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Discussion Paper

Commodity Risk Factors and the Cross-Section of Equity Returns

September 2014

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Discussion Paper Number:
ICM-2014-09

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Abstract
The article examines whether commodity risk is priced in the cross-section of equity returns. Alongside a long-only equally-weighted portfolio of commodity futures, we employ as an alternative commodity risk factor a term structure portfolio that captures the propensity of commodity futures markets to be backwardated or contangoed. Equity-sorted portfolios with greater sensitivities to the two commodity risk factors command higher average returns. The two commodity portfolios are also found to explain part of the size, value and momentum anomalies. Conclusions regarding the pricing of the commodity risk factors are not an artifact driven by crude oil and are robust to the inclusion of financial and macroeconomic variables and to the addition of a composite leading indicator in the pricing model.

Keywords
Long-only commodity portfolio, term structure portfolio, commodity risk, cross-section of equity returns

JEL Classifications
G11, G13

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1 Introduction

A recent strand of the asset pricing literature argues that commodity risk factors have a role to play in pricing traditional assets. For example, Boons *et al*. (2012) find that a long-only commodity futures portfolio commands a risk premium of – 5.5% before 2003 and +8.5% post-2003 in equity markets,[1] while Hou and Szymanowska (2013) show that a commodity-based consumption tracking portfolio explains the cross-section of average stock returns. Along the same lines, Miffre *et al*. (2014) document that commodity risk factors relating to backwardation and contango act as sources of intertemporal risks in traditional asset markets.

Commodity variables have also been shown to act as leading economic indicators. For example, Hamilton (1983), Jones and Kaul (1996) and Driesprong *et al*. (2008) argue that oil price rises contribute to economic recessions and to falling stock prices. Jacobsen *et al*. (2013) demonstrate that industrial metal price movements forecast economic growth, with Hu and Xiong (2013) also ascribing such a barometric role to copper and soybean prices and Bakshi *et al*. (2014) to a measure of shipping freight activity (the Baltic Dry Index). Commodity open interest and phases of backwardation and contango in commodity futures markets have also been shown to matter as indicators of forthcoming changes in investment opportunities (Baker and Routledge, 2012; Hong and Yogo, 2012; Bakshi *et al*., 2013; Miffre *et al*., 2014).

This article tests whether two commodity portfolios – a long-only equally-weighted portfolio of commodity futures (*EW* hereafter) and a term structure portfolio that is long backwardated commodities and short contangoed commodities (*TS* hereafter) – explain the pricing of the 100 size and book-to-market sorted equity portfolios of Fama and French (1992). The rationale for treating the commodity-based *TS* portfolio as a priced factor follows from the theory of storage of Kaldor (1939), Working (1949) and Brennan (1958). The theory of storage argues that backwardation (as evidenced by a downward-sloping *TS* of commodity futures prices) signals scarce supply and forthcoming price rises, while contango (supported by an upward-sloping *TS*) translates into abundant supply and upcoming price falls (see also Fama and French, 1987; Erb and Harvey, 2006; Gorton and Rouwenhorst, 2006; Gorton *et al*., 2012). Assuming that firms are net consumers of commodities,[2] phases of backwardation could be considered as bad news to

[1] They attribute the switch in the signs of the commodity risk premium to the Commodity Futures Modernization Act of 2000 that enabled investors post-2000 to hedge commodity price risk directly using futures markets as opposed to indirectly using stock markets (as they did before then).

[2] A casual glance suggests that only around 6% of firms in the CRSP universe can be classified as commodity producers while the remainder are either light or heavy users of commodities that are likely to be hurt by price rises. Aggregating to national levels, there are some economies which may benefit from commodity price rises because the net balance of firms is in favor of producers rather than

equity investors as rising commodity prices would then translate into potentially falling net profit margins. Vice versa, phases of contango could be considered good news to equity investors as falling commodity prices could translate into potentially rising net profit margins. Other things being equal, equity investors would demand greater expected returns on stocks that are more sensitive to backwardation, lower expected returns on stocks that are more sensitive to contango and thus the *TS* portfolio that is long backwardated commodities and short contangoed commodities would then command a positive risk premium. Alternatively, rising commodity prices could signal improved economic prospects especially during recessions (Hu and Xiong, 2013; Jacobsen *et al*., 2013) and thus potentially lower equity expected returns. Under this alternate setting, the *EW* and *TS* commodity portfolios will be priced negatively in the cross-section of equity returns. The question of the sign and statistical significance of the *EW* and *TS* risk premia in the cross-section of equity returns thus needs to be empirically tested, which is the primary objective of this paper.

We present strong evidence in support of the hypotheses that both the *EW* and *TS* commodity portfolios command positive and significant prices of risk in equity markets. Other things being equal, equity investors are willing to pay less for stocks that are exposed to commodity risk. The conclusions are not an artifact driven by crude oil; they are also robust to the consideration of sub-periods pre and post the Commodity Futures Modernization Act (CFMA) of 2000 or to the formulation of various asset pricing models such as Fama and French (1993) and Chen *et al*. (1986).

This study also tests whether anomalies such as the size, value and momentum effects are still present in the data once the *EW* and *TS* commodity risk factors are included in the pricing model. When the *EW* and *TS* portfolio returns are treated as additional risk factors, the magnitude and statistical significance of the risk premia associated with the value, momentum and, to a lesser extent, size, factors are reduced. The commodity risk factors we propose therefore explain part of the size, value and momentum anomalies.

