	-1.01	(-3.15)	4.35%	-0.24	(-5.98)	-0.32	(-1.52)	0.90%
	Wheat	-0.01	(-1.69)	0.00	(0)	-0.02%	-0.11	(-2.82)	0.24	(1.09)	1.03%
Livestock	Lean Hogs	0.05	(3.77)	-0.25	(-1.31)	0.46%	0.27	(2.92)	-0.17	(-0.85)	0.23%
	Live Cattle	0.00	(-4.91)	-0.35	(-1.12)	0.84%	-0.27	(-6.17)	-0.27	(-1.52)	1.08%
	Copper	-0.02	(-2.8)	-0.29	(-0.68)	0.30%	-0.32	(-6.07)	-0.19	(-1)	0.35%
Metals	Gold	-0.01	(-3.78)	-1.02	(-1.63)	4.67%	-0.38	(-5.89)	-0.15	(-0.81)	0.35%
	Silver	-0.01	(-2.8)	-1.29	(-0.9)	2.46%	-0.13	(-0.89)	-1.41	(-3.23)	6.13%
	Cocoa	-0.03	(-7.85)	-0.26	(-1.61)	0.54%	-0.32	(-8.58)	0.12	(0.65)	0.16%
	Colombian Coffee	-0.01	(-0.5)	0.22	(0.83)	0.24%	-0.20	(-1.86)	-0.23	(-0.84)	0.41%
Tropical	Oats	-0.02	(-0.73)	-0.04	(-0.48)	-0.03%	-0.60	(-5.29)	0.13	(0.8)	0.24%
	Orange Juice	-0.03	(-5.09)	-0.23	(-0.75)	0.18%	-0.25	(-4.13)	0.21	(1.37)	0.46%
	Rough Rice	-0.02	(-5.62)	-0.30	(-0.94)	0.65%	-0.35	(-5.36)	0.08	(0.54)	0.10%
Wood	Lumber	-0.02	(-5.27)	-0.85	(-1.85)	2.56%	-0.27	(-6.77)	-0.11	(-0.73)	0.21%

Table 6: **Market Regimes**

This table reports mean variance risk premia, t-statistics and number of observations over each subsample. We report Newey-West corrected t-statistics, with lag length equal to the maturity of variance swaps, in brackets. The first subsample covers the period ending before December 2004. The second period runs from December 2004 onward.

Panel A: 60 Day Variance Risk Premia

Sector	Commodity	Before Dec 2004			After Dec 2004		
		Mean	T-Stat	Obs	Mean	T-Stat	Obs
Energy	Crude Oil	-3.24%	-5.83	3,357	-3.68%	-2.84	1,668
	Heating Oil	-2.51%	-6.02	3,550	-4.18%	-4.75	1,660
	Natural Gas	-9.21%	-7.15	2,739	-11.88%	-6.03	1,655
Grains	Corn	-2.15%	-10.39	3,544	-2.55%	-3.21	1,480
	Cotton	2.83%	10.93	3,485	1.45%	3.48	664
	Soybean	-0.04%	-0.07	3,428	-2.49%	-4.45	1,583
	Soybean Meal	0.29%	0.81	2,353	-0.47%	-0.50	1,268
	Soybean Oil	-0.85%	-3.99	2,408	-1.31%	-1.80	1,259
	Sugar	-2.42%	-5.38	3,574	-2.82%	-2.83	1,651
	Wheat	-0.69%	-2.88	3,064	-0.77%	-1.00	1,276
Livestock	Lean Hogs	-1.12%	-2.07	1,837	-1.37%	-2.22	1,394
	Live Cattle	-0.81%	-8.34	3,388	-1.55%	-9.68	1,254
Metals	Copper	-1.25%	-5.23	2,579	-4.12%	-2.56	1,641
	Gold	-0.77%	-5.34	1,996	-1.31%	-2.77	1,635
	Silver	0.78%	3.50	3,515	-2.41%	-4.50	1,635
Tropical	Cocoa	-2.80%	-6.21	2,453	-3.41%	-5.85	1,551
	Colombian Coffee	-1.72%	-0.73	1,794	—	—	—
	Oats	-7.01%	-6.08	1,244	-5.01%	-5.19	851
	Orange Juice	-2.54%	-2.36	1,788	-2.03%	-2.47	1,515
	Rough Rice	-3.53%	-7.79	1,861	-1.91%	-3.96	974
Wood	Lumber	-3.89%	-9.30	2,585	-2.50%	-5.32	1,075

Panel B: 90 Day Variance Risk Premia

Sector	Commodity	Before Dec 2004			After Dec 2004		
		Mean	T-Stat	Obs	Mean	T-Stat	Obs
Energy	Crude Oil	-3.46%	-5.52	3,842	-3.89%	-2.33	1,635
	Heating Oil	-2.61%	-5.14	3,550	-4.42%	-3.95	1,640
	Natural Gas	-8.29%	-6.85	2,739	-10.33%	-5.73	1,635
Grains	Corn	-1.47%	-4.62	3,544	-2.50%	-2.95	1,460
	Cotton	1.63%	7.13	3,488	0.54%	1.30	646
	Soybean	3.44%	1.62	3,428	-1.66%	-2.71	1,563
	Soybean Meal	3.25%	2.71	2,353	6.10%	1.17	1,248
	Soybean Oil	-0.52%	-2.15	2,408	-1.14%	-1.40	1,239
	Sugar	-1.99%	-3.95	3,560	-2.70%	-2.30	1,631
	Wheat	-0.58%	-2.09	3,069	-0.56%	-0.63	1,256
Livestock	Lean Hogs	3.57%	2.66	1,837	5.20%	2.61	1,373
	Live Cattle	-0.34%	-3.40	3,388	-0.80%	-4.52	1,234
Metals	Copper	-1.29%	-5.10	2,568	-4.10%	-2.15	1,621
	Gold	-0.88%	-5.36	1,996	-1.36%	-2.27	1,615
	Silver	0.33%	1.01	3,624	-4.77%	-6.18	1,615
Tropical	Cocoa	-2.83%	-5.78	2,453	-3.51%	-5.18	1,531
	Colombian Coffee	-1.30%	-0.48	1,774	—	—	—
	Oats	-1.22%	-0.34	1,244	-3.16%	-2.97	831
	Orange Juice	-3.73%	-4.78	1,788	-2.16%	-2.41	1,495
	Rough Rice	-2.53%	-4.42	1,861	-1.73%	-3.35	954
Wood	Lumber	-2.87%	-5.33	2,585	-0.99%	-1.64	1,055

Table 7: **Commonalities in Variance Swap Returns**

This table summarizes the correlations of log variance risk premia within and across different commodity sectors. In Panel A, we report the average pair-wise correlation across all commodities of the same family. For example, we calculate the pair-wise correlations between crude oil, heating oil and natural gas. We then compute the average of these correlations which we report under the appropriate sector: energy. Columns headed "60-Day" and "90-Day" indicate a maturity of 60 and 90 days, respectively. Panels B and C report correlations across different commodity sectors for variance swaps of maturity 60 and 90 days, respectively. These correlations are calculated as follows. For each sector and trading day, we calculate the return on an equally-weighted portfolio of variance swaps of all commodities belonging to that specific sector. After calculating the returns of each portfolio, we compute the pair-wise correlations of returns across sectors, which we report in Panels B and C.

Panel A: Commonalities Within Sector

Sector	Correlation	
	60 Day	90 Day
Energy	33.42%	32.83%
Grains	24.19%	21.02%
Livestock	31.38%	20.07%
Metals	30.08%	33.05%
Tropical	5.68%	11.48%
Wood	—	—

Panel B: Commonalities Across Sectors (60 Day)

Sector	Energy	Grains	Livestock	Metals	S&P500	Treasury	Tropical	Wood
Energy	100.00%							
Grains	9.01%	100.00%						
Livestock	13.21%	14.88%	100.00%					
Metals	22.13%	14.47%	6.54%	100.00%				
S&P500	26.50%	1.98%	16.37%	30.71%	100.00%			
Treasury	20.18%	16.04%	5.31%	23.10%	39.34%	100.00%		
Tropical	8.88%	24.65%	11.73%	11.56%	5.86%	0.30%	100.00%	
Wood	7.31%	0.88%	7.83%	3.85%	9.47%	6.53%	11.73%	100.00%

Panel C: Commonalities Across Sectors (90 Day)

Sector	Energy	Grains	Livestock	Metals	S&P500	Treasury	Tropical	Wood
Energy	100.00%							
Grains	8.17%	100.00%						
Livestock	11.69%	15.81%	100.00%					
Metals	24.23%	10.69%	-7.05%	100.00%				
S&P500	27.50%	6.57%	16.15%	32.30%	100.00%			
Treasury	21.38%	20.45%	-0.81%	11.90%	51.89%	100.00%		
Tropical	17.80%	33.87%	14.39%	13.54%	5.32%	-5.39%	100.00%	
Wood	16.33%	6.75%	10.41%	-3.44%	9.43%	15.91%	12.13%	100.00%

Table 8: **Time Varying Commonalities in Variance Swap Returns**

This table summarizes the correlations of variance swap returns across different markets. For each commodity sector and trading day, we calculate the return on an equally-weighted portfolio of variance swaps of all commodities belonging to a specific sector. After calculating the returns of each portfolio, we compute the pair-wise correlations of returns across different sectors. We then compute the correlations between Energy, Grains, Livestock, Metals, S&P 500, Treasury, Tropical and Wood variance swap returns. We perform our analysis over two distinct periods. The pre-financialization period stops before December, 2004. The financialization period covers the remaining sample.

Panel A: Pre-Financialization (60 Day)

Sector	Energy	Grains	Livestock	Metals	S&P500	Treasury	Tropical	Wood
Energy	100.00%							
Grains	7.24%	100.00%						
Livestock	11.35%	15.83%	100.00%					
Metals	13.53%	2.91%	-0.74%	100.00%				
S&P500	2.62%	-7.11%	7.51%	16.35%	100.00%			
Treasury	1.98%	-2.08%	1.93%	0.98%	25.00%	100.00%		
Tropical	9.35%	21.92%	8.02%	14.43%	-14.36%	-4.64%	100.00%	
Wood	-0.17%	-3.55%	7.39%	9.99%	-0.73%	8.46%	10.87%	100.00%

Panel B: Pre-Financialization (90 Day)

Sector	Energy	Grains	Livestock	Metals	S&P500	Treasury	Tropical	Wood
Energy	100.00%							
Grains	8.27%	100.00%						
Livestock	14.57%	27.49%	100.00%					
Metals	17.43%	0.96%	-11.63%	100.00%				
S&P500	-4.80%	-4.64%	8.83%	10.32%	100.00%			
Treasury	4.61%	7.04%	5.95%	-10.41%	41.47%	100.00%		
Tropical	18.93%	33.66%	13.11%	16.39%	-15.46%	-12.94%	100.00%	
Wood	7.94%	4.20%	6.16%	-2.28%	-12.67%	11.30%	10.03%	100.00%

Panel C: Financialization (60 Day)

Sector	Energy	Grains	Livestock	Metals	S&P500	Treasury	Tropical	Wood
Energy	100.00%							
Grains	8.01%	100.00%						
Livestock	14.50%	9.58%	100.00%					
Metals	46.30%	22.96%	19.29%	100.00%				
S&P500	47.50%	12.08%	30.11%	64.30%	100.00%			
Treasury	43.90%	35.26%	6.84%	56.74%	61.78%	100.00%		
Tropical	12.24%	43.09%	29.01%	32.69%	28.31%	20.82%	100.00%	
Wood	23.91%	12.76%	11.46%	3.67%	15.26%	6.00%	10.43%	100.00%

Panel D: Financialization (90 Day)

Sector	Energy	Grains	Livestock	Metals	S&P500	Treasury	Tropical	Wood
Energy	100.00%							
Grains	5.99%	100.00%						
Livestock	8.06%	-0.72%	100.00%					
Metals	47.32%	18.22%	12.95%	100.00%				
S&P500	54.85%	18.07%	23.23%	67.10%	100.00%			
Treasury	46.23%	42.97%	-12.27%	59.70%	65.74%	100.00%		
Tropical	17.30%	44.94%	16.96%	28.89%	32.12%	10.46%	100.00%	
Wood	33.87%	16.74%	13.97%	8.45%	26.04%	21.12%	12.25%	100.00%

Table 9: **Equity Risk Premia v.s. Commodity Variance Risk Premia: 60 Day**

This table reports results of regressions of 60 day variance swap returns on the Fama–French 3 factors. Specifically, we run the following regression:

$$LVRP_t = \alpha + \beta MKT_t + \gamma SMB_t + \delta HML_t + \epsilon$$

where LVRP, MKT, and SMB denote the quarterly log variance risk premium, the market risk premium, small minus big, and high minus low factors, respectively. We download the Fama–French factors from French's website. We report in brackets the Newey-West corrected t-statistics of the coefficient estimates.