Since commodities have important uses in numerous production processes, it is intuitive to think that commodity risk factors could affect the pricing of stocks. However, two important questions to ask at the outset are first, whether investors can diversify away commodity price risk, and second, whether firms themselves are able to hedge the risks. If the answer to either or both of these questions is affirmative, we would not expect commodity risk to be priced. Concerning the issue relating to diversification, there is convincing evidence that commodity

consumers of commodities (e.g., oil producing countries in Africa and the Gulf region). Yet such economies are small in number and on a global scale, the world economy is a net consumer.

variables predict the business cycle (Hamilton, 1983; Jones and Kaul, 1996; Hu and Xiong, 2013; Bakshi *et al*., 2014; Miffre *et al*., 2014), suggesting that commodity risk is a pervasive, market-wide risk factor that could be priced cross-sectionally. When it comes to the question pertaining to hedging, the positions of energy producers, refiners and consumers highlight selective hedging and some speculation (Dewally *et al*., 2013), suggesting that hedging is incomplete. Likewise, producers' hedging demand has been shown to relate to distress and default risks, with safer producers presenting a lower propensity to hedge (Haushalter, 2000; Acharya *et al*., 2013).[3] If hedging is – as it seems – incomplete, investors in the cross-section could well demand, as we hypothesize, a premium for exposure to commodity risk.

Given the obvious importance of the relationship between commodity prices and economic activity (see, for example, Driesprong *et al*., 2008), it is perhaps surprising that there have been very few studies which have tested for a commodity risk premium in stock returns and the majority of existing research has examined the link at the aggregate equity market level and has focused on oil, ignoring all other commodities. On the cross-sectional side, early research by Chen, Roll and Ross (1986) suggested that changes in oil prices were not significantly priced in the cross-section of returns to portfolios sorted on size, although it is possible that any oil price effects were subsumed by the influences of inflation, which was also included in their specification. The closest research to our own is the recent study by Boons *et al*. (2012), discussed below, which directly estimates a commodity risk premium in so far as it applies to equities.

We contribute to this literature in two important ways. First, existing studies have essentially employed commodity price indices as the basis for measuring risk but they do not capture the forward-looking nature of firms' underlying risk premia. By using a measure of the extent to which the commodity markets are on aggregate backwardated or contangoed, by contrast our measure of commodity price risk has a forward-looking dimension and reflects underlying demand and supply conditions and investor beliefs about how they will change in those markets. We show that this factor has explanatory power in addition to that embodied in an equally weighted index of commodities. Second, we employ data on a broad range of 27 commodities to construct the risk premium measure rather than focusing exclusively on oil and ignoring the remainder of resource markets, as has been the case in the majority of prior studies. While oil is

[3] There are many reasons to believe that commodity producers, processors and consumers cannot hedge price risk fully. Full hedging would be too expensive in terms of both transaction costs and losses incurred from not benefiting from anticipated price changes. Besides, it may be seen as simply impossible for a producer to fully hedge the indirect effects that commodity price shocks have on the real economy and thereby on consumers' demand for the products and services that this specific producer offers.

still indisputably a key economic driver and the most heavily used commodity by value, the world economy has become less dependent on it. A benefit of this approach is that our measure of commodity price risk will be less influenced by oil price noise and should therefore be more broadly representative of the costs that firms actually face. [4]

The remainder of this study is laid out as follows. Section 2 presents the methodology we employ, which is a variant of the two-step approach of Fama and MacBeth (1973). Section 3 describes the sources and nature of the data and explains how the commodity risk factors are constructed. Section 4 discusses the results while Section 5 presents some additional analyses and robustness checks. Finally, Section 6 concludes.

2 Methodology

We employ a variant of the standard two-step Fama and MacBeth (1973) methodology. In the first step, we run regressions of the excess returns of size and book-to-market (*B/M*) ratio-sorted equity portfolios on a set of risk premia or a set of unexpected risk factors

$$R_{P,t} = \alpha_P + \beta_P F_t + \varepsilon_{P,t} \tag{1}$$

where $R_{P,t}$ are the time *t* excess returns of size- and book-to-market (*B/M*) sorted portfolios of Fama and French (1992), $P \in \{1,2,\ldots 100\}$, F_t is a vector of *K* risk premia or a set of *K* unexpected risk factors that are known or assumed to explain the cross-section of equity returns, β_P is a vector of sensitivities of portfolio *P* to these *K* risk premia or risk factors, α_P is a constant and ε_{Pt} is an error term.

Regression (1) is first estimated over the sample January 1980 to December 1984. The measures of risk (β_P) are used in a second step to explain the cross-section of mean excess returns in each month *k* from January 1985 to December 1985. The cross-sectional regression in a given month *t+k* is:

$$R_{P,t+k} = \lambda_{0,t+k} + \lambda_{t+k}\beta_P + \vartheta_{P,t+k} \tag{2}$$

[4] We do, however, consider the impact of oil on our findings as a robustness check later in the paper.

where λ is a K-vector of prices of risk associated with F_t, λ_0 is an intercept and ϑ_P is an error term. This step produces 12 estimates of the vector $\{\lambda_0,\lambda\}$. Finally, the sample is rolled-over by 12 observations at a time, with each repetition of the two steps producing 12 new estimates of each of the factor risk premia. *t*-tests are then performed on the resulting risk premia to determine which factors explain the cross-section of realized stock returns. Throughout, we employ the adjustment of Shanken (1992) to the second stage standard errors which takes into account the estimation error in the betas from the first stage.

3 Data

3.1 Commodity risk factors

Our dataset runs from January 1979 to December 2012. End-of-month settlement prices are obtained from *Thomson Datastream* on a total of 27 commodities. These include 12 agricultural commodities (cocoa, coffee C, corn, cotton n°2, frozen concentrated orange juice, oats, rough rice, soybean meal, soybean oil, soybeans, sugar n° 11, wheat), five energy commodities (blendstock RBOB gasoline, electricity, heating oil n° 2, light sweet crude oil, natural gas), four livestock commodities (feeder cattle, frozen pork bellies, lean hogs, live cattle), five metal commodities (copper, gold, palladium, platinum, silver) and random length lumber. As is standard in the literature, futures returns are calculated using the settlement prices of front contracts up to one month prior to maturity and the settlement prices of second nearest contracts in months when front contracts mature. All series are on an end-of-month basis.

We first calculate the roll-yields of each commodity as the price differentials between the front and second nearest contracts. These roll-yields are argued to have information regarding the market's expectation of the subsequent direction of spot price changes: positive roll-yields imply backwardation, scarce inventories and anticipated rises in futures prices, while negative roll-yields indicate contango, abundant inventories and subsequent falls in futures prices. The 27 commodities are ordered according to the average of these monthly roll-yields over the previous R months ($R = 3, 6, 12$). We consider relatively long ranking periods of up to 12 months to reflect the fact that inventory levels are slow to replenish or deplete; the relatively long moving average employed is thus deemed to capture the slow changes in the slope of the term structure over time. We then buy the front contracts of the 25% of the cross-section of commodities with the highest average roll-yields and sell the front contracts of the 25% of the cross-section of commodities with the lowest average roll-yields. We call these roll yields a term structure (*TS*) of commodity futures prices since they embody the differences in prices for delivery nearby and further into the future. This term structure provides information about the level of inventories and thus about the supply of and demand for the physical asset (Gorton, Hayashi and Rouwenhorst, 2013).

We also form a fully-collateralized *TS* portfolio that includes both long positions in the 25% most backwardated commodities and short positions in the 25% most contangoed commodities. The positions are held for one month, the sample is recursively updated and a new set of backwardated, contangoed and *TS* portfolios is formed. We then use the returns to these three portfolios as separate factor-mimicking portfolios for commodity price risk. In order to proxy for commodity market prices more generally, we also employ a long-only monthly-rebalanced equally-weighted portfolio of all commodities (*EW* hereafter).

A benefit of using portfolios of commodities constructed on the basis of the term structure of prices is that our commodity price risk measure will hone in on those series where expected future price changes are the greatest. These commodity factor-mimicking portfolios will also capture the extent of systematic hedging pressure since commodities that are in backwardation (respectively, contango) according to their term structures typically tend to be in backwardation (contango) with respect to their hedging pressures as well.

Table 1 presents summary statistics for the excess returns of the fully-collateralized backwardated, contangoed and *TS* portfolios over the period January 1980 to December 2012. Clearly the *TS* strategy works in the sense that forming portfolios in this fashion generates positive mean excess returns, as Erb and Harvey (2006) and Gorton and Rouwenhorst (2006), amongst others, have already documented. The fully-collateralized portfolios that include both long and short positions are able to generate average excess returns between 6.04% and 8.03% a year, with Sharpe ratios between 0.60 and 0.87. A monthly-rebalanced equally-weighted portfolio of the three *TS* portfolios earns a mean excess return of 7.24% a year, significant at the 1% level and a Sharpe ratio of 0.83. Alongside the long-only *EW* portfolio of all commodities, the *TS* portfolios have been shown to explain the cross-section of commodity futures returns (Bakshi *et al*., 2013; Basu and Miffre, 2013; Szymanowska *et al*., 2014). The key question of our paper is whether they are similarly able to explain the cross-section of equity returns.

3.2 Traditional risk factors

Aside from these commodity risk factors, we employ two separate sets of variables for inclusion in the vector *F* in equation (1). The first set includes the Fama and French (1993), Carhart (1997) and Pastor and Stambaugh (2003) series: the equity risk premium, *ERM*; the size premium, *SMB* (small-minus-big); the value premium, *HML* (high *B/M*-minus-low-*B/M*); the momentum factor (*UMD*, up-minus-down) and the liquidity risk premium, *LRP*. The value-weighted return on all NYSE, AMEX, and NASDAQ stocks in excess of the one-month Treasury bill rate is used as a proxy for the market risk premium. Data on *ERM*, *SMB*, *HML* and *UMD* are obtained from K. French's website; data on *LRP* are from R. Stambaugh's.

Commodity price shocks are drivers of upward movements in the costs of production and therefore general price levels; consequently, the periods of historically very high commodity prices (during the 1970s in particular) were associated with high inflation and reduced economic activity. It is thus plausible that the commodity price effects assumed to be present in the cross-section of sorted portfolios are merely an indirect way to capture premia relating to macroeconomic risks. To test this empirically, we employ as a second set of risk factors variables that capture the macroeconomic environment. Following Chen *et al*. (1986), these factors are: the monthly growth in industrial production (*IP*), the changes in expected inflation (*DEI*), unexpected inflation (*UI*), shocks to default (*UDS*) and term (*UTS*) spreads.[5]

Table 2 presents the correlations and associated *t*-statistics for the risk factors. The correlations between the backwardated, contangoed and *TS* portfolios and traditional risk factors are low, ranging from -0.12 to 0.24. As expected, the correlation is positive and highly significant between the excess returns on the equally-weighted portfolio of commodities (*EW*) and the excess returns on the backwardated portfolios in Panel A, with coefficients of around 0.72. The same conclusion applies to the return correlations between *EW* and the contangoed portfolios in Panel B. Therefore, in the following regressions we analyze the effect of backwardation and contango after accounting for the effects of the equally-weighted portfolio of all commodities by systematically considering as risk factors the residuals from regressions of the excess returns of the backwardated (contangoed and *TS*, respectively) portfolios onto a constant and the excess returns of the *EW* portfolio. Then we model the impact of the *TS* slope after accounting for the pricing of *EW*.

[5] The *IP* series is computed by taking the log differences of industrial production series. To derive the *DEI* series, we first calculate the inflation rate by taking log changes in the consumer price index. Then, we calculate expected inflation to be the 3-month moving average of the inflation rate series. *UI* is estimated by deducting the expected inflation rate from the observed inflation rate. The difference between Moody's seasoned Baa corporate bond yield and long-term government bond yields (10-years) gives the *UDS* series whilst the *UTS* measure is the difference between long-term government bond yields (10-year) and the yield on 3-month Treasury bills. All the macroeconomic series used in the aforementioned calculations are retrieved from the Federal Reserve Economic Data website.