Sector	**Commodity**	α	MKT	SMB	HML	$AdjR^2$	**Nobs**
Energy	Crude Oil	-0.34	-0.01	-0.01	-0.01	0.07%	5025
		(-10.63)	(-2.17)	(-1.01)	(-0.71)		
	Heating Oil	-0.29	-0.02	-0.02	-0.01	0.16%	5210
		(-10.03)	(-3.2)	(-1.57)	(-1.16)		
	Natural Gas	-0.43	-0.01	-0.01	0.03	0.26%	4394
		(-12.75)	(-1.62)	(-0.88)	(2.65)		
Grains	Corn	-0.44	-0.01	0.00	0.00	-0.03%	5024
		(-12.66)	(-0.98)	(0.14)	(0.38)		
	Cotton	0.67	0.03	0.01	0.04	0.05%	4149
		(16.79)	(2.02)	(0.61)	(1.24)		
	Soybeans	-0.26	-0.01	0.00	0.01	-0.01%	5011
		(-6.54)	(-1.1)	(-0.38)	(1.05)		
	Soybean Meal	-0.09	0.01	0.00	0.02	-0.03%	3621
		(-2.32)	(1.06)	(0.04)	(1.1)		
	Soybean Oil	-0.22	-0.01	0.02	0.00	0.01%	3667
		(-5.75)	(-1.55)	(1.24)	(0.1)		
	Sugar	-0.23	-0.01	0.00	0.00	0.01%	5225
		(-7.2)	(-2.17)	(0)	(-0.34)		
	Wheat	-0.16	-0.01	-0.02	0.00	0.09%	4340
		(-4.93)	(-2.45)	(-1.71)	(0.04)		
Livestock	Lean Hogs	-0.18	0.01	0.02	0.01	0.02%	3231
		(-4.05)	(1.5)	(1.58)	(0.39)		
	Live Cattle	-0.46	-0.01	-0.01	-0.01	0.02%	4642
		(-13.93)	(-1.85)	(-0.56)	(-0.69)		
Metals	Copper	-0.30	-0.02	0.01	0.01	0.15%	4220
		(-7.67)	(-3.07)	(0.46)	(0.65)		
	Gold	-0.35	-0.01	0.00	-0.01	0.02%	3631
		(-8.33)	(-1.95)	(0.21)	(-0.72)		
	Silver	0.44	-0.02	-0.01	-0.08	0.14%	5150
		(3.9)	(-1.63)	(-0.45)	(-2.43)		
Tropical	Cocoa	-0.32	-0.01	0.00	0.00	0.04%	4004
		(-10.26)	(-2.42)	(-0.26)	(0.3)		
	Colombian Coffee	-0.22	0.01	0.01	-0.03	0.03%	1794
		(-2.43)	(0.41)	(0.15)	(-0.51)		
	Oats	-0.87	0.00	0.04	0.05	0.12%	2095
		(-10)	(-0.1)	(1.62)	(2.13)		
	Orange Juice	-0.23	-0.01	-0.02	0.00	-0.05%	3303
		(-4.39)	(-0.94)	(-0.67)	(-0.06)		
	Rough Rice	-0.45	0.00	0.00	0.00	-0.10%	2835
		(-9.4)	(-0.54)	(0.25)	(0.08)		
Wood	Lumber	-0.37	0.00	-0.01	0.01	0.03%	3660
		(-13.56)	(-0.25)	(-1.08)	(1.11)		

Table 10: **Equity Risk Premia v.s. Commodity Variance Risk Premia: 90 Day**

This table reports results of regressions of 90 day variance swap returns on the Fama–French 3 factors. Specifically, we run the following regression:

$$LVRP_t = \alpha + \beta MKT_t + \gamma SMB_t + \delta HML_t + \epsilon$$

where LVRP, MKT, and SMB denote the quarterly log variance risk premium, the market risk premium, small minus big, and high minus low factors, respectively. We download the Fama–French factors from French's website. We report in brackets the Newey-West corrected t-statistics of the coefficient estimates.

Sector	**Commodity**	α	MKT	SMB	HML	$AdjR^2$	**Nobs**
Energy	Crude Oil	-0.40	-0.03	-3.59%	-0.04	0.11%	3362
		(-7.31)	(-1.16)	(-1.24)	(-0.96)		
	Heating Oil	-0.31	-0.04	-0.05	-0.06	0.35%	3074
		(-6.02)	(-1.87)	(-1.84)	(-1.55)		
	Natural Gas	-0.44	0.03	-0.01	0.10	1.01%	2262
		(-9.02)	(2.01)	(-0.31)	(3.18)		
Grains	Corn	-0.45	0.02	0.04	0.03	0.05%	3167
		(-8.12)	(1.06)	(1.64)	(1.06)		
	Cotton	0.32	0.01	0.01	0.02	-0.05%	3010
		(7.89)	(0.63)	(0.32)	(0.77)		
	Soybeans	-0.10	0.02	0.03	0.04	-0.02%	2982
		(-1.34)	(0.77)	(0.91)	(0.87)		
	Soybean Meal	0.13	0.00	-0.01	0.00	-0.14%	2003
		(2.25)	(-0.03)	(-0.26)	(0.03)		
	Soybean Oil	-0.12	-0.01	0.02	-0.04	0.08%	2038
		(-2.42)	(-0.75)	(0.71)	(-1.18)		
	Sugar	-0.18	-0.01	-0.01	-0.02	-0.05%	3081
		(-3.64)	(-0.58)	(-0.55)	(-0.59)		
	Wheat	-0.19	-0.02	-0.01	-0.02	0.01%	2767
		(-3.52)	(-1.49)	(-0.67)	(-0.77)		
Livestock	Lean Hogs	0.23	0.02	0.00	0.06	0.05%	1398
		(1.95)	(0.71)	(-0.02)	(0.96)		
	Live Cattle	-0.20	-0.01	-0.01	0.00	-0.02%	3092
		(-4.85)	(-0.43)	(-0.57)	(0.11)		
Metals	Copper	-0.30	-0.01	0.00	0.02	-0.02%	2197
		(-6.16)	(-0.24)	(0.13)	(0.43)		
	Gold	-0.34	-0.01	-0.01	-0.02	-0.18%	1527
		(-4.62)	(-0.39)	(-0.31)	(-0.34)		
	Silver	0.70	-0.11	-0.11	-0.21	0.64%	3165
		(4.86)	(-1.76)	(-1.86)	(-2.06)		
Tropical	Cocoa	-0.35	-0.03	-0.05	-0.05	0.33%	1975
		(-6.52)	(-1.6)	(-1.84)	(-1.39)		
	Colombian Coffee	-0.11	-0.01	-0.02	-0.06	0.00%	1379
		(-0.86)	(-0.28)	(-0.28)	(-0.82)		
	Oats	-0.86	0.06	0.07	0.14	0.27%	986
		(-5.51)	(1.07)	(1.21)	(1.87)		
	Orange Juice	-0.38	-0.05	-0.05	-0.07	0.20%	1591
		(-4.54)	(-1.54)	(-1.11)	(-0.98)		
	Rough Rice	-0.45	0.01	0.02	0.02	-0.17%	1514
		(-5.41)	(0.69)	(0.53)	(0.52)		
Wood	Lumber	-0.29	0.00	0.00	0.01	-0.11%	2165
		(-6.75)	(0.28)	(0.1)	(0.59)		

Table 11: **Bond Risk Premia v.s. Commodity Risk Premia: 60 Day**

This table presents results from regressions of 60 day log variance risk premia on the determinants of bond risk premia. We use the Cochrane and Piazzesi (CP) factor and the 8 factors (F_1 through F_8) estimated by Ludvigson and Ng (2009). Newey-West adjusted t-statistics are reported in brackets.

Sector	**Commodity**	α	CP	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	$AdjR^2$	**Nobs**
	Crude Oil	-0.25	-0.05	-0.01	0.12	0.08	-0.03	0.02	-0.02	0.02	0.00	1.46%	180
		(-5.05)	(-1.55)	(-0.18)	(1.75)	(2.36)	(-0.7)	(0.32)	(-0.41)	(0.42)	(0.12)		
Energy	Heating Oil	-0.28	0.01	0.02	0.02	0.06	-0.08	0.04	-0.02	0.02	0.01	-1.70%	175
		(-5.06)	(0.24)	(0.24)	(0.22)	(1.77)	(-1.5)	(0.69)	(-0.57)	(0.46)	(0.3)		
	Natural Gas	-0.41	-0.02	-0.03	-0.11	0.02	0.02	0.02	0.04	-0.04	0.02	-5.24%	135
		(-6.07)	(-0.42)	(-0.29)	(-1.19)	(0.42)	(0.21)	(0.25)	(0.71)	(-0.66)	(0.47)		
	Corn	-0.48	0.00	0.05	0.02	0.06	-0.02	-0.05	-0.04	0.07	-0.02	-0.98%	178
		(-9.53)	(-0.03)	(0.87)	(0.39)	(1.38)	(-0.36)	(-1)	(-0.97)	(1.66)	(-0.4)		
	Cotton	0.67	-0.01	-0.10	-0.15	-0.03	0.02	0.11	0.08	-0.14	-0.01	2.15%	168
		(6.48)	(-0.14)	(-1.15)	(-1.28)	(-0.87)	(0.18)	(1.39)	(1.43)	(-2.1)	(-0.36)		
	Soybeans	-0.19	-0.08	-0.04	-0.04	0.08	-0.10	0.03	0.04	0.02	-0.04	-0.65%	179
		(-3.03)	(-2.09)	(-0.58)	(-0.53)	(1.39)	(-1.18)	(0.48)	(1)	(0.54)	(-0.91)		
Grains	Soybean Meal	-0.02	-0.05	-0.01	-0.06	0.09	-0.07	0.00	0.07	0.00	0.00	-1.33%	170
		(-0.26)	(-1.47)	(-0.17)	(-0.66)	(1.99)	(-0.93)	(0.08)	(1.66)	(0.02)	(-0.05)		
	Soybean Oil	-0.19	0.01	-0.01	-0.07	0.11	-0.13	0.01	0.03	0.05	-0.04	6.68%	165
		(-3.26)	(0.39)	(-0.26)	(-0.98)	(2.77)	(-2.16)	(0.16)	(0.82)	(1.2)	(-1.23)		
	Sugar	-0.21	-0.03	-0.01	-0.06	0.04	-0.02	0.16	0.02	0.00	-0.01	3.51%	166
		(-3.61)	(-0.83)	(-0.21)	(-0.66)	(1.29)	(-0.41)	(3.26)	(0.49)	(0.06)	(-0.24)		
	Wheat	-0.21	-0.02	0.03	-0.15	0.02	-0.02	-0.02	0.03	-0.02	0.04	-1.15%	177
		(-4.06)	(-0.7)	(0.5)	(-2.07)	(0.56)	(-0.45)	(-0.51)	(0.65)	(-0.49)	(1.15)		
	Lean Hogs	0.02	0.03	-0.14	0.09	0.01	0.03	0.07	-0.09	0.14	-0.01	-2.51%	85
		(0.19)	(0.47)	(-1.1)	(0.49)	(0.12)	(0.3)	(0.85)	(-0.85)	(1.3)	(-0.21)		
Livestock	Live Cattle	-0.45	0.02	0.11	0.02	0.00	0.01	0.00	0.02	-0.04	-0.03	-0.20%	201
		(-8.97)	(0.6)	(1.68)	(0.31)	(0.09)	(0.13)	(0.02)	(0.5)	(-0.83)	(-0.97)		
	Copper	-0.25	0.02	0.18	-0.09	0.02	-0.10	-0.07	0.02	0.02	-0.06	2.18%	166
		(-3.11)	(0.39)	(2.16)	(-1.01)	(0.53)	(-1.42)	(-1.47)	(0.3)	(0.34)	(-1.25)		
Metals	Gold	-0.28	0.06	0.06	0.17	-0.03	0.02	0.02	-0.08	0.05	-0.04	-2.78%	145
		(-3.6)	(1.17)	(0.63)	(1.7)	(-0.51)	(0.3)	(0.29)	(-1.31)	(0.77)	(-0.81)		
	Silver	1.16	-0.02	-0.21	0.49	0.04	-0.14	0.39	0.04	-0.13	-0.03	16.61%	178
		(8.82)	(-0.3)	(-1.36)	(3.09)	(0.61)	(-1.21)	(3.97)	(0.43)	(-1.36)	(-0.42)		
	Cocoa	-0.32	0.02	0.04	0.01	0.06	-0.03	-0.08	-0.06	0.07	0.04	3.26%	157
		(-5.2)	(0.8)	(0.74)	(0.2)	(1.7)	(-0.75)	(-1.69)	(-1.53)	(1.72)	(1.09)		
	Colombian Coffee	0.19	0.14	0.41	0.47	0.00	0.11	-0.03	0.07	-0.18	-0.06	27.51%	93
		(0.98)	(2.17)	(2.66)	(2.49)	(0.08)	(1.19)	(-0.35)	(1.02)	(-2.18)	(-0.69)		
Tropical	Oats	-0.85	-0.02	0.21	0.21	0.07	0.11	0.02	-0.03	0.10	-0.13	8.34%	106
		(-7.2)	(-0.34)	(1.77)	(1.32)	(0.81)	(0.85)	(0.22)	(-0.37)	(1.05)	(-1.43)		
	Orange Juice	-0.16	0.01	0.04	0.22	0.02	0.03	0.14	0.05	-0.07	0.07	3.79%	135
		(-1.61)	(0.24)	(0.41)	(1.85)	(0.34)	(0.47)	(1.5)	(0.85)	(-0.87)	(1.15)		
	Rough Rice	-0.49	-0.04	-0.10	-0.02	0.03	-0.02	0.02	-0.04	0.03	-0.04	-2.77%	125
		(-6.03)	(-0.76)	(-0.8)	(-0.14)	(0.56)	(-0.29)	(0.28)	(-0.46)	(0.33)	(-0.79)		
Wood	Lumber	-0.31	0.04	-0.06	0.15	-0.03	0.06	0.02	-0.05	0.03	-0.01	1.18%	166
		(-5.95)	(1.55)	(-1.03)	(1.9)	(-0.9)	(1.34)	(0.51)	(-1.35)	(0.73)	(-0.35)		

Table 12: **Bond Risk Premia v.s. Commodity Risk Premia: 90 Day**

This table presents results from regressions of 90 day log variance risk premia on the determinants of bond risk premia. We use the Cochrane and Piazzesi (CP) factor and the 8 factors (F_1 through F_8) estimated by Ludvigson and Ng (2009). Newey-West adjusted t-statistics are reported in brackets.

Sector	**Commodity**	α	CP	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	$AdjR^2$	**Nobs**
	Crude Oil	-0.27	-0.04	-0.01	0.17	0.05	-0.07	0.05	-0.02	0.02	0.01	2.54%	180
		(-4.93)	(-1.33)	(-0.09)	(2.44)	(1.7)	(-1.11)	(1.01)	(-0.44)	(0.43)	(0.28)		
Energy	Heating Oil	-0.22	-0.01	-0.04	0.16	0.07	-0.09	0.03	-0.04	0.04	0.01	-0.12%	175
		(-3.13)	(-0.24)	(-0.55)	(1.79)	(2.07)	(-1.87)	(0.53)	(-0.75)	(0.68)	(0.17)		
	Natural Gas	-0.45	0.00	-0.21	-0.09	0.03	-0.02	0.06	0.07	-0.07	0.02	-1.24%	135
		(-6.14)	(-0.1)	(-2.15)	(-0.95)	(0.62)	(-0.27)	(1.04)	(1.41)	(-1.33)	(0.51)		
	Corn	-0.39	-0.01	0.07	0.01	0.03	-0.08	-0.02	-0.02	0.08	-0.04	-0.76%	178
		(-6.77)	(-0.21)	(1.12)	(0.22)	(0.63)	(-1.21)	(-0.37)	(-0.5)	(1.62)	(-1.11)		
	Cotton	0.25	-0.05	-0.06	-0.19	-0.03	-0.03	-0.04	0.06	-0.07	0.02	1.99%	168
		(4.4)	(-1.69)	(-1.3)	(-2.86)	(-1)	(-0.55)	(-0.8)	(2.11)	(-2.15)	(0.62)		
	Soybeans	-0.03	-0.07	-0.03	-0.03	0.03	-0.09	0.03	-0.01	0.08	-0.10	1.08%	179
		(-0.34)	(-1.59)	(-0.38)	(-0.31)	(0.58)	(-0.9)	(0.4)	(-0.26)	(1.6)	(-1.87)		
Grains	Soybean Meal	0.19	-0.06	-0.01	-0.07	0.05	-0.07	0.02	0.00	0.06	-0.04	-1.29%	170
		(2.86)	(-1.34)	(-0.09)	(-0.83)	(0.96)	(-0.81)	(0.3)	(-0.04)	(1.19)	(-0.94)		
	Soybean Oil	-0.12	0.02	-0.05	-0.05	0.05	-0.10	0.02	0.02	0.02	-0.04	1.74%	165
		(-2.01)	(0.56)	(-0.95)	(-0.66)	(1.2)	(-1.59)	(0.62)	(0.57)	(0.51)	(-1.05)		
	Sugar	-0.14	0.00	-0.02	0.00	-0.02	0.04	0.18	-0.02	0.00	-0.04	2.24%	166
		(-2.18)	(-0.02)	(-0.36)	(0.01)	(-0.46)	(0.68)	(3.18)	(-0.38)	(0.04)	(-1)		
	Wheat	-0.25	-0.05	-0.05	-0.22	0.00	-0.06	-0.02	0.07	-0.09	0.06	5.31%	177
		(-4.82)	(-1.9)	(-0.99)	(-2.98)	(-0.1)	(-0.97)	(-0.47)	(2.12)	(-2.35)	(1.77)		
	Lean Hogs	0.26	0.07	-0.12	0.03	-0.03	0.07	0.02	-0.10	0.09	0.04	-4.33%	85
		(2.47)	(0.76)	(-0.58)	(0.13)	(-0.45)	(0.59)	(0.24)	(-0.75)	(0.67)	(0.7)		
Livestock	Live Cattle	-0.23	0.01	0.09	0.05	-0.02	0.00	-0.06	-0.01	0.01	-0.02	-1.03%	201
		(-5.07)	(0.34)	(1.58)	(0.86)	(-0.55)	(-0.06)	(-1.28)	(-0.3)	(0.3)	(-0.74)		
	Copper	-0.31	0.03	0.12	-0.08	0.01	-0.06	-0.10	-0.01	0.00	-0.03	2.42%	166
		(-5.07)	(0.77)	(2.01)	(-0.88)	(0.16)	(-0.96)	(-2.1)	(-0.25)	(0.07)	(-0.85)		
Metals	Gold	-0.30	0.04	0.08	0.18	-0.01	0.02	-0.01	-0.09	0.09	-0.07	-0.24%	145
		(-3.96)	(0.98)	(0.88)	(2.06)	(-0.3)	(0.25)	(-0.19)	(-1.72)	(1.49)	(-1.66)		
	Silver	0.77	0.05	-0.15	0.50	0.07	0.00	0.41	0.08	-0.11	-0.04	20.38%	178
		(5.83)	(0.78)	(-1.29)	(3.08)	(0.99)	(-0.05)	(4.77)	(1.12)	(-1.4)	(-0.53)		
	Cocoa	-0.32	0.01	0.03	0.02	0.05	-0.06	-0.10	-0.06	0.07	0.04	6.06%	157
		(-5.14)	(0.38)	(0.64)	(0.29)	(1.71)	(-1.51)	(-2.21)	(-1.9)	(1.87)	(1.36)		
	Colombian Coffee	0.21	0.14	0.41	0.53	0.01	0.08	-0.06	0.08	-0.18	-0.04	33.42%	93
		(1.11)	(2.27)	(2.71)	(3.08)	(0.1)	(0.98)	(-0.74)	(1.32)	(-2.46)	(-0.57)		
Tropical	Oats	-0.64	0.00	0.20	0.24	-0.02	0.14	0.04	-0.10	0.13	-0.17	4.11%	106
		(-4.49)	(0.01)	(1.45)	(1.56)	(-0.24)	(0.84)	(0.34)	(-1.12)	(1.38)	(-1.52)		
	Orange Juice	-0.27	0.01	0.03	0.21	0.03	-0.02	0.11	0.07	-0.08	0.04	6.93%	135
		(-3.14)	(0.25)	(0.36)	(1.89)	(0.62)	(-0.37)	(1.76)	(1.33)	(-1.11)	(0.91)		
	Rough Rice	-0.33	-0.06	-0.06	0.03	0.05	-0.06	-0.01	-0.01	0.03	-0.05	-3.03%	125
		(-3.91)	(-0.96)	(-0.43)	(0.21)	(1.06)	(-0.53)	(-0.14)	(-0.07)	(0.35)	(-0.95)		
Wood	Lumber	-0.23	0.03	-0.09	0.12	-0.04	0.07	0.01	-0.07	0.05	0.02	2.59%	166
		(-3.96)	(1)	(-1.41)	(1.41)	(-1.19)	(1.38)	(0.28)	(-1.88)	(1.15)	(0.83)		

Table 13: **Price v.s. Variance Risk Premia**

This table reports results of regressions of variance swap returns on commodity futures returns. Specifically, we run the following regression:

$$LVRP_t = \alpha + \beta RET_t + \epsilon$$

where LVRP and RET denote the variance swap return and futures return, respectively. We report in brackets the Newey–West corrected t-statistics of the coefficient estimates.

Panel A: 60 Day Log Variance risk premia

Sector	Commodity	α		FRP		$AdjR^2$	Nobs
	Crude Oil	-0.33	(-11.1)	-0.78	(-2.29)	6.3%	5025
Energy	Heating Oil	-0.29	(-10.02)	-0.06	(-0.18)	0.0%	5210
	Natural Gas	-0.43	(-12.78)	0.24	(1.45)	1.1%	4394
	Corn	-0.44	(-12.57)	0.48	(1.29)	1.4%	5024
	Cotton	0.67	(16.65)	0.03	(0.1)	0.0%	4149
	Soybeans	-0.26	(-6.45)	0.09	(0.19)	0.0%	5011
Grains	Soybean Meal	-0.08	(-2.24)	0.47	(1.18)	1.1%	3621
	Soybean Oil	-0.22	(-5.54)	0.75	(1.19)	2.7%	3667
	Sugar	-0.23	(-7.27)	-0.31	(-1.39)	1.0%	5225
	Wheat	-0.17	(-5.18)	1.15	(3.51)	7.8%	4340
Livestock	Lean Hogs	-0.18	(-4.4)	-1.11	(-4.25)	8.8%	3231
	Live Cattle	-0.45	(-13.76)	-1.86	(-3.68)	6.8%	4642
	Copper	-0.29	(-7.5)	-0.77	(-1.46)	3.6%	4220
Metals	Gold	-0.35	(-7.91)	0.11	(0.15)	0.0%	3631
	Silver	0.47	(4.22)	-1.86	(-2.85)	2.8%	5150
	Cocoa	-0.32	(-10.3)	0.28	(0.97)	0.5%	4004
	Colombian Coffee	-0.28	(-3.62)	2.52	(3.13)	24.5%	1794
Tropical	Oats	-0.86	(-9.96)	-0.63	(-1.11)	1.4%	2095
	Orange Juice	-0.23	(-4.32)	0.90	(1.54)	2.9%	3303
	Rough Rice	-0.45	(-9.21)	0.71	(1.63)	2.6%	2835
Wood	Lumber	-0.37	(-13.75)	-0.15	(-0.62)	0.3%	3660

Panel A: 90 Day Log Variance risk premia

Sector	Commodity	α		FRP		$AdjR^2$	Nobs
	Crude Oil	-0.38	(-9.78)	-0.70	(-1.92)	6.5%	5477
Energy	Heating Oil	-0.32	(-8.13)	-0.08	(-0.3)	0.1%	5190
	Natural Gas	-0.44	(-11.47)	0.22	(1.28)	1.1%	4374
	Corn	-0.38	(-8.93)	0.15	(0.45)	0.2%	5004
	Cotton	0.31	(7.92)	0.11	(0.35)	0.1%	4134
	Soybeans	-0.12	(-1.96)	-0.62	(-1.21)	1.8%	4991
Grains	Soybean Meal	0.13	(2.29)	-0.23	(-0.48)	0.3%	3601
	Soybean Oil	-0.15	(-3.59)	0.10	(0.19)	0.1%	3647
	Sugar	-0.20	(-5.18)	-0.19	(-0.87)	0.5%	5191
	Wheat	-0.16	(-3.95)	0.75	(2.45)	5.8%	4325
Livestock	Lean Hogs	0.28	(4.02)	-2.00	(-7.83)	28.0%	3210
	Live Cattle	-0.22	(-6.53)	-1.57	(-3.75)	8.6%	4622
	Copper	-0.28	(-6.2)	-0.67	(-1.31)	4.5%	4189
Metals	Gold	-0.35	(-6.02)	0.00	(0)	0.0%	3611
	Silver	0.14	(1.07)	-2.02	(-2.9)	5.1%	5239
	Cocoa	-0.32	(-8.9)	0.22	(0.91)	0.5%	3984
	Colombian Coffee	-0.25	(-2.99)	2.11	(3.22)	32.2%	1774
Tropical	Oats	-0.65	(-5.71)	-0.42	(-0.72)	0.7%	2075
	Orange Juice	-0.26	(-4.51)	0.36	(0.75)	0.8%	3283
	Rough Rice	-0.35	(-6.3)	0.07	(0.15)	0.0%	2815
Wood	Lumber	-0.26	(-7.55)	-0.17	(-0.56)	0.3%	3640

Table 14: **Expected Variance Risk Premia**

This table presents summary statistics of expected commodity variance risk premia. We use the historical variance of commodity returns as the floating leg of the variance swap. Columns entitled Mean, T-Stat, Median, AR(1), Min and Max report the average, Newey-West corrected t-statistic (same lag length as the maturity of the swap), median, first order auto-correlation, minimum and maximum variance risk premia. The next three columns display the standard deviation, skewness and kurtosis, respectively. The penultimate column reports the correlation between expected and realized variance risk premia. The last column shows the number of observations. Panel A presents the results for a horizon of 60 days, Panel B for a horizon of 90 days.

Panel A: 60 Day Variance risk premia

Sector	Commodity	Mean	T-Stat	Median	AR(1)	Min	Max	Std Dev	Skew	Kurt	Corr	Obs
	Crude Oil	-3.3%	-4.92	-3.1%	0.96	-0.79	0.85	0.10	3.33	44.61	4.18	5025
Energy	Heating Oil	-0.6%	-0.70	-1.8%	0.97	-0.45	1.04	0.11	4.62	35.89	-3.55	5210
	Natural Gas	-3.7%	-1.25	-5.4%	0.97	-2.04	3.35	0.35	7.26	68.85	17.67	4394
	Corn	-2.4%	-8.64	-2.0%	0.95	-0.26	0.15	0.04	-0.62	6.37	41.46	5024
	Cotton	2.7%	12.05	2.4%	0.94	-0.15	0.16	0.03	0.29	7.69	43.50	4149
	Soybeans	-1.2%	-3.06	-1.4%	0.97	-0.21	0.39	0.05	2.25	16.25	5.70	5011
Grains	Soybean Meal	0.0%	0.05	-0.8%	0.97	-0.17	0.41	0.06	2.60	14.86	8.12	3621
	Soybean Oil	-1.0%	-4.07	-1.1%	0.95	-0.14	0.19	0.03	1.07	11.17	30.33	3667
	Sugar	-2.7%	-5.96	-2.1%	0.94	-0.64	0.23	0.06	-1.85	18.17	48.07	5225
	Wheat	-1.1%	-5.35	-1.0%	0.93	-0.18	0.22	0.03	0.13	9.25	27.64	4340
Livestock	Lean Hogs	-1.1%	-3.84	-1.0%	0.92	-0.38	0.20	0.04	-0.23	11.15	44.59	3231
	Live Cattle	-1.0%	-13.80	-0.8%	0.92	-0.08	0.03	0.01	-1.69	7.86	57.42	4642
	Copper	-2.2%	-4.51	-1.5%	0.96	-0.51	0.43	0.06	-1.26	19.57	35.53	4220
Metals	Gold	-1.0%	-6.58	-0.8%	0.95	-0.11	0.07	0.02	-0.43	7.47	24.43	3631
	Silver	5.3%	9.72	3.7%	0.95	-0.10	0.56	0.06	3.14	17.99	-30.33	5150
	Cocoa	-2.6%	-7.94	-2.5%	0.94	-0.21	0.15	0.04	-0.12	4.43	20.02	4004
	Colombian Coffee	-3.6%	-2.73	-3.5%	0.95	-0.51	0.62	0.11	1.81	13.14	32.35	1794
Tropical	Oats	-2.4%	-3.92	-2.6%	0.93	-0.33	0.17	0.06	0.16	4.13	31.77	2095
	Orange Juice	-2.0%	-3.59	-1.7%	0.96	-0.48	0.27	0.07	-0.51	8.10	39.29	3303
	Rough Rice	-2.7%	-8.71	-2.2%	0.91	-0.24	0.08	0.04	-0.88	5.07	58.60	2835
Wood	Lumber	-3.5%	-10.74	-2.8%	0.95	-0.22	0.05	0.04	-1.87	7.91	66.84	3660