3.3 Base assets

Our dependent variables ($R_{P,t}$ in equation (1)) are the returns on 100 size and *B*/*M*-portfolios in excess of the one-month Treasury-bill rate. This is a key difference between our study and that of Boons *et al*. (2012) who use as base assets 30 commodity-beta sorted portfolios. One could argue that this constitutes a 'home game' for the commodity factors and the relatively modest size of their cross-section and resulting noisy risk premia may go part of the way to explaining why their estimates are never statistically significant in the post-2004 regressions and thus why commodity risk is not priced in their case.

4 Empirical Results

Table 3 presents the average values and associated *t*-statistics for the risk premia, i.e., the λs, when only *EW* and the orthogonalized *TS* portfolios enter equation (1). The estimated λ_{TS} coefficients shown in Panel A of Table 3 are positive and indicative that backwardation represents bad news to equity investors; equities with high sensitivity to backwardation are priced down, with investors demanding yearly mean returns that are 8.56% higher on these stocks. This relationship, albeit economically significant, is not statistically significant. By contrast, the results in Panel B show that contango represents good news to equity investors: Other things being equal, equities with high sensitivity to contango are more highly priced with investors demanding yearly expected returns that are 14.29% lower on these stocks. This relationship is strongly significant at the 1% level. The long-short *TS* portfolios in Panel C command a positive annualized risk premium of 12.2% that is statistically significant at the 1% level. The *TS* portfolios command a risk premium that goes beyond the role played by commodity price levels (*EW*). Unlike Boons *et al*. (2012), the latter is found to command a positive risk premium that stands 14.88% a year on average and is significant at the 1% level.

Overall, the results in Table 3 clearly suggest that commodity risk is priced in equity markets: investors demand more for stocks that are sensitive to the risk that commodity prices may rise. The results pertaining to the contangoed and *TS* portfolios also suggest that the slope of the term structure of commodity futures prices has a role to play beyond that embodied in the *EW* commodity portfolio. The λ_{EW} coefficients are more significant than the λ_{TS} coefficients, but this is expected by design since the backwardated, contangoed and *TS* risk factors have all been orthogonalized with respect to the excess returns of the *EW* commodity portfolio.

Table 4 proceeds to investigate whether the conclusions of Table 3 are robust to the inclusion in equation (1) of the traditional risk factors of Fama and French (1993), Carhart (1997) and Pastor and Stambaugh (2003) – *ERM*, *SMB*, *HML*, *UMD* and *LRP*. The first row of Panel A shows the prices of risk associated with the market, size, value, momentum and liquidity factors only, excluding any commodity risk measures at all, while in the second row the equally-weighted commodity portfolio *EW* is also added to regressions (1) and (2).

The results in the first row show that only value, momentum and liquidity are positively and significantly priced in the cross-section of size and book-to-market sorted portfolios. When the *EW* excess returns are treated as an additional factor (row two of Panel A), both the value and momentum factor risk premia are reduced to around half their previous values and become statistically insignificant. Most importantly, the inclusion of traditional risk factors does not alter the conclusions of Table 3 regarding the pricing of *EW*: the *EW* portfolio still commands a risk premium that is positive at 14.16% a year and highly significant (*t*-statistic of 4.04).

Panels B to D of Table 4 replicate the analysis of Panels A to C of Table 3 respectively, except that now the traditional risk factors are also included in regressions (1) and (2). It is clear that the conclusions of Table 3 remain valid inasmuch as the risk that commodity prices could rise still commands a positive risk premium. Again, backwardation is considered as bad news: investors price stocks with strong exposure to backwardation lower and demand a yearly risk premium that is, other things being equal, 5% higher on average on these stocks. On the other hand, contango is treated as good news: investors price stocks with strong exposure to contango higher and demand a yearly risk premium that is, other things being equal, 8.02% lower on average on these stocks. As in Table 3, the results when both backwardation and contango are considered together (Panel D) show that the *TS* portfolios command strongly positive and highly significant risk premium that average 7.4% per year. Similar unreported results were obtained when the backwardated, contangoed and *TS* portfolios were forced to be orthogonalized to both *EW* and all traditional risk factors.

Does the inclusion of both *EW* and the backwardated (contangoed and *TS*, respectively) portfolios change our conclusions regarding the statistical and economic significances of the prices of risk estimated for *ERM*, *SMB*, *HML*, *UMD* and *LRP*? A comparison of the appropriate *t*-ratios in Panels B to D of Table 4 with the corresponding values in the first row of Panel A show that when both commodity factors are added, the magnitude of the size premium is around five times lower in Panel B, 23 times smaller in Panel C and eight times smaller in Panel D; the magnitude of the value premium is halved in Panels C and D; the magnitude of the momentum premium is roughly four times lower in Panels B and C and one eleventh the size in Panel D. It therefore appears that the commodity factors are able to explain the size, value and momentum anomalies, which is a particularly strong result given that the portfolios used as dependent variables are sorted on size and book-to-market.

5 Robustness Checks and Additional Analysis

5.1 Sub-sample Analysis

Tables 5 and 6 repeat the analysis reported in Panels B to D of Table 4 over two consecutive sub-samples, spanning January 1980–December 2003 and January 2004–December 2012, respectively. As in Boons *et al*. (2012), the choice of December 2003 as break date leaves three years for the Commodity Futures Modernization Act (CFMA) of December 2000 to become effective. As in Table 4, the signs of the commodity risk premia reported in Tables 5 and 6 are positive throughout. For the most part, the magnitudes of the commodity risk premia are similar to those reported in Table 4. This indicates that investors persistently require rewards for holding stocks bearing commodity price risk. We note, however, a considerable reduction in the statistical significance of all risk premia in the second sub-sample. We conjecture that this fall in statistical significance is at least in part a function of the fall in sample size from the regressions using the whole sample (396 monthly observations) to those using the second sub-period (108 monthly observations). This has obvious implications for the magnitudes of the standard errors that are inversely related to number of data points, all else equal.