Panel B: 90 Day Variance risk premia

Sector	Commodity	Mean	T-Stat	Median	AR(1)	Min	Max	Std Dev	Skew	Kurt	Corr	Obs
	Crude Oil	-3.6%	-5.63	-3.1%	0.97	-0.77	0.47	0.07	0.17	17.63	20.08	5477
Energy	Heating Oil	-3.2%	-5.44	-2.7%	0.95	-0.72	0.30	0.06	-0.92	13.84	26.06	5190
	Natural Gas	-9.1%	-7.50	-6.6%	0.96	-1.79	0.24	0.12	-2.16	17.14	56.97	4374
	Corn	-1.8%	-4.56	-1.6%	0.97	-0.20	0.22	0.04	0.79	9.69	14.94	5004
	Cotton	1.5%	7.69	1.3%	0.97	-0.09	0.10	0.02	0.57	4.91	22.88	4134
	Soybeans	1.8%	1.03	-0.8%	0.99	-0.19	1.29	0.15	6.06	44.89	-1.21	4991
Grains	Soybean Meal	4.2%	2.12	0.3%	0.99	-0.15	1.47	0.18	5.54	38.11	0.00	3601
	Soybean Oil	-0.7%	-2.30	-0.8%	0.96	-0.13	0.19	0.03	1.35	10.23	33.29	3647
	Sugar	-2.2%	-4.89	-2.0%	0.91	-0.85	0.34	0.07	-2.52	33.45	48.34	5191
	Wheat	-0.6%	-2.01	-0.9%	0.96	-0.22	0.21	0.04	1.21	8.61	22.61	4325
Livestock	Lean Hogs	4.3%	4.64	1.2%	0.98	-0.26	0.42	0.10	1.28	4.44	11.75	3210
	Live Cattle	-0.5%	-6.87	-0.5%	0.94	-0.09	0.04	0.01	-0.08	6.66	25.32	4622
	Copper	-2.4%	-4.37	-2.0%	0.95	-0.63	0.49	0.08	1.00	17.09	38.54	4189
Metals	Gold	-1.1%	-6.60	-1.0%	0.94	-0.18	0.12	0.03	-0.33	10.10	40.13	3611
	Silver	-1.2%	7.94	-0.1%	0.95	-0.27	0.10	0.04	-1.60	8.58	-22.59	5239
	Cocoa	-3.1%	-7.20	-3.1%	0.93	-0.24	0.12	0.04	-0.03	4.97	40.18	3984
	Colombian Coffee	-1.3%	-2.28	-3.0%	0.95	-0.45	0.81	0.16	2.63	12.50	37.22	1774
Tropical	Oats	-2.0%	-1.71	-5.1%	0.96	-0.27	1.24	0.17	5.05	31.91	1.42	2075
	Orange Juice	-3.0%	-4.93	-2.4%	0.96	-0.36	0.13	0.06	-1.00	5.93	62.33	3283
	Rough Rice	-2.3%	-4.78	-2.2%	0.95	-0.29	0.15	0.04	-0.27	5.60	43.86	2815
Wood	Lumber	-2.3%	-5.72	-2.3%	0.97	-0.21	0.12	0.04	-1.03	7.31	67.29	3640

Table 15: **Expected Log Variance Risk Premia**

This table presents summary statistics of expected log variance risk premia. We use the historical variance of commodity returns as the floating leg of variance swaps. Columns entitled Mean, T-Stat, Median, AR(1), Min and Max report the average, Newey-West corrected t-statistic (same lag length as the maturity of variance swaps) , median, first order auto-correlation, minimum and maximum values of log variance risk premia. The next four columns report the standard deviation, skewness, kurtosis and Newey-West adjusted Sharpe Ratios (annualized), respectively. The penultimate column reports the correlation between expected and realized log variance risk premia. The last column reports the number of observations. Panel A presents the results for a horizon of 60 days, Panel B for a horizon of 90 days.

Panel A: 60 Day Log Variance Risk Premia

Sector	Commodity	Mean	T-Stat	Median	AR(1)	Min	Max	Std Dev	Skew	Kurt	SR	Corr	Obs
	Crude Oil	-33.6%	-11.72	-34.4%	0.97	-1.88	2.23	0.38	0.80	6.93	40.5%	5.77	5025
Energy	Heating Oil	-13.6%	-3.28	-20.2%	0.97	-1.82	2.71	0.50	1.45	6.86	11.1%	7.78	5210
	Natural Gas	-22.9%	-5.26	-30.3%	0.96	-1.72	2.92	0.52	1.87	10.56	19.4%	-1.95	4394
	Corn	-46.2%	-10.56	-46.1%	0.96	-2.10	1.33	0.54	-0.07	3.03	36.5%	17.06	5024
	Cotton	68.5%	18.57	69.0%	0.90	-1.40	5.16	0.52	0.08	5.65	70.6%	64.05	4149
	Soybeans	-31.1%	-6.57	-33.2%	0.97	-1.93	2.15	0.59	0.51	4.11	22.8%	4.71	5011
Grains	Soybean Meal	-11.2%	-2.45	-16.2%	0.96	-1.67	2.90	0.57	0.78	4.69	10.0%	8.74	3621
	Soybean Oil	-22.4%	-6.48	-22.5%	0.95	-1.52	1.13	0.41	0.05	3.19	26.2%	21.14	3667
	Sugar	-23.5%	-7.92	-23.5%	0.95	-2.65	1.19	0.39	-0.12	5.06	26.8%	23.51	5225
	Wheat	-21.6%	-7.14	-20.6%	0.92	-1.93	5.01	0.39	0.07	11.56	26.6%	37.47	4340
Livestock	Lean Hogs	-17.1%	-5.05	-17.9%	0.93	-1.38	1.19	0.42	0.30	3.33	21.8%	36.93	3231
	Live Cattle	-46.5%	-18.07	-44.1%	0.94	-2.27	0.81	0.37	-0.53	3.74	65.0%	31.18	4642
	Copper	-26.5%	-8.59	-24.7%	0.92	-2.01	4.12	0.39	0.17	7.56	32.4%	26.96	4220
Metals	Gold	-32.4%	-9.04	-31.3%	0.96	-1.68	1.02	0.42	0.13	3.36	36.7%	4.58	3631
	Silver	159.8%	12.99	122.1%	0.89	-2.01	7.44	1.28	0.54	2.66	44.3%	69.53	5150
	Cocoa	-27.3%	-9.70	-26.0%	0.95	-1.51	0.67	0.35	-0.30	3.23	37.5%	7.17	4004
	Colombian Coffee	-31.4%	-5.38	-32.2%	0.95	-2.22	1.23	0.47	0.21	3.80	31.1%	33.18	1794
Tropical	Oats	-33.7%	-4.57	-25.7%	0.96	-2.16	0.94	0.60	-0.60	3.06	24.4%	25.42	2095
	Orange Juice	-21.3%	-4.71	-21.3%	0.95	-1.88	2.09	0.53	0.07	3.25	20.1%	24.93	3303
	Rough Rice	-39.2%	-10.42	-37.3%	0.91	-1.77	1.76	0.42	-0.05	3.16	47.9%	39.62	2835
Wood	Lumber	-36.8%	-14.95	-34.6%	0.93	-1.86	0.53	0.30	-0.53	3.69	60.5%	25.36	3660

Panel B: 90 Day Log Variance Risk Premia

Sector	Commodity	Mean	T-Stat	Median	AR(1)	Min	Max	Std Dev	Skew	Kurt	SR	Corr	Obs
	Crude Oil	-39.3%	-11.25	-42.0%	0.98	-1.52	1.71	0.45	0.61	3.83	30.4%	1.27	5477
Energy	Heating Oil	-32.2%	-7.80	-31.6%	0.98	-1.65	1.74	0.43	0.55	4.76	21.6%	15.57	5190
	Natural Gas	-43.6%	-9.47	-44.1%	0.98	-2.04	1.48	0.45	-0.11	3.05	28.6%	5.77	4374
	Corn	-37.4%	-6.73	-38.0%	0.98	-1.88	1.13	0.46	0.19	3.30	19.0%	-0.03	5004
	Cotton	31.4%	9.72	31.3%	0.96	-0.88	1.51	0.39	-0.06	2.70	30.2%	34.07	4134
	Soybeans	-12.0%	-1.86	-20.6%	0.99	-1.82	3.06	0.63	1.22	5.94	5.3%	-2.07	4991
Grains	Soybean Meal	13.4%	1.20	6.1%	0.98	-1.37	2.40	0.59	0.92	4.44	4.0%	1.35	3601
	Soybean Oil	-15.4%	-3.38	-17.0%	0.97	-1.73	1.29	0.44	0.18	3.39	11.2%	30.52	3647
	Sugar	-19.8%	-6.02	-23.1%	0.91	-2.40	3.03	0.47	0.64	5.14	16.7%	27.89	5191
	Wheat	-15.1%	-4.41	-18.5%	0.97	-1.41	1.24	0.41	0.34	3.36	13.4%	27.13	4325
Livestock	Lean Hogs	28.1%	4.45	18.5%	0.97	-1.11	4.46	0.71	0.70	3.47	15.7%	25.04	3210
	Live Cattle	-22.9%	-8.15	-28.0%	0.95	-1.32	1.38	0.41	0.67	3.73	24.0%	13.39	4622
	Copper	-29.3%	-8.12	-32.7%	0.94	-1.55	1.85	0.49	0.81	4.68	25.1%	27.15	4189
Metals	Gold	-34.7%	-8.48	-37.5%	0.96	-1.86	1.67	0.53	0.33	3.48	28.2%	18.04	3611
	Silver	9.8%	8.62	-9.1%	0.95	-2.86	3.80	1.12	0.56	2.83	23.8%	65.06	5239
	Cocoa	-31.9%	-8.73	-33.2%	0.95	-1.35	1.05	0.38	0.39	3.67	27.7%	15.10	3984
	Colombian Cofee	-18.6%	-4.26	-28.8%	0.95	-1.54	2.68	0.68	1.63	7.04	20.2%	37.11	1774
Tropical	Oats	-65.5%	-3.00	-73.2%	0.97	-2.19	2.43	0.78	1.29	5.79	13.2%	26.37	2075
	Orange Juice	-26.5%	-4.42	-31.5%	0.97	-2.39	1.43	0.55	-0.09	3.74	15.4%	44.25	3283
	Rough Rice	-35.4%	-6.34	-37.4%	0.95	-1.65	1.62	0.52	0.08	2.84	23.9%	26.15	2815
Wood	Lumber	-25.8%	-7.82	-29.3%	0.96	-1.50	1.25	0.40	0.26	3.31	25.9%	25.15	3640

Table 16: **Spline Interpolation: Variance Risk Premia**

This table presents summary statistics of commodity variance risk premia. We use a cubic spline (rather than linear) interpolation to obtain a fine grid of implied volatilities. Columns entitled Mean, T-Stat, Median, AR(1), Min and Max report the average, Newey-West corrected t-statistic (same lag length as the maturity of the swap), median, first order auto-correlation, minimum and maximum variance risk premia. The next three columns report the standard deviation, skewness and kurtosis, respectively. "Corr" reports the correlation between the log variance risk premia based on the cubic spline interpolation and those based on our (baseline) linear interpolation. The last column reports the number of observations. Panel A presents the results for a horizon of 60 days, Panel B for a horizon of 90 days.

Panel A: 60 Day Variance risk premia

Sector	Commodity	Mean	T-Stat	Median	AR(1)	Min	Max	Std Dev	Skew	Kurt	Corr	Obs
	Crude Oil	-3.4%	-5.94	-3.2%	0.96	-0.62	0.71	0.08	1.28	18.69	99.99	5025
Energy	Heating Oil	-3.1%	-7.54	-2.6%	0.94	-0.63	0.63	0.07	0.48	19.72	99.91	5210
	Natural Gas	-10.5%	-8.90	-7.3%	0.94	-1.67	0.30	0.15	-1.64	9.32	99.04	4394
	Corn	-2.3%	-8.05	-1.9%	0.95	-0.24	0.22	0.04	-0.19	9.34	99.63	5024
	Cotton	2.6%	10.99	2.4%	0.95	-0.18	0.16	0.03	0.00	7.42	99.82	4148
	Soybeans	-0.8%	-2.07	-1.2%	0.97	-0.19	0.46	0.05	3.01	24.68	99.89	5011
Grains	Soybean Meal	0.0%	0.06	-0.6%	0.97	-0.16	0.34	0.05	2.17	13.48	99.89	3621
	Soybean Oil	-1.0%	-3.46	-0.9%	0.96	-0.14	0.25	0.04	1.47	12.48	99.99	3667
	Sugar	-2.5%	-5.71	-2.2%	0.94	-0.67	0.25	0.06	-0.88	11.34	99.94	5225
	Wheat	-0.7%	-2.53	-1.0%	0.94	-0.22	0.26	0.04	0.87	8.81	99.97	4339
Livestock	Lean Hogs	-1.3%	-3.10	-1.1%	0.94	-0.30	0.27	0.05	0.07	8.12	99.66	3231
	Live Cattle	-1.0%	-11.11	-0.8%	0.93	-0.11	0.05	0.01	-0.49	5.95	99.91	4642
	Copper	-2.4%	-3.55	-1.9%	0.97	-0.53	0.62	0.08	1.79	24.22	100.00	4219
Metals	Gold	-1.0%	-4.40	-0.9%	0.97	-0.16	0.13	0.03	0.33	10.95	100.00	3631
	Silver	-0.2%	-0.79	0.2%	0.98	-0.29	0.13	0.03	-1.40	14.77	100.00	5146
	Cocoa	-3.0%	-8.45	-3.1%	0.95	-0.23	0.16	0.05	0.28	4.74	99.98	4004
	Colombian Coffee	-1.7%	-0.72	-3.2%	0.97	-0.51	1.04	0.17	3.01	16.52	100.00	1794
Tropical	Oats	-6.2%	-7.59	-6.1%	0.95	-0.52	0.41	0.07	0.40	9.85	99.90	2095
	Orange Juice	-2.3%	-3.29	-2.3%	0.97	-0.52	0.30	0.08	-0.33	10.42	100.00	3303
	Rough Rice	-3.0%	-8.31	-2.7%	0.92	-0.30	0.20	0.04	-0.10	6.60	99.92	2835
Wood	Lumber	-3.5%	-10.42	-3.1%	0.95	-0.22	0.13	0.04	-0.86	5.47	99.92	3660

Panel B: 90 Day Variance risk premia

Sector	Commodity	Mean	T-Stat	Median	AR(1)	Min	Max	Std Dev	Skew	Kurt	Corr	Obs
	Crude Oil	-3.6%	-5.40	-3.1%	0.97	-0.76	0.47	0.07	0.18	17.48	99.99	5477
Energy	Heating Oil	-3.2%	-6.34	-2.7%	0.96	-0.76	0.30	0.06	-0.97	14.69	99.96	5190
	Natural Gas	-9.2%	-8.74	-6.6%	0.95	-1.80	0.24	0.12	-2.17	16.45	99.54	4374
	Corn	-1.8%	-5.29	-1.6%	0.96	-0.20	0.20	0.04	0.72	9.57	99.91	5004
	Cotton	1.5%	6.89	1.3%	0.97	-0.09	0.10	0.02	0.57	4.87	99.93	4134
	Soybeans	1.9%	1.23	-0.8%	0.99	-0.19	1.29	0.15	6.06	44.95	99.99	4991
Grains	Soybean Meal	4.2%	2.14	0.3%	0.99	-0.15	1.47	0.18	5.55	38.23	99.99	3601
	Soybean Oil	-0.7%	-2.23	-0.8%	0.96	-0.13	0.19	0.03	1.35	10.24	99.99	3647
	Sugar	-2.2%	-4.31	-2.0%	0.92	-0.78	0.34	0.07	-2.08	26.81	99.89	5191
	Wheat	-0.6%	-1.76	-0.9%	0.96	-0.22	0.21	0.04	1.21	8.62	99.99	4325
Livestock	Lean Hogs	4.2%	3.65	1.2%	0.98	-0.26	0.42	0.10	1.29	4.50	99.98	3208
	Live Cattle	-0.5%	-5.03	-0.5%	0.96	-0.09	0.04	0.01	-0.07	6.59	99.95	4622
	Copper	-2.4%	-3.05	-2.0%	0.97	-0.61	0.49	0.08	1.01	17.05	100.00	4189
Metals	Gold	-1.1%	-3.82	-1.0%	0.97	-0.18	0.12	0.03	-0.33	10.10	100.00	3611
	Silver	-1.2%	-2.74	-0.1%	0.99	-0.27	0.10	0.04	-1.60	8.57	100.00	5239
	Cocoa	-3.1%	-7.69	-3.1%	0.95	-0.25	0.12	0.04	-0.03	4.99	99.99	3984
	Colombian Coffee	-1.3%	-0.47	-2.9%	0.98	-0.45	0.81	0.16	2.64	12.51	100.00	1774
Tropical	Oats	-2.0%	-0.90	-5.1%	0.98	-0.28	1.24	0.17	5.04	31.86	100.00	2075
	Orange Juice	-3.0%	-4.98	-2.4%	0.96	-0.36	0.13	0.06	-1.00	5.93	99.99	3283
	Rough Rice	-2.3%	-5.33	-2.2%	0.95	-0.29	0.15	0.04	-0.27	5.56	99.98	2815
Wood	Lumber	-2.3%	-5.33	-2.3%	0.98	-0.21	0.12	0.04	-1.04	7.34	99.98	3640

Table 17: **Spline Interpolation: Log Variance Risk Premia**

This table presents summary statistics of commodity variance swap returns. We use a cubic spline (rather than linear) interpolation to obtain a fine grid of implied volatilities. Columns entitled Mean, T-Stat, Median, AR(1), Min and Max report the average, Newey-West corrected t-statistic (same lag length as the maturity of variance swaps) , median, first order auto-correlation, minimum and maximum values of log variance risk premia. The next four columns report the standard deviation, skewness, kurtosis and Newey-West adjusted Sharpe Ratios (annualized), respectively. "Corr" reports the correlation between the log variance risk premia based on the cubic spline interpolation and those based on our (baseline) linear interpolation. The last column reports the number of observations. Panel A presents the results for a horizon of 60 days, Panel B for a horizon of 90 days.

Panel A: 60 Day Log Variance Risk Premia

Sector	Commodity	Mean	T-Stat	Median	AR(1)	Min	Max	Std Dev	Skew	Kurt	SR	Corr	Obs
	Crude Oil	-33.9%	-10.61	-37.8%	0.97	-1.51	1.63	0.43	0.57	3.59	36.7%	99.99	5025
Energy	Heating Oil	-29.8%	-10.09	-32.2%	0.95	-1.78	2.01	0.42	0.41	4.42	34.2%	99.93	5210
	Natural Gas	-43.6%	-12.57	-43.6%	0.96	-1.96	1.24	0.47	0.03	3.19	46.4%	99.37	4394
	Corn	-44.1%	-12.62	-44.1%	0.96	-2.14	1.22	0.47	0.01	2.97	43.6%	99.91	5024
	Cotton	66.6%	16.59	69.9%	0.92	-1.30	3.58	0.57	-0.04	4.09	63.1%	99.87	4148
	Soybeans	-25.4%	-6.52	-29.9%	0.97	-1.64	1.83	0.53	0.50	3.62	22.5%	99.96	5011
Grains	Soybean Meal	-8.5%	-2.29	-12.1%	0.95	-1.90	2.12	0.50	0.36	3.66	9.3%	99.95	3621
	Soybean Oil	-21.4%	-5.69	-20.2%	0.96	-1.76	1.32	0.47	-0.02	3.09	23.0%	99.98	3667
	Sugar	-22.5%	-7.10	-23.9%	0.95	-1.87	1.27	0.43	0.32	3.24	24.0%	99.98	5225
	Wheat	-16.1%	-4.93	-18.6%	0.95	-2.17	1.94	0.46	0.15	3.94	18.3%	99.91	4339
Livestock	Lean Hogs	-18.6%	-4.09	-18.3%	0.95	-1.90	1.44	0.51	0.01	3.25	17.6%	99.90	3231
	Live Cattle	-46.1%	-14.00	-49.4%	0.95	-1.93	1.45	0.46	0.41	3.61	50.3%	99.95	4642
	Copper	-30.0%	-7.64	-32.5%	0.96	-1.72	1.72	0.50	0.55	4.30	28.8%	99.99	4219
Metals	Gold	-34.5%	-8.29	-37.7%	0.96	-1.79	2.10	0.54	0.51	3.88	33.7%	100.00	3631
	Silver	46.2%	4.02	26.7%	0.91	-2.58	6.74	1.21	0.76	3.64	13.7%	99.75	5146
	Cocoa	-32.2%	-10.24	-32.3%	0.95	-1.60	1.09	0.40	0.10	3.38	39.6%	99.98	4004
	Colombian Coffee	-22.4%	-2.45	-30.8%	0.97	-2.22	2.87	0.68	1.31	6.16	14.2%	99.99	1794
Tropical	Oats	-86.3%	-9.91	-85.0%	0.97	-2.34	1.25	0.67	0.47	3.09	53.0%	99.97	2095
	Orange Juice	-23.1%	-4.36	-27.5%	0.97	-2.54	2.45	0.61	0.40	4.80	18.6%	99.99	3303
	Rough Rice	-45.3%	-9.43	-47.5%	0.93	-1.93	1.85	0.53	0.32	3.26	43.4%	99.95	2835
Wood	Lumber	-37.2%	-13.62	-39.0%	0.95	-1.92	1.19	0.36	0.19	3.76	55.1%	99.94	3660

Panel B: 90 Day Log Variance Risk Premia

Sector	Commodity	Mean	T-Stat	Median	AR(1)	Min	Max	Std Dev	Skew	Kurt	SR	Corr	Obs
	Crude Oil	-39.3%	-9.31	-42.0%	0.98	-1.51	1.70	0.45	0.62	3.84	25.2%	99.99	5477
Energy	Heating Oil	-32.4%	-8.25	-31.9%	0.97	-1.63	1.72	0.43	0.54	4.72	22.9%	99.95	5190
	Natural Gas	-44.0%	-11.61	-44.1%	0.97	-2.05	1.49	0.45	-0.12	3.05	35.1%	99.88	4374
	Corn	-37.3%	-9.10	-37.9%	0.97	-1.86	1.12	0.46	0.18	3.29	25.7%	99.96	5004
	Cotton	31.3%	7.93	31.2%	0.97	-0.88	1.51	0.39	-0.05	2.69	24.7%	99.94	4134
	Soybeans	-11.7%	-1.95	-20.4%	0.98	-1.82	3.06	0.63	1.23	5.97	5.5%	99.97	4991
Grains	Soybean Meal	13.5%	2.27	6.2%	0.97	-1.37	2.32	0.59	0.93	4.47	7.6%	99.96	3601
	Soybean Oil	-15.3%	-3.63	-16.9%	0.96	-1.73	1.29	0.44	0.18	3.38	12.0%	99.98	3647
	Sugar	-19.6%	-5.11	-22.8%	0.93	-2.31	2.61	0.46	0.59	4.60	14.2%	99.85	5191
	Wheat	-15.1%	-3.82	-18.4%	0.97	-1.39	1.24	0.41	0.35	3.37	11.6%	99.99	4325
Livestock	Lean Hogs	27.9%	3.30	18.4%	0.98	-1.11	4.50	0.71	0.76	3.94	11.7%	99.79	3208
	Live Cattle	-23.0%	-6.69	-27.9%	0.97	-1.32	1.39	0.41	0.68	3.74	19.7%	99.96	4622
	Copper	-29.3%	-6.41	-32.8%	0.96	-1.55	1.85	0.49	0.81	4.68	19.8%	100.00	4189
Metals	Gold	-34.6%	-6.66	-37.3%	0.97	-1.86	1.68	0.53	0.34	3.48	22.2%	100.00	3611
	Silver	11.5%	0.84	-7.7%	0.98	-2.86	3.82	1.13	0.55	2.79	2.3%	99.99	5239
	Cocoa	-31.8%	-8.90	-33.2%	0.96	-1.35	1.05	0.38	0.40	3.68	28.2%	99.99	3984
	Colombian Coffee	-18.5%	-1.68	-28.3%	0.98	-1.54	2.68	0.68	1.63	7.05	8.0%	99.99	1774
Tropical	Oats	-65.3%	-5.71	-73.1%	0.98	-2.19	2.43	0.78	1.29	5.78	25.1%	99.99	2075
	Orange Juice	-26.3%	-4.53	-31.3%	0.97	-2.39	1.43	0.55	-0.09	3.75	15.8%	99.99	3283
	Rough Rice	-35.3%	-6.37	-37.4%	0.96	-1.64	1.61	0.52	0.08	2.84	24.0%	99.98	2815
Wood	Lumber	-26.0%	-7.38	-29.6%	0.97	-1.50	1.23	0.40	0.26	3.33	24.5%	99.97	3640

Table 18: **Truncation Points: Variance Risk Premia**

This table presents summary statistics of commodity variance risk premia. We truncate the first and second integrals in Equation (2) at K_l and K_u, respectively:

$$\begin{aligned} K_l &= F_{t,T} \exp^{-8\sigma(T-t)} \\ K_u &= F_{t,T} \exp^{8\sigma(T-t)} \end{aligned}$$

where K_l and K_u refer to the lower and higher truncated strikes. $F_{t,T}$ refers to the futures contract observed at time t and expiring at T, σ is the average implied volatility of all OTM options and $T-t$ denotes the time to maturity of the option contract. Columns entitled Mean, T-Stat, Median, AR(1), Min and Max report the average, Newey-West corrected t-statistic (same lag length as the maturity of the swap), median, first order auto-correlation, minimum and maximum variance risk premia. The next three columns display the standard deviation, skewness and kurtosis, respectively. "Corr" reports the correlation between the variance risk premia based on the tighter (8 standard deviation) truncation points and those based on our baseline truncation points (10 standard deviation). The last column presents the number of observations. Panel A presents the results for a horizon of 60 days, Panel B for a horizon of 90 days.

Panel A: 60 Day Variance risk premia

Sector	Commodity	Mean	T-Stat	Median	AR(1)	Min	Max	Std Dev	Skew	Kurt	Corr	Obs
	Crude Oil	-3.3%	-5.85	-3.2%	0.96	-0.52	0.71	0.08	1.47	18.83	99.88	5025
Energy	Heating Oil	-3.0%	-7.41	-2.6%	0.94	-0.59	0.63	0.07	0.64	19.57	99.95	5210
	Natural Gas	-10.1%	-9.23	-7.3%	0.94	-1.23	0.30	0.14	-1.34	7.20	99.75	4394
	Corn	-2.3%	-8.19	-1.9%	0.94	-0.25	0.22	0.04	-0.06	9.19	100.00	5024
	Cotton	2.6%	11.10	2.4%	0.94	-0.18	0.16	0.03	0.06	7.41	100.00	4149
	Soybeans	-0.8%	-2.05	-1.2%	0.97	-0.19	0.46	0.05	3.01	24.53	100.00	5011
Grains	Soybean Meal	0.0%	0.08	-0.6%	0.96	-0.16	0.34	0.05	2.20	13.62	100.00	3621
	Soybean Oil	-1.0%	-3.48	-0.9%	0.96	-0.14	0.25	0.04	1.47	12.48	100.00	3667
	Sugar	-2.5%	-5.77	-2.3%	0.94	-0.65	0.25	0.06	-0.98	12.18	100.00	5225
	Wheat	-0.7%	-2.48	-1.1%	0.94	-0.22	0.26	0.04	0.90	8.87	99.99	4340
Livestock	Lean Hogs	-1.2%	-2.97	-1.1%	0.94	-0.28	0.27	0.05	0.20	8.31	99.99	3231
	Live Cattle	-1.0%	-11.05	-0.8%	0.93	-0.11	0.05	0.01	-0.45	6.00	100.00	4642
	Copper	-2.3%	-3.53	-1.9%	0.97	-0.46	0.62	0.08	1.87	24.35	99.97	4220
Metals	Gold	-1.0%	-4.41	-0.9%	0.97	-0.16	0.13	0.03	0.33	10.94	100.00	3631
	Silver	-0.2%	-0.82	0.2%	0.98	-0.28	0.13	0.03	-1.33	14.09	99.99	5150
	Cocoa	-3.0%	-8.50	-3.1%	0.93	-0.36	0.16	0.05	0.19	5.23	99.35	4004
	Colombian Coffee	-1.7%	-0.71	-3.2%	0.97	-0.51	1.05	0.17	3.03	16.56	100.00	1794
Tropical	Oats	-6.2%	-7.68	-6.2%	0.95	-0.51	0.42	0.07	0.58	9.27	99.99	2095
	Orange Juice	-2.3%	-3.29	-2.3%	0.97	-0.52	0.30	0.08	-0.35	10.54	99.99	3303
	Rough Rice	-3.0%	-8.24	-2.7%	0.92	-0.29	0.20	0.04	-0.08	6.55	99.99	2835
Wood	Lumber	-3.5%	-10.42	-3.0%	0.95	-0.21	0.13	0.04	-0.83	5.39	99.99	3660