Boons *et al*. (2012, e.g., their Table 9) report commodity risk premia that switch from negative at an average of –5.6% pre-CFMA to positive at an average of 8.63% post-CFMA. The cross-section results they report are not directly comparable to the results presented in Tables 5 and 6, not only because of differences in test assets (they use 30 commodity beta-sorted portfolios when we use 100 two-way size- and value-sorted portfolios), but also because of differences in the commodity risk factors used (we use two different sources of commodity risk *EW* and *TS*, when they consider only one which is similar in spirit to our *EW*). These points notwithstanding, our annualized commodity risk premia equal 15.2% and 7.45% for *EW* and *TS* pre-CFMA, changing to 8.06% and 7.09% respectively post-CFMA. Thus, we can only confirm their *EW* estimate for the period spanning January 2003 onwards and we find that the risk premia are positive throughout rather than switching signs as in their case.

5.2 Is the Commodity Risk Premium an Oil Risk Premium?

Crude oil makes up the majority of most weighted commodity index baskets. Shocks to crude oil prices are also likely to have a more perilous impact on economic output, consumer price levels and firms' profits than changes in the prices of other less traded commodities such as frozen pork bellies. As a result, it is reasonable to question whether the observed premium which investors require for holding equities susceptible to commodity price changes is actually a noisy way to proxy for the impact of crude oil rather than a broader class of commodities.[6] In order to test this, we replicate the analysis reported in Table 4 excluding crude oil futures contracts from both the long-only *EW* portfolio of all commodities and from the cross-section of commodities upon which the backwardated, contangoed and *TS* portfolios are formed. The results are reported in Table 7. Our main conclusions regarding the signs and statistical significances of the commodity risk premia are robust to the exclusion of crude oil. We conclude therefore that the results reported thus far are not an artifact of crude oil.

5.3 Financial and Macroeconomic Risk Factors

As discussed in Section 3, it may be that commodity price changes are merely capturing information that could be modeled more directly using macroeconomic variables, including most notably exposures to unexpected inflation. In order to test this, Table 8 presents the averages of the prices of risk estimated from second-stage cross-sectional regressions that employ as risk factors a set of financial and macroeconomic variables. It is clear from the parameter estimates and their standard errors that the key messages from the above analysis still remain. While both the sizes and significances of the premium associated with the *EW* factor are slightly reduced compared to the results presented in Table 4, the estimated *TS* risk premia are somewhat larger in absolute magnitude than in Table 4, with unchanged levels of statistical significance. Therefore, we can conclude that commodities constitute a risk factor that is distinct from, and more important than, any inflationary or other macroeconomic risk factors. Interestingly, among the financial and macroeconomic factors themselves, only unexpected changes in the term structure of interest rates are positively and significantly (at the 1% level) priced in the cross-section of portfolios sorted on size and book-to-market; none of the other financial and macroeconomic risk premia is significant even at the 10% level.

5.4 Are the Commodity Risk Factors Proxies for Future Economic Activity?

The motivation for a link between equity returns and commodity prices presented above presumed that rises in the latter are unambiguously negative due to the adverse impact that they will have on firm profitability and general economic inflation, with consequent reductions

[6] Chen *et al*. (1986) originally test for, and find evidence against, an oil term being significant in pricing the cross-section of equity returns. They surmise that the effect of oil price rises could be picked up more cleanly by other variables such as national output.

in consumer purchasing power. This is the case of rises in crude oil prices that are deemed to contribute to a reduction of economic growth and falling stock prices (Hamilton, 1983; Jones and Kaul, 1996; Driesprong *et al*., 2008). However, it has also been argued that commodity price rises may be a positive signal of increasing economic activity in the future. Hu and Xiong (2013) argue that the positive correlation between commodity futures overnight returns and next day East Asian stock price changes is indicative of the information-content of the former concerning world economic activity. Similarly, Bakshi *et al*. (2014) suggest that increases in the Baltic Dry Index might occur at the same time as commodity and stock price rises in anticipation of a subsequent increase in economic growth. It is also possible that the relationship between commodity prices and the business cycle is time-varying. Specifically focusing on industrial metals, Jacobsen *et al*. (2013) suggest that during recessions, a rise in commodity prices is a positive signal of increasing subsequent economic activity, while the reverse is true during expansions when the level of activity is already high and further price rises are considered as signs of "overheating".

There exists a substantive and entirely separate literature that investigates the properties of certain time-series to predict future levels of industrial production several quarters ahead (see, for example, Bandholz and Funke, 2003; Banerjee and Maellino, 2006). Since these series are noisy and their individual forecasting power may vary over time, a set of composite leading indicators, combining several individual leading series in a weighted fashion, are also constructed. The most commonly used such composite leading indicator (*CLI*) is produced by the OECD. The constituent series and weightings vary between countries, but we opt to use the OECD World *CLI* figures, obtained from their web site, on the grounds that commodity prices are affected by global supply and demand factors.[7]

We rerun the two-step regression procedure, using all financial and macroeconomic indicators in Table 8, alongside the monthly unexpected change in the OECD World *CLI* (*UCLI*) for the entire 1980–2012 sample period. The results for the lambda estimates are presented in Table 9. The risk premia for *UCLI* are uniformly positive and statistically significant at the 5% level or lower.[8] Of particular interest to the present study is whether the coefficients on the *EW* and *TS* portfolios differ compared with the corresponding values reported in Table 8. There is clearly no reduction

[7] The series comprise: Dwellings started (number), Net new orders for durable goods (*USD*), Share prices: NYSE composite (2010=100), Consumer sentiment indicator (normal = 100), Weekly hours of work: manufacturing (hours), Purchasing managers index (% balance), Spread of interest rates (% p.a.). Source: http://www.oecd.org/std/leading-indicators/CLI-components-and-turning-points.pdf

[8] This result fits well with the prediction of the Intertemporal CAPM of Merton (1973): equity portfolios with positive sensitivities to *UCLI* follow the ups and downs of the business cycle and thus fail to hedge unwelcome changes in investment opportunities; investors who hold such portfolios demand higher risk premia as compensation for the intertemporal risk they are subjected to.

in the strength of the *EW* risk premium – if anything, the coefficients are slightly larger with higher *t*-statistics when *UCLI* is included. Similarly, relative to Table 8, the magnitude and significance of the prices of risk associated with the backwardated, contangoed and *TS* portfolios are only marginally reduced. This suggests that the two risk factors we propose (*EW* and *TS*) are entirely separate sources of risk compared with that embodied in *UCLI*.

6 Conclusions

This article tests whether two commodity risk factors – a long-only equally-weighted portfolio of commodity futures (*EW*) and a long-short term structure portfolio (*TS*) – are priced in the cross-section of equity returns. Intuitively, commodity price rises have an ambiguous impact on stock returns. It is possible that such price rises represent worsening cost bases and reductions in profitability; on the other hand, commodity price rises may signal expected growth in the real economy, resulting in higher firm profitability. The question of the sign and statistical significance of the *EW* and *TS* risk premia in the cross-section of equity returns thus needs to be tested empirically, which is the primary objective of this article.

We present evidence that both *EW* and *TS* command positive and statistically significant risk premia in the cross-section of size- and *B/M*-sorted equity returns. The signs obtained on the risk premia indicate that investors perceive periods of backwardation and of forthcoming rising commodity prices as bad news; they then demand an increased compensation for exposure to commodity price risk. Vice versa, periods of contango and of forthcoming falling commodity prices are perceived as good news; investors are then happy to earn lower expected returns on equities that are sensitive to contango. Further evidence suggest that the conclusions are not an artifact of crude oil and are robust to various sub-samples and to several specifications of the asset pricing model at hand such as Fama and French (1993) or Chen *et al.* (1986). The *EW* and *TS* commodity risk factors are further found to explain part of the value, momentum and, to a lower extent, size effects.

While our research has presented a clear demonstration that commodity risk is priced in the financial markets, an obvious question for future research is why this is the case. Commodity and stock prices are linked, both directly and indirectly, as a result of the important use of commodities in production processes. The direct effect of commodity price rises occurs when changes in the cost of commodities affect a firm's profitability where commodities are a significant proportion of their overall costs. The indirect impact takes place through their effects on the inflation rate via the costs of goods, and the resulting fall in consumers' purchasing powers will then adversely affect their demand for end products and services. Eventually, this will feed through to firms' cashflows (see Jones and Kaul, 1996).[9] It would be of interest to investigate which of these two channels is the more prominent.

[9] Hou and Szymanowska (2013) argue that commodity futures prices and consumption are highly correlated since around 40% of personal expenditure is effectively on commodities, roughly half of which is on energy and food.

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Table 1. Summary statistics for the excess returns of backwardated, contangoed and term structure portfolios

	Backwardation				Contango				Term structure			
	Mean		SD	Sharpe	Mean		SD	Sharpe	Mean		SD	Sharpe
R=3	0.0514	(1.71)	0.1729	0.2971	-0.1093	(-3.89)	0.1615	-0.6771	0.0803	(5.02)	0.0920	0.8735
R=6	0.0545	(1.82)	0.1720	0.3167	-0.0981	(-3.58)	0.1576	-0.6224	0.0763	(4.58)	0.0957	0.7967
R=12	0.0346	(1.13)	0.1765	0.1960	-0.0863	(-3.01)	0.1645	-0.5246	0.0604	(3.45)	0.1006	0.6008
EW (R=3, 6, 12)	0.0468	(1.64)	0.1635	0.2863	-0.0979	(-3.67)	0.1532	-0.6391	0.0724	(4.76)	0.0873	0.8292

The table shows summary statistics for the monthly returns of portfolios formed by taking the 25% of most backwardated or/and most contangoed commodities based on roll-yields averaged over the previous *R* months. *EW (R=3, 6, 12)* stands for the excess returns of a portfolio that equally weights and monthly rebalances the backwardated (contangoed and *TS*, respectively) portfolios with *R*=3, 6 and 12 months. *Mean* and *SD* stand for annualized mean excess returns and annualized standard deviation of excess returns, respectively; *Sharpe* equals *Mean/SD*, *t*-statistics are in parentheses. Estimation period: January 1980–December 2012.