Panel B: 90 Day Variance risk premia

Sector	Commodity	Mean	T-Stat	Median	AR(1)	Min	Max	Std Dev	Skew	Kurt	Corr	Obs
	Crude Oil	-3.5%	-5.32	-3.1%	0.98	-0.56	0.47	0.07	0.78	14.92	99.08	5477
Energy	Heating Oil	-3.1%	-6.21	-2.6%	0.97	-0.40	0.30	0.06	-0.42	9.08	99.32	5190
	Natural Gas	-8.8%	-8.90	-6.5%	0.96	-1.40	0.24	0.11	-1.64	10.48	99.41	4374
	Corn	-1.8%	-5.16	-1.6%	0.96	-0.20	0.22	0.04	0.82	9.79	99.99	5004
	Cotton	1.5%	6.92	1.3%	0.97	-0.09	0.10	0.02	0.57	4.91	100.00	4134
	Soybeans	1.8%	1.23	-0.8%	0.99	-0.19	1.29	0.15	6.06	44.90	100.00	4991
Grains	Soybean Meal	4.2%	2.14	0.3%	0.99	-0.15	1.47	0.18	5.54	38.11	100.00	3601
	Soybean Oil	-0.7%	-2.24	-0.8%	0.96	-0.13	0.19	0.03	1.35	10.23	100.00	3647
	Sugar	-2.2%	-4.35	-2.0%	0.92	-0.85	0.34	0.07	-2.48	32.90	100.00	5191
	Wheat	-0.6%	-1.71	-0.9%	0.96	-0.22	0.21	0.04	1.24	8.69	99.99	4325
Livestock	Lean Hogs	4.3%	3.70	1.2%	0.98	-0.24	0.42	0.10	1.29	4.42	100.00	3210
	Live Cattle	-0.5%	-4.95	-0.5%	0.96	-0.09	0.04	0.01	-0.07	6.65	100.00	4622
	Copper	-2.4%	-3.04	-2.0%	0.97	-0.54	0.49	0.08	1.11	16.96	99.94	4189
Metals	Gold	-1.1%	-3.83	-1.0%	0.97	-0.18	0.12	0.03	-0.32	10.08	100.00	3611
	Silver	-1.2%	-2.76	-0.1%	0.99	-0.26	0.10	0.04	-1.57	8.31	99.99	5239
	Cocoa	-3.1%	-7.71	-3.1%	0.94	-0.24	0.12	0.04	-0.05	5.04	99.74	3984
	Colombian Coffee	-1.2%	-0.46	-2.9%	0.98	-0.45	0.81	0.16	2.65	12.54	100.00	1774
Tropical	Oats	-2.0%	-0.89	-5.1%	0.98	-0.27	1.25	0.17	5.06	31.97	100.00	2075
	Orange Juice	-3.0%	-4.97	-2.4%	0.96	-0.35	0.13	0.06	-1.00	5.94	99.99	3283
	Rough Rice	-2.2%	-5.26	-2.1%	0.95	-0.27	0.15	0.04	-0.21	5.33	99.97	2815
Wood	Lumber	-2.3%	-5.33	-2.3%	0.97	-0.21	0.12	0.04	-0.92	6.95	99.96	3640

Table 19: **Truncation Points: Log Variance Risk Premia**

This table presents summary statistics of commodity variance swap returns. We truncate the first and second integrals in Equation (2) at K_l and K_u respectively:

$$\begin{aligned} K_l &= F_{t,T} \exp^{-8\sigma(T-t)} \\ K_u &= F_{t,T} \exp^{8\sigma(T-t)} \end{aligned}$$

where K_l and K_u refer to the lower and higher truncated strikes. $F_{t,T}$ refers to the futures contract observed at time t and expiring at T, σ is the average implied volatility of all OTM options and $T-t$ denotes the time to maturity of the option contract. Columns entitled Mean, T-Stat, Median, AR(1), Min and Max report the average, Newey-West corrected t-statistic (same lag length as the maturity of variance swaps) , median, first order auto-correlation, minimum and maximum values of log variance risk premia. The next four columns report the standard deviation, skewness, kurtosis and Newey-West adjusted Sharpe Ratios (annualized), respectively. "Corr" reports the correlation between the log variance risk premia based on the tighter (8 standard deviation) truncation points and those based on our baseline truncation points (10 standard deviation). The last column presents the number of observations. Panel A presents the results for a horizon of 60 days, Panel B for a horizon of 90 days.

Panel A: 60 Day Log Variance Risk Premia

Sector	Commodity	Mean	T-Stat	Median	AR(1)	Min	Max	Std Dev	Skew	Kurt	SR	Corr	Obs
	Crude Oil	-33.8%	-10.58	-37.8%	0.97	-1.51	1.63	0.43	0.57	3.58	36.6%	99.99	5025
Energy	Heating Oil	-29.4%	-10.00	-32.0%	0.95	-1.80	2.01	0.42	0.41	4.40	33.9%	100.00	5210
	Natural Gas	-42.7%	-12.67	-43.0%	0.95	-1.92	1.26	0.46	0.08	3.20	46.8%	99.96	4394
	Corn	-44.2%	-12.64	-43.9%	0.95	-2.17	1.22	0.47	0.00	3.00	43.7%	100.00	5024
	Cotton	66.9%	16.70	69.9%	0.91	-1.30	5.13	0.57	0.11	4.85	63.5%	99.99	4149
	Soybeans	-25.6%	-6.54	-29.9%	0.97	-1.65	1.82	0.53	0.50	3.62	22.6%	100.00	5011
Grains	Soybean Meal	-8.5%	-2.29	-12.2%	0.95	-1.90	2.11	0.50	0.37	3.67	9.3%	100.00	3621
	Soybean Oil	-21.5%	-5.72	-20.5%	0.96	-1.77	1.32	0.47	-0.02	3.09	23.2%	100.00	3667
	Sugar	-22.8%	-7.18	-24.1%	0.95	-1.94	1.27	0.43	0.31	3.27	24.3%	100.00	5225
	Wheat	-16.1%	-4.91	-18.6%	0.93	-2.19	4.85	0.47	0.40	6.76	18.3%	100.00	4340
Livestock	Lean Hogs	-18.2%	-4.02	-18.2%	0.95	-1.92	1.44	0.50	0.04	3.24	17.3%	100.00	3231
	Live Cattle	-46.0%	-13.94	-49.5%	0.95	-1.95	1.45	0.46	0.42	3.61	50.1%	100.00	4642
	Copper	-29.8%	-7.61	-32.3%	0.95	-1.72	3.74	0.50	0.66	5.18	28.7%	99.96	4220
Metals	Gold	-34.6%	-8.31	-37.9%	0.96	-1.79	2.09	0.54	0.50	3.88	33.8%	100.00	3631
	Silver	44.2%	3.90	24.8%	0.90	-2.58	5.96	1.21	0.81	3.78	13.3%	100.00	5150
	Cocoa	-32.3%	-10.25	-32.2%	0.95	-1.66	1.09	0.40	0.09	3.39	39.7%	99.94	4004
	Colombian Coffee	-22.5%	-2.45	-31.0%	0.97	-2.21	2.87	0.68	1.32	6.16	14.2%	100.00	1794
Tropical	Oats	-86.4%	-9.96	-85.7%	0.97	-2.33	1.26	0.67	0.48	3.10	53.3%	100.00	2095
	Orange Juice	-23.2%	-4.38	-27.6%	0.96	-2.54	2.46	0.61	0.40	4.81	18.7%	100.00	3303
	Rough Rice	-45.1%	-9.37	-47.0%	0.93	-1.92	1.85	0.53	0.31	3.25	43.1%	100.00	2835
Wood	Lumber	-36.8%	-13.57	-38.5%	0.95	-1.93	1.20	0.36	0.20	3.75	54.9%	100.00	3660

Panel B: 90 Day Log Variance Risk Premia

Sector	Commodity	Mean	T-Stat	Median	AR(1)	Min	Max	Std Dev	Skew	Kurt	SR	Corr	Obs
	Crude Oil	-39.1%	-9.22	-41.6%	0.98	-1.52	1.72	0.45	0.61	3.82	24.9%	99.95	5477
Energy	Heating Oil	-31.9%	-8.09	-31.3%	0.97	-1.64	1.74	0.43	0.55	4.75	22.5%	99.97	5190
	Natural Gas	-43.2%	-11.54	-43.8%	0.97	-1.79	1.49	0.44	-0.07	2.96	34.9%	99.90	4374
	Corn	-37.3%	-9.05	-38.0%	0.96	-1.88	1.13	0.46	0.19	3.30	25.6%	100.00	5004
	Cotton	31.4%	7.95	31.3%	0.97	-0.88	1.51	0.39	-0.06	2.70	24.7%	100.00	4134
	Soybeans	-11.9%	-1.98	-20.5%	0.98	-1.82	3.06	0.63	1.23	5.95	5.6%	100.00	4991
Grains	Soybean Meal	13.4%	2.27	6.2%	0.97	-1.37	2.40	0.59	0.92	4.44	7.6%	100.00	3601
	Soybean Oil	-15.3%	-3.64	-17.0%	0.96	-1.73	1.30	0.44	0.19	3.39	12.0%	99.99	3647
	Sugar	-19.7%	-5.15	-23.1%	0.92	-2.39	3.03	0.47	0.64	5.13	14.3%	100.00	5191
	Wheat	-15.0%	-3.79	-18.4%	0.97	-1.41	1.24	0.41	0.35	3.36	11.5%	100.00	4325
Livestock	Lean Hogs	28.2%	3.35	18.6%	0.98	-1.11	4.42	0.71	0.70	3.45	11.8%	100.00	3210
	Live Cattle	-22.9%	-6.64	-28.0%	0.97	-1.32	1.38	0.41	0.67	3.73	19.5%	100.00	4622
	Copper	-29.2%	-6.38	-32.6%	0.96	-1.55	1.85	0.49	0.81	4.68	19.7%	99.99	4189
Metals	Gold	-34.6%	-6.67	-37.4%	0.97	-1.86	1.68	0.53	0.33	3.48	22.2%	100.00	3611
	Silver	9.8%	0.72	-9.1%	0.98	-2.86	3.80	1.12	0.56	2.83	2.0%	100.00	5239
	Cocoa	-31.8%	-8.89	-33.1%	0.95	-1.35	1.05	0.38	0.39	3.67	28.2%	99.96	3984
	Colombian Coffee	-18.3%	-1.67	-28.5%	0.98	-1.51	2.68	0.68	1.64	7.05	7.9%	100.00	1774
Tropical	Oats	-65.2%	-5.71	-73.0%	0.98	-2.19	2.44	0.78	1.30	5.80	25.1%	100.00	2075
	Orange Juice	-26.3%	-4.53	-31.3%	0.97	-2.39	1.43	0.55	-0.09	3.75	15.8%	100.00	3283
	Rough Rice	-35.1%	-6.30	-37.0%	0.96	-1.64	1.62	0.52	0.08	2.84	23.8%	100.00	2815
Wood	Lumber	-25.5%	-7.30	-29.0%	0.97	-1.50	1.25	0.39	0.28	3.31	24.2%	99.99	3640

Table 20: **The Role of Jumps: Variance Risk Premia**

This table presents summary statistics of commodity variance risk premia. We account for the role of jumps in the variance swap rate by using the approach of Rompolis and Tzavalis (2013). Columns entitled Mean, T-Stat, Median, AR(1), Min and Max report the average, Newey-West corrected t-statistic (same lag length as the maturity of the swap), median, first order auto-correlation, minimum and maximum variance risk premia. The last four columns display the standard deviation, skewness, kurtosis and number of observations, respectively. Panel A presents the results for a horizon of 60 days, Panel B for a horizon of 90 days.

Panel A: 60 Day Variance risk premia

Sector	Commodity	Mean	T-Stat	Median	AR(1)	Min	Max	Std Dev	Skew	Kurt	Obs
	Crude Oil	-2.0%	-3.46	-2.5%	0.97	-0.47	0.77	0.08	2.89	24.78	5025
Energy	Heating Oil	-1.9%	-4.98	-1.8%	0.94	-0.51	0.67	0.07	1.96	25.17	5210
	Natural Gas	-6.2%	-7.39	-5.0%	0.94	-0.92	0.37	0.12	-0.73	6.38	4393
	Corn	-1.6%	-5.98	-1.5%	0.95	-0.21	0.23	0.04	0.72	10.24	5024
	Cotton	2.8%	11.50	2.5%	0.95	-0.16	0.17	0.03	0.37	6.70	4150
	Soybeans	-0.3%	-0.67	-0.9%	0.97	-0.16	0.47	0.05	3.47	26.74	5011
Grains	Soybean Meal	0.6%	1.40	-0.3%	0.97	-0.13	0.35	0.05	2.56	14.97	3621
	Soybean Oil	-0.5%	-1.84	-0.6%	0.97	-0.11	0.25	0.03	1.98	14.76	3667
	Sugar	-1.2%	-2.98	-1.3%	0.94	-0.56	0.27	0.06	-0.15	8.87	5225
	Wheat	-0.1%	-0.35	-0.6%	0.95	-0.19	0.27	0.04	1.31	9.42	4342
Livestock	Lean Hogs	-0.6%	-1.47	-0.7%	0.94	-0.22	0.28	0.05	0.68	8.77	3231
	Live Cattle	-0.9%	-10.21	-0.7%	0.93	-0.10	0.05	0.01	-0.21	5.97	4642
	Copper	-1.5%	-2.38	-1.4%	0.97	-0.43	0.63	0.07	3.02	29.93	4220
Metals	Gold	-0.8%	-3.58	-0.8%	0.97	-0.13	0.13	0.02	1.10	11.72	3631
	Silver	0.0%	-0.09	0.3%	0.98	-0.24	0.14	0.03	-0.78	12.64	5150
	Cocoa	-2.0%	-5.99	-2.2%	0.94	-0.19	0.17	0.04	0.58	4.80	4004
	Colombian Coffee	0.2%	0.07	-2.1%	0.97	-0.41	1.05	0.16	3.34	17.97	1794
Tropical	Oats	-5.0%	-6.58	-5.3%	0.95	-0.45	0.43	0.07	0.99	9.59	2095
	Orange Juice	-1.2%	-1.85	-1.6%	0.97	-0.43	0.30	0.07	0.23	9.42	3303
	Rough Rice	-2.3%	-7.13	-2.2%	0.92	-0.26	0.20	0.04	0.24	6.88	2835
Wood	Lumber	-2.5%	-8.66	-2.3%	0.95	-0.18	0.14	0.04	-0.53	5.30	3660