Table 2. Correlations between traditional and commodity risk factors

	R=3		R=6		R=12		EW (R=3, 6, 12)	
Panel A: Correlation with backwardated portfolios								
ERM	0.18	(3.55)	0.22	(4.47)	0.23	(4.77)	0.22	(4.54)
SMB	0.03	(0.50)	-0.01	(-0.11)	-0.01	(-0.27)	0.00	(0.04)
HML	0.03	(0.55)	-0.01	(-0.24)	0.07	(1.47)	0.03	(0.64)
UMD	0.08	(1.55)	-0.02	(-0.43)	-0.02	(-0.46)	0.01	(0.23)
LRP	0.05	(1.00)	0.02	(0.32)	0.06	(1.17)	0.04	(0.88)
EW	0.74	(21.82)	0.73	(20.94)	0.72	(20.62)	0.77	(24.30)
Panel B: Correlation with contangoed portfolios								
ERM	0.23	(4.68)	0.23	(4.68)	0.23	(4.66)	0.24	(4.93)
SMB	0.04	(0.77)	0.07	(1.40)	0.08	(1.51)	0.06	(1.29)
HML	-0.12	(-2.42)	-0.11	(-2.21)	-0.10	(-2.07)	-0.12	(-2.35)
UMD	-0.06	(-1.11)	-0.09	(-1.76)	-0.07	(-1.31)	-0.07	(-1.46)
LRP	0.05	(0.95)	0.07	(1.43)	0.06	(1.29)	0.06	(1.28)
EW	0.74	(22.13)	0.73	(21.27)	0.71	(20.21)	0.77	(23.77)
Panel C: Correlation with term structure portfolios								
ERM	-0.04	(-0.72)	0.01	(0.17)	0.02	(0.36)	0.00	(-0.05)
SMB	-0.01	(-0.20)	-0.06	(-1.25)	-0.07	(-1.47)	-0.06	(-1.09)
HML	0.13	(2.65)	0.08	(1.60)	0.15	(3.00)	0.13	(2.67)
UMD	0.12	(2.44)	0.05	(1.05)	0.03	(0.66)	0.08	(1.49)
LRP	0.01	(0.11)	-0.04	(-0.89)	0.00	(-0.03)	-0.02	(-0.30)
EW	0.04	(0.83)	0.05	(1.00)	0.05	(0.97)	0.05	(1.03)

The table presents correlations between the excess returns of various traditional risk factors and the excess returns of backwardated, contangoed and term structure (*TS*)portfolios; the latter are formed by taking the 25% most backwardated or/and most contangoed commodities based on roll-yields averaged over the previous *R* months. *EW (R=3, 6, 12)* stands for the excess returns of a portfolio that equally weights and monthly rebalances the backwardated (contangoed and *TS*, respectively) portfolios with *R*=3, 6 and 12 months. *ERM*, *SMB*, *HML*, *UMD*, *LRP* and *EW* are the market, the size, value, momentum and liquidity risk premia and the excess returns on an equally-weighted monthly-rebalanced portfolio that is long all 27 commodities. *t*-statistics are in parentheses. Estimation period: January 1980–December 2012.

Table 3. Cross-sectional pricing of commodity risk factors

	λ_0		λ_{EW}		λ_{Roll}	
Panel A: Backwardation						
R=3	0.0006	(0.19)	0.0154	(4.03)	0.0048	(1.24)
R=6	0.0002	(0.06)	0.0162	(4.16)	0.0058	(1.52)
R=12	0.0001	(0.03)	0.0169	(4.11)	0.0101	(2.51)
EW (R=3, 6, 12)	0.0001	(0.03)	0.0163	(4.18)	0.0078	(2.19)
Panel B: Contango						
R=3	0.0028	(0.95)	0.0106	(3.37)	-0.0127	(-3.36)
R=6	0.0038	(1.33)	0.0093	(3.13)	-0.0103	(-2.66)
R=12	0.0037	(1.28)	0.0090	(2.95)	-0.0129	(-3.25)
EW (R=3, 6, 12)	0.0040	(1.37)	0.0085	(2.85)	-0.0117	(-3.36)
Panel C: Term structure						
R=3	0.0026	(0.89)	0.0111	(3.57)	0.0091	(2.83)
R=6	0.0019	(0.65)	0.0117	(3.65)	0.0095	(2.70)
R=12	0.0017	(0.60)	0.0126	(3.71)	0.0122	(3.28)
EW (R=3, 6, 12)	0.0020	(0.70)	0.0114	(3.58)	0.0099	(3.15)

The table presents averages of the prices of risk estimated from second-stage cross-sectional regressions using 100 size and *B/M* sorted portfolios as base assets. λ_0 is a constant, λ_{EW} stands for the price of risk associated with a long-only equally-weighted portfolio of all 27 commodities, λ_{Roll} stands for the price of risk associated with the backwardated (contangoed and term structure *TS*, respectively) risk factors after the latter have been orthogonalized with respect to *EW*. The backwardated, contangoed and *TS* portfolios are formed by taking the 25% most backwardated or/and most contangoed commodities based on roll-yields averaged over the previous *R* months. *EW (R=3, 6, 12)* stands for the excess returns of a portfolio that equally weights and monthly rebalances the backwardated (contangoed and *TS*, respectively) portfolios with *R*=3, 6 and 12 months. Estimation period: January 1980–December 2012. Shanken-corrected *t*-statistics are in parentheses.