Panel B: 90 Day Variance risk premia

Sector	Commodity	Mean	T-Stat	Median	AR(1)	Min	Max	Std Dev	Skew	Kurt	Obs
	Crude Oil	-2.2%	-3.52	-2.3%	0.97	-0.47	0.49	0.07	2.12	18.65	5477
Energy	Heating Oil	-1.9%	-4.31	-1.8%	0.96	-0.57	0.31	0.05	0.03	11.88	5190
	Natural Gas	-5.2%	-6.60	-4.4%	0.95	-0.97	0.26	0.10	-1.21	8.92	4374
	Corn	-1.1%	-3.13	-1.2%	0.96	-0.17	0.23	0.04	1.63	11.40	5004
	Cotton	1.7%	7.70	1.5%	0.97	-0.08	0.10	0.02	0.81	4.77	4134
	Soybeans	2.4%	1.61	-0.5%	0.99	-0.15	1.30	0.15	6.07	44.66	4991
Grains	Soybean Meal	4.9%	2.42	0.7%	0.99	-0.13	1.49	0.18	5.54	38.02	3601
	Soybean Oil	-0.2%	-0.63	-0.4%	0.97	-0.12	0.20	0.03	1.82	11.87	3647
	Sugar	-0.9%	-1.93	-1.0%	0.92	-0.61	0.37	0.06	-0.83	17.92	5192
	Wheat	0.1%	0.22	-0.5%	0.96	-0.19	0.22	0.04	1.71	9.49	4325
Livestock	Lean Hogs	4.9%	4.24	1.6%	0.98	-0.20	0.43	0.10	1.39	4.50	3211
	Live Cattle	-0.3%	-3.56	-0.4%	0.96	-0.08	0.04	0.01	0.26	6.26	4622
	Copper	-1.4%	-1.97	-1.4%	0.97	-0.51	0.51	0.07	2.19	20.50	4189
Metals	Gold	-0.8%	-3.07	-0.8%	0.97	-0.16	0.12	0.02	0.43	10.16	3611
	Silver	-0.9%	-2.30	0.0%	0.99	-0.22	0.11	0.04	-1.21	7.33	5239
	Cocoa	-1.9%	-5.32	-2.1%	0.95	-0.20	0.13	0.04	0.35	4.72	3984
	Colombian Coffee	0.6%	0.23	-1.8%	0.98	-0.35	0.81	0.15	2.95	13.58	1774
Tropical	Oats	-0.8%	-0.38	-4.2%	0.98	-0.22	1.26	0.17	5.11	32.29	2075
	Orange Juice	-1.8%	-3.44	-1.7%	0.96	-0.29	0.14	0.05	-0.72	5.35	3283
	Rough Rice	-1.5%	-3.89	-1.6%	0.95	-0.24	0.15	0.04	0.11	5.32	2815
Wood	Lumber	-1.4%	-3.60	-1.6%	0.97	-0.17	0.13	0.04	-0.57	6.55	3640

Table 21: **The Role of Jumps: Log Variance Risk Premia**

This table presents summary statistics of log variance risk premia. We account for the role of jumps in the variance swap rate by using the approach of Rompolis and Tzavalis (2013). Columns entitled Mean, T-Stat, Median, AR(1), Min and Max report the average, Newey-West corrected t-statistic (same lag length as the maturity of variance swaps) , median, first order auto-correlation, minimum and maximum values of log variance risk premia. The last five columns report the standard deviation, skewness, kurtosis, Newey-West adjusted Sharpe Ratios (annualized) and number of observations, respectively. Panel A presents the results for a horizon of 60 days, Panel B for a horizon of 90 days.

Panel A: 60 Day Log Variance Risk Premia

Sector	Commodity	Mean	T-Stat	Median	AR(1)	Min	Max	Std Dev	Skew	Kurt	SR	Obs
	Crude Oil	-25.7%	-8.04	-29.8%	0.97	-1.46	1.68	0.43	0.60	3.62	27.8%	5025
Energy	Heating Oil	-21.8%	-7.48	-24.6%	0.95	-1.70	2.06	0.42	0.44	4.41	25.4%	5210
	Natural Gas	-30.9%	-9.41	-31.5%	0.94	-1.72	3.00	0.46	0.16	3.74	34.8%	4393
	Corn	-36.8%	-10.36	-36.6%	0.95	-2.11	1.31	0.47	-0.02	3.01	35.8%	5024
	Cotton	70.5%	17.99	74.0%	0.92	-1.20	5.10	0.56	0.01	4.49	68.4%	4150
	Soybeans	-18.6%	-4.75	-23.2%	0.97	-1.57	1.88	0.53	0.52	3.61	16.5%	5011
Grains	Soybean Meal	-1.8%	-0.48	-5.4%	0.95	-1.80	2.13	0.50	0.38	3.65	2.0%	3621
	Soybean Oil	-14.9%	-3.98	-14.2%	0.96	-1.70	1.36	0.46	-0.01	3.10	16.1%	3667
	Sugar	-13.1%	-4.18	-14.4%	0.95	-1.63	1.38	0.43	0.33	3.22	14.2%	5225
	Wheat	-9.4%	-2.85	-11.8%	0.94	-2.12	2.27	0.46	0.14	4.07	10.6%	4342
Livestock	Lean Hogs	-11.3%	-2.52	-11.4%	0.95	-1.85	1.47	0.50	0.04	3.25	10.9%	3231
	Live Cattle	-41.7%	-12.72	-45.3%	0.95	-1.90	1.47	0.45	0.43	3.61	45.7%	4642
Metals	Copper	-23.3%	-5.99	-26.1%	0.96	-1.62	2.37	0.49	0.61	4.48	22.6%	4220
	Gold	-29.4%	-7.14	-32.8%	0.96	-1.74	2.13	0.53	0.52	3.90	29.0%	3631
	Silver	49.3%	4.41	30.5%	0.90	-2.46	6.85	1.20	0.82	3.85	15.1%	5150
	Cocoa	-24.3%	-7.76	-24.6%	0.95	-1.58	1.14	0.40	0.10	3.40	30.0%	4004
	Colombian Coffee	-12.1%	-1.36	-20.5%	0.97	-2.03	2.92	0.67	1.34	6.19	7.8%	1794
Tropical	Oats	-77.5%	-8.97	-76.8%	0.97	-2.24	1.33	0.67	0.48	3.09	48.0%	2095
	Orange Juice	-15.0%	-2.90	-19.1%	0.96	-2.35	2.51	0.60	0.44	4.76	12.3%	3303
	Rough Rice	-38.0%	-7.93	-39.2%	0.93	-1.88	1.90	0.53	0.29	3.24	36.5%	2835
Wood	Lumber	-29.1%	-10.81	-30.4%	0.95	-1.86	1.24	0.36	0.19	3.75	43.8%	3660

Panel B: 90 Day Log Variance Risk Premia

Sector	Commodity	Mean	T-Stat	Median	AR(1)	Min	Max	Std Dev	Skew	Kurt	SR	Obs
	Crude Oil	-29.9%	-7.10	-32.9%	0.98	-1.45	1.79	0.44	0.62	3.88	19.2%	5477
Energy	Heating Oil	-23.1%	-5.93	-22.7%	0.97	-1.52	1.82	0.43	0.57	4.73	16.5%	5190
	Natural Gas	-30.2%	-8.04	-30.3%	0.97	-1.92	1.63	0.44	-0.13	3.07	24.3%	4374
	Corn	-29.3%	-7.00	-30.0%	0.97	-1.82	1.19	0.46	0.17	3.31	19.8%	5004
	Cotton	37.2%	9.43	37.1%	0.97	-0.79	1.56	0.39	-0.06	2.69	29.3%	4134
	Soybeans	-4.2%	-0.69	-13.1%	0.98	-1.70	3.13	0.62	1.24	5.96	2.0%	4991
Grains	Soybean Meal	21.0%	3.54	13.4%	0.97	-1.24	2.51	0.59	0.95	4.51	11.8%	3601
	Soybean Oil	-8.0%	-1.91	-9.6%	0.96	-1.66	1.35	0.44	0.19	3.38	6.3%	3647
	Sugar	-10.0%	-2.58	-13.4%	0.91	-2.10	4.98	0.47	0.94	7.68	7.2%	5192
	Wheat	-7.6%	-1.91	-11.0%	0.97	-1.36	1.32	0.41	0.32	3.37	5.8%	4325
Livestock	Lean Hogs	35.9%	4.29	25.6%	0.97	-1.02	5.92	0.71	0.81	4.33	15.1%	3211
	Live Cattle	-18.1%	-5.25	-23.1%	0.97	-1.25	1.41	0.41	0.67	3.69	15.5%	4622
	Copper	-21.9%	-4.81	-25.8%	0.97	-1.46	1.88	0.48	0.85	4.75	14.9%	4189
Metals	Gold	-28.8%	-5.61	-31.7%	0.97	-1.74	1.73	0.52	0.35	3.48	18.7%	3611
	Silver	16.7%	1.24	-1.6%	0.98	-2.71	3.87	1.12	0.57	2.86	3.4%	5239
	Cocoa	-22.9%	-6.44	-24.0%	0.96	-1.27	1.10	0.37	0.40	3.65	20.4%	3984
	Colombian Coffee	-7.2%	-0.68	-17.8%	0.98	-1.42	2.73	0.67	1.65	7.04	3.2%	1774
Tropical	Oats	-55.4%	-4.84	-63.0%	0.98	-2.07	2.51	0.78	1.31	5.79	21.3%	2075
	Orange Juice	-17.2%	-3.05	-21.4%	0.97	-2.21	1.47	0.54	-0.07	3.68	10.6%	3283
	Rough Rice	-27.1%	-4.93	-29.0%	0.96	-1.54	1.67	0.52	0.07	2.84	18.6%	2815
Wood	Lumber	-17.1%	-4.90	-20.6%	0.97	-1.46	1.29	0.39	0.26	3.32	16.2%	3640

Table 22: **The Role of Transaction Costs: VRP**

This table presents summary statistics of commodity variance risk premia after accounting for transaction costs. We use two distinct approaches to capture transaction costs. "Proportional" assumes that the true variance swap rate is 95 % of the synthetic variance swap rate. For example, if the synthetic variance swap rate is 10 %, the true variance swap rate is 9.5 %. "Fixed" assumes that the square root of the true variance swap rate is 1 % less than the square root of the synthetic variance swap rate. For example, if the square root of the synthetic variance swap rate is 10 %, then the square root of the true variance swap rate is 9 %. Columns entitled Mean and T-Stat report the average and Newey-West corrected t-statistic (same lag length as the maturity of the swap), respectively. Nobs shows the number of observations. Panel A presents the results for a horizon of 60 days, Panel B for a horizon of 90 days.

Panel A: 60 Day Variance risk premia

Sector	Commodity	Proportional		Fixed		Nobs
		Mean	T-Stat	Mean	T-Stat	
Energy	Crude Oil	-2.6%	-4.72	-2.7%	-4.74	5025
	Heating Oil	-2.4%	-6.11	-2.4%	-5.95	5210
	Natural Gas	-8.7%	-8.40	-9.2%	-8.48	4394
Grains	Corn	-1.8%	-6.83	-1.7%	-6.33	5024
	Cotton	2.8%	11.60	2.9%	12.27	4149
	Soybeans	-0.5%	-1.16	-0.3%	-0.80	5011
	Soybean Meal	0.4%	0.99	0.5%	1.34	3621
	Soybean Oil	-0.7%	-2.34	-0.5%	-1.80	3667
	Sugar	-1.9%	-4.42	-1.8%	-4.28	5225
	Wheat	-0.3%	-1.05	-0.2%	-0.61	4340
Livestock	Lean Hogs	-0.8%	-2.00	-0.7%	-1.67	3231
	Live Cattle	-0.9%	-9.93	-0.7%	-7.98	4642
Metals	Copper	-1.8%	-2.83	-1.8%	-2.68	4220
	Gold	-0.8%	-3.65	-0.6%	-2.85	3631
	Silver	-0.1%	-0.32	0.0%	0.14	5150
Tropical	Cocoa	-2.4%	-6.90	-2.3%	-6.66	4004
	Colombian Coffee	-0.9%	-0.37	-0.9%	-0.39	1794
	Oats	-5.6%	-7.03	-5.5%	-6.89	2095
	Orange Juice	-1.7%	-2.50	-1.6%	-2.39	3303
	Rough Rice	-2.5%	-7.39	-2.4%	-6.91	2835
Wood	Lumber	-2.9%	-9.19	-2.8%	-8.72	3660

Panel B: 90 Day Variance risk premia

Sector	Commodity	Proportional		Fixed		Nobs
		Mean	T-Stat	Mean	T-Stat	
Energy	Crude Oil	-2.9%	-4.55	-2.9%	-4.45	5477
	Heating Oil	-2.6%	-5.32	-2.5%	-5.12	5190
	Natural Gas	-7.7%	-8.07	-8.1%	-8.10	4374
Grains	Corn	-1.4%	-4.05	-1.2%	-3.67	5004
	Cotton	1.7%	7.65	1.8%	8.47	4134
	Soybeans	2.2%	1.46	2.3%	1.55	4991
	Soybean Meal	4.6%	2.32	4.8%	2.39	3601
	Soybean Oil	-0.4%	-1.21	-0.2%	-0.73	3647
	Sugar	-1.6%	-3.23	-1.5%	-3.09	5191
	Wheat	-0.2%	-0.53	0.0%	-0.13	4325
Livestock	Lean Hogs	4.7%	4.02	4.8%	4.14	3210
	Live Cattle	-0.3%	-3.61	-0.2%	-1.70	4622
Metals	Copper	-1.9%	-2.45	-1.8%	-2.32	4189
	Gold	-0.9%	-3.21	-0.7%	-2.56	3611
	Silver	-1.0%	-2.48	-0.9%	-2.18	5239
Tropical	Cocoa	-2.5%	-6.36	-2.4%	-6.12	3984
	Colombian Coffee	-0.5%	-0.18	-0.5%	-0.20	1774
	Oats	-1.4%	-0.65	-1.3%	-0.61	2075
	Orange Juice	-2.4%	-4.17	-2.4%	-3.99	3283
	Rough Rice	-1.8%	-4.47	-1.7%	-4.11	2815
Wood	Lumber	-1.8%	-4.34	-1.7%	-4.00	3640

Table 23: **The Role of Transaction Costs: LVRP**

This table presents summary statistics of commodity log variance risk premia after accounting for transaction costs. We use two distinct approaches to capture transaction costs. "Proportional" assumes that the true variance swap rate is 95 % of the synthetic variance swap rate. For example, if the synthetic variance swap rate is 10 %, the true variance swap rate is 9.5 %. "Fixed" assumes that the square root of the true variance swap rate is 1 % less than the square root of the synthetic variance swap rate. For example, if the square root of the synthetic variance swap rate is 10 %, then the square root of the true variance swap rate is 9 %. Columns entitled Mean, T-Stat, SR, and Nobs report the average, Newey-West corrected t-statistic (same lag length as the maturity of the swap), Newey-West adjusted Sharpe Ratios (annualized) and the number of observations, respectively. Panel A presents the results for a horizon of 60 days, Panel B for a horizon of 90 days.

Panel A: 60 Day Variance risk premia

Sector	Commodity	Proportional			Fixed			Nobs
		Mean	T-Stat	SR	Mean	T-Stat	SR	
Energy	Crude Oil	-28.8%	-9.03	31.2%	-27.9%	-8.72	30.1%	5025
	Heating Oil	-24.4%	-8.29	28.1%	-23.0%	-7.68	26.1%	5210
	Natural Gas	-37.9%	-11.19	41.4%	-38.8%	-11.37	42.0%	4394
Grains	Corn	-39.1%	-11.19	38.7%	-36.0%	-10.67	36.9%	5024
	Cotton	72.0%	17.96	68.3%	80.8%	19.02	72.3%	4149
	Soybeans	-20.5%	-5.24	18.1%	-16.8%	-4.31	14.9%	5011
	Soybean Meal	-3.4%	-0.92	3.8%	-0.1%	-0.03	0.1%	3621
	Soybean Oil	-16.5%	-4.38	17.7%	-13.0%	-3.42	13.9%	3667
	Sugar	-17.7%	-5.59	18.9%	-16.6%	-5.21	17.7%	5225
	Wheat	-11.0%	-3.37	12.5%	-8.0%	-2.46	9.2%	4340
Livestock	Lean Hogs	-13.2%	-2.91	12.5%	-10.6%	-2.31	10.0%	3231
	Live Cattle	-40.9%	-12.40	44.6%	-32.6%	-9.73	35.0%	4642
Metals	Copper	-24.8%	-6.33	23.9%	-22.5%	-5.67	21.4%	4220
	Gold	-29.5%	-7.09	28.8%	-23.0%	-5.44	22.1%	3631
	Silver	49.2%	4.34	14.8%	72.5%	5.56	19.0%	5150
Tropical	Cocoa	-27.2%	-8.63	33.4%	-26.3%	-8.32	32.2%	4004
	Colombian Coffee	-17.5%	-1.91	11.0%	-17.2%	-1.86	10.8%	1794
	Oats	-81.4%	-9.38	50.2%	-80.5%	-9.26	49.5%	2095
	Orange Juice	-18.2%	-3.43	14.6%	-16.8%	-3.12	13.3%	3303
	Rough Rice	-40.1%	-8.34	38.4%	-37.7%	-7.83	36.0%	2835
Wood	Lumber	-31.8%	-11.70	47.4%	-30.4%	-10.95	44.3%	3660

Panel B: 90 Day Variance risk premia

Sector	Commodity	Proportional			Fixed			Nobs
		Mean	T-Stat	SR	Mean	T-Stat	SR	
Energy	Crude Oil	-34.2%	-8.10	21.9%	-32.7%	-7.74	20.9%	5477
	Heating Oil	-27.0%	-6.87	19.1%	-25.6%	-6.41	17.8%	5190
	Natural Gas	-38.5%	-10.19	30.8%	-39.1%	-10.32	31.2%	4374
Grains	Corn	-32.3%	-7.84	22.2%	-29.1%	-7.30	20.6%	5004
	Cotton	36.5%	9.24	28.8%	43.0%	10.77	33.5%	4134
	Soybeans	-6.8%	-1.14	3.2%	-3.2%	-0.53	1.5%	4991
	Soybean Meal	18.5%	3.13	10.4%	21.7%	3.69	12.3%	3601
	Soybean Oil	-10.3%	-2.45	8.1%	-6.8%	-1.61	5.3%	3647
	Sugar	-14.6%	-3.83	10.6%	-13.3%	-3.45	9.6%	5191
	Wheat	-10.0%	-2.53	7.7%	-7.0%	-1.80	5.5%	4325
Livestock	Lean Hogs	33.2%	3.94	13.9%	36.0%	4.25	15.0%	3210
	Live Cattle	-17.8%	-5.17	15.2%	-9.1%	-2.64	7.8%	4622
Metals	Copper	-24.2%	-5.29	16.3%	-21.9%	-4.73	14.6%	4189
	Gold	-29.5%	-5.68	18.9%	-23.3%	-4.40	14.6%	3611
	Silver	14.9%	1.10	3.0%	30.8%	2.06	5.7%	5239
Tropical	Cocoa	-26.8%	-7.47	23.7%	-25.8%	-7.19	22.8%	3984
	Colombian Coffee	-13.5%	-1.23	5.8%	-13.1%	-1.18	5.6%	1774
	Oats	-60.3%	-5.28	23.2%	-59.2%	-5.19	22.8%	2075
	Orange Juice	-21.3%	-3.67	12.8%	-19.9%	-3.37	11.8%	3283
	Rough Rice	-30.3%	-5.44	20.5%	-27.8%	-4.96	18.7%	2815
Wood	Lumber	-20.7%	-5.87	19.4%	-18.8%	-5.25	17.4%	3640

Table 24: **Seasonality and Comovements in Variance Swap Returns**

This table summarizes the correlations of deseasonalized log variance risk premia within and across different commodity sectors. In Panel A, we report the average pair-wise correlation across all commodities of the same family. For example, we calculate the pair-wise correlations between crude oil, heating oil and natural gas. We then compute the average of these correlations which we report under the appropriate sector: energy. Columns headed "60-Day" and "90-Day" indicate a maturity of 60 and 90 days, respectively. Panels B and C report correlations across different commodity sectors for variance swaps of maturity 60 and 90 days, respectively. These correlations are calculated as follows. For each sector and trading day, we calculate the return on an equally-weighted portfolio of variance swaps of all commodities belonging to that specific sector. After calculating the returns of each portfolio, we compute the pair-wise correlations of returns across sectors, which we report in Panels B and C.

Panel A: Commonalities Within Sector

Sector	Correlation	
	60 Day	**90 Day**
Energy	33.35%	32.82%
Grains	24.03%	20.32%
Livestock	33.08%	25.12%
Metals	30.18%	34.11%
Tropical	3.54%	7.47%
Wood	—	—

Panel B: Commonalities Across Sectors (60 Day)

Sector	Energy	Grains	Livestock	Metals	S&P500	Treasury	Tropical	Wood
Energy	100.00%							
Grains	10.50%	100.00%						
Livestock	16.56%	17.36%	100.00%					
Metals	21.84%	10.81%	15.08%	100.00%				
S&P500	27.23%	2.70%	11.97%	31.96%	100.00%			
Treasury	21.59%	14.32%	9.54%	20.19%	39.34%	100.00%		
Tropical	6.13%	27.57%	10.34%	7.11%	-1.34%	-0.48%	100.00%	
Wood	8.74%	1.20%	8.30%	2.33%	7.18%	8.30%	8.96%	100.00%

Panel C: Commonalities Across Sectors (90 Day)

Sector	Energy	Grains	Livestock	Metals	S&P500	Treasury	Tropical	Wood
Energy	100.00%							
Grains	7.93%	100.00%						
Livestock	14.06%	15.30%	100.00%					
Metals	24.91%	11.20%	4.71%	100.00%				
S&P500	27.40%	2.87%	10.78%	32.26%	100.00%			
Treasury	23.49%	22.50%	12.98%	9.06%	51.89%	100.00%		
Tropical	14.90%	32.91%	12.66%	11.79%	-2.53%	-4.19%	100.00%	
Wood	17.81%	4.79%	14.21%	-2.94%	6.37%	17.31%	8.05%	100.00%

Table 25: **Non-Overlapping Variance Risk Premia**

This table displays summary statistics for non-overlapping variance risk premia. Columns under Mean, T-Stat, Median, AR(1), Min and Max report the average, Newey-West corrected t-statistics (6 lags), median, first order auto-correlation, minimum and maximum values. Std Dev, Skew and Kurt refer to standard deviation, skewness and kurtosis. The last column reports the number of observations.

Panel A: 60 Day Variance Risk Premia

Sector	Commodity	Mean	T-Stat	Median	AR(1)	Min	Max	Std Dev	Skew	Kurt	Obs
	Crude Oil	-2.8%	-3.55	-2.9%	0.17	-0.29	0.54	0.09	2.17	18.26	135
Energy	Heating Oil	-2.7%	-4.56	-2.4%	-0.17	-0.46	0.34	0.07	-0.23	16.40	132
	Natural Gas	-9.1%	-8.18	-6.7%	-0.04	-0.46	0.25	0.13	-0.62	3.81	112
	Corn	-2.7%	-9.51	-2.2%	-0.20	-0.15	0.16	0.04	0.18	6.85	134
	Cotton	2.8%	8.32	2.6%	0.13	-0.09	0.14	0.03	0.42	6.19	106
	Soybeans	-1.4%	-2.95	-1.4%	0.02	-0.17	0.35	0.05	2.94	23.49	135
Grains	Soybean Meal	0.1%	0.15	-0.5%	-0.11	-0.10	0.25	0.05	1.84	9.45	129
	Soybean Oil	-0.9%	-2.69	-1.0%	0.07	-0.08	0.18	0.03	1.42	10.69	126
	Sugar	-2.5%	-4.04	-2.4%	0.12	-0.22	0.15	0.06	0.02	4.86	128
	Wheat	-1.0%	-3.47	-1.2%	-0.10	-0.13	0.16	0.04	0.47	6.16	132
Livestock	Lean Hogs	-0.3%	-0.69	-0.9%	0.11	-0.10	0.18	0.04	1.35	7.83	84
	Live Cattle	-1.0%	-6.23	-0.7%	0.02	-0.10	0.03	0.02	-1.60	11.14	142
	Copper	-1.7%	-2.46	-1.5%	0.01	-0.33	0.57	0.08	2.01	24.44	128
Metals	Gold	-0.8%	-3.41	-0.7%	0.21	-0.14	0.12	0.03	0.17	13.45	118
	Silver	-0.3%	-0.58	0.3%	0.19	-0.25	0.12	0.04	-2.42	19.44	134
	Cocoa	-2.5%	-4.85	-2.2%	0.30	-0.22	0.12	0.05	-0.05	4.75	123
	Colombian Coffee	-0.2%	-0.05	-3.5%	0.36	-0.22	1.04	0.21	3.02	14.40	51
Tropical	Oats	-5.9%	-5.55	-6.4%	0.21	-0.24	0.22	0.07	1.27	6.43	90
	Orange Juice	-2.7%	-3.51	-2.5%	0.08	-0.25	0.29	0.07	0.61	7.58	112
	Rough Rice	-2.8%	-6.22	-2.6%	0.10	-0.17	0.07	0.04	-0.42	4.06	101
Wood	Lumber	-2.6%	-5.88	-2.5%	0.05	-0.21	0.07	0.04	-1.21	7.74	122

Panel B: 90 Day Variance Risk Premia

Sector	Commodity	Mean	T-Stat	Median	AR(1)	Min	Max	Std Dev	Skew	Kurt	Obs
	Crude Oil	-3.3%	-4.05	-2.8%	0.00	-0.28	0.32	0.07	0.90	12.01	89
Energy	Heating Oil	-2.5%	-4.29	-2.3%	-0.10	-0.16	0.28	0.05	1.64	14.66	88
	Natural Gas	-9.0%	-6.35	-6.7%	-0.04	-0.51	0.12	0.11	-1.33	5.72	74
	Corn	-1.5%	-3.67	-1.6%	-0.21	-0.15	0.16	0.04	0.75	7.33	89
	Cotton	1.3%	5.35	1.1%	-0.07	-0.04	0.08	0.02	0.93	5.20	70
	Soybeans	1.2%	0.79	-0.7%	-0.01	-0.10	1.15	0.14	6.61	51.85	89
Grains	Soybean Meal	3.3%	1.89	0.2%	-0.05	-0.11	1.28	0.16	6.37	49.61	86
	Soybean Oil	-0.9%	-2.52	-0.8%	0.16	-0.10	0.16	0.03	1.25	10.04	84
	Sugar	-4.2%	-4.82	-3.7%	0.12	-0.21	0.17	0.06	0.08	4.49	85
	Wheat	-0.5%	-1.67	-0.8%	0.09	-0.09	0.16	0.03	1.68	10.46	88
Livestock	Lean Hogs	5.5%	5.12	2.2%	-0.35	-0.11	0.31	0.10	0.98	3.03	55
	Live Cattle	-0.5%	-5.72	-0.5%	-0.08	-0.03	0.03	0.01	0.32	4.35	94
	Copper	-2.3%	-3.12	-1.5%	0.15	-0.25	0.26	0.06	-0.20	10.14	85
Metals	Gold	-0.8%	-2.83	-0.8%	0.00	-0.14	0.10	0.03	-0.74	13.42	78
	Silver	-1.2%	-1.53	-0.1%	0.49	-0.19	0.10	0.04	-1.57	7.69	89
	Cocoa	-3.0%	-6.11	-2.8%	0.06	-0.14	0.08	0.04	0.05	3.42	82
	Colombian Coffee	-2.2%	-0.65	-2.3%	0.23	-0.45	0.51	0.16	0.91	7.39	33
Tropical	Oats	-1.1%	-0.47	-5.0%	-0.02	-0.13	0.87	0.16	3.91	19.64	60
	Orange Juice	-2.3%	-3.71	-2.0%	0.04	-0.15	0.09	0.05	-0.37	2.85	74
	Rough Rice	-1.7%	-4.04	-1.8%	0.02	-0.13	0.11	0.04	0.31	4.27	67
Wood	Lumber	-2.0%	-3.55	-2.2%	0.11	-0.17	0.09	0.04	-0.33	4.67	81