Table 4. Cross-sectional pricing of commodity and traditional risk factors

	λ_0		λ_{ERM}		λ_{SMB}		λ_{HML}		λ_{UMD}		λ_{LRP}		λ_{EW}		λ_{Roll}	
Panel A: Without commodities																
Without EW and TS	0.0084	(2.55)	-0.0033	(-1.05)	-0.0054	(-1.77)	0.0066	(2.33)	0.0046	(1.92)	0.0130	(3.81)				
Without TS	0.0077	(2.30)	-0.0031	(-0.97)	-0.0012	(-0.58)	0.0038	(1.85)	0.0019	(0.87)	0.0127	(4.68)	0.0118	(3.91)		
Panel B: Backwardation																
R=3	0.0074	(2.18)	-0.0028	(-0.89)	-0.0011	(-0.53)	0.0038	(1.84)	0.0008	(0.36)	0.0124	(4.57)	0.0122	(4.01)	0.0033	(1.39)
R=6	0.0073	(2.08)	-0.0028	(-0.87)	-0.0012	(-0.58)	0.0039	(1.85)	0.0009	(0.43)	0.0129	(4.66)	0.0127	(4.11)	0.0058	(2.28)
R=12	0.0082	(2.38)	-0.0034	(-1.06)	-0.0010	(-0.48)	0.0036	(1.75)	0.0015	(0.69)	0.0130	(4.78)	0.0117	(3.93)	0.0031	(1.24)
EW (R=3, 6, 12)	0.0076	(2.16)	-0.0030	(-0.94)	-0.0011	(-0.53)	0.0038	(1.83)	0.0010	(0.45)	0.0126	(4.63)	0.0125	(4.13)	0.0045	(2.27)
Panel C: Contango																
R=3	0.0073	(2.15)	-0.0028	(-0.87)	0.0003	(0.16)	0.0025	(1.36)	0.0013	(0.57)	0.0110	(4.50)	0.0115	(3.73)	-0.0065	(-2.44)
R=6	0.0080	(2.36)	-0.0032	(-1.00)	0.0002	(0.08)	0.0024	(1.33)	0.0014	(0.66)	0.0119	(4.51)	0.0107	(3.68)	-0.0072	(-2.65)
R=12	0.0074	(2.30)	-0.0028	(-0.92)	0.0000	(0.02)	0.0030	(1.56)	0.0013	(0.61)	0.0131	(4.57)	0.0105	(3.63)	-0.0061	(-2.22)
EW (R=3, 6, 12)	0.0073	(2.17)	-0.0026	(-0.84)	0.0004	(0.22)	0.0024	(1.34)	0.0013	(0.60)	0.0118	(4.53)	0.0106	(3.62)	-0.0070	(-2.93)
Panel D: Term structure																
R=3	0.0071	(2.00)	-0.0026	(-0.81)	-0.0006	(-0.31)	0.0034	(1.73)	0.0000	(-0.00)	0.0126	(4.57)	0.0121	(3.98)	0.0069	(3.03)
R=6	0.0075	(2.15)	-0.0029	(-0.91)	-0.0007	(-0.37)	0.0033	(1.67)	0.0005	(0.24)	0.0127	(4.61)	0.0120	(3.94)	0.0068	(2.92)
R=12	0.0075	(2.27)	-0.0029	(-0.94)	-0.0007	(-0.34)	0.0035	(1.70)	0.0008	(0.38)	0.0133	(4.75)	0.0114	(3.82)	0.0049	(2.23)
EW (R=3, 6, 12)	0.0071	(2.03)	-0.0026	(-0.81)	-0.0006	(-0.32)	0.0034	(1.68)	0.0003	(0.14)	0.0125	(4.60)	0.0119	(3.95)	0.0061	(3.07)

The table presents averages of the prices of risk λ estimated from second-stage cross-sectional regressions using 100 size and *B/M* sorted portfolios as base assets. λ_0 is a constant. ERM, *SMB*, *HML*, *UMD*, *LRP* and *EW* are the market, size, value, momentum and liquidity risk premia and the excess returns on the long-only equally-weighted portfolio of all 27 commodities. λ_{Roll} stands for the price of risk associated with the backwardated (contangoed and term structure (*TS*), respectively) risk factors after the latter have been orthogonalized with respect to *EW*. The backwardated, contangoed and *TS* portfolios are formed by taking the 25% most backwardated or/and most contangoed commodities based on roll-yields averaged over the previous *R* months. *EW (R=3, 6, 12)* stands for the excess returns of a portfolio that equally weights and monthly rebalances the backwardated (contangoed and *TS*, respectively) portfolios with *R*=3, 6 and 12 months. Estimation period: January 1980–December 2012. Shanken-corrected *t*-statistics are in parentheses.

Table 5. Cross-sectional pricing of commodity and traditional risk factors – Early sub-sample: 1980–2003

	λ_0		λ_{ERM}		λ_{SMB}		λ_{HML}		λ_{UMD}		λ_{LRP}		λ_{EW}		λ_{Roll}	
Panel A: Backwardation																
R=3	0.0119	(2.62)	-0.0072	(-1.65)	-0.0013	(-0.46)	0.0041	(1.40)	-0.0011	(-0.43)	0.0145	(3.98)	0.0130	(3.18)	0.0058	(1.96)
R=6	0.0119	(2.51)	-0.0073	(-1.63)	-0.0014	(-0.47)	0.0041	(1.38)	-0.0011	(-0.41)	0.0147	(3.95)	0.0141	(3.39)	0.0081	(2.34)
R=12	0.0131	(2.86)	-0.0082	(-1.84)	-0.0012	(-0.42)	0.0038	(1.32)	0.0003	(0.11)	0.0146	(3.99)	0.0130	(3.29)	0.0028	(0.84)
EW (R=3, 6, 12)	0.0123	(2.61)	-0.0076	(-1.70)	-0.0013	(-0.44)	0.0040	(1.38)	-0.0009	(-0.37)	0.0143	(3.92)	0.0138	(3.39)	0.0063	(2.39)
Panel B: Contango																
R=3	0.0118	(2.58)	-0.0071	(-1.62)	0.0006	(0.22)	0.0022	(0.87)	-0.0003	(-0.12)	0.0119	(3.77)	0.0127	(3.02)	-0.0090	(-2.51)
R=6	0.0128	(2.86)	-0.0077	(-1.77)	0.0005	(0.18)	0.0020	(0.81)	0.0002	(0.07)	0.0135	(3.88)	0.0120	(3.06)	-0.0076	(-2.22)
R=12	0.0122	(2.90)	-0.0073	(-1.80)	0.0002	(0.09)	0.0029	(1.10)	0.0002	(0.08)	0.0153	(3.94)	0.0110	(2.86)	-0.0057	(-1.56)
EW (R=3, 6, 12)	0.0118	(2.65)	-0.0069	(-1.61)	0.0009	(0.33)	0.0021	(0.81)	-0.0001	(-0.04)	0.0134	(3.89)	0.0119	(2.98)	-0.0078	(-2.50)
Panel C: Term structure																
R=3	0.0115	(2.41)	-0.0071	(-1.56)	-0.0006	(-0.21)	0.0036	(1.27)	-0.0024	(-0.93)	0.0141	(3.82)	0.0128	(3.14)	0.0099	(3.33)
R=6	0.0121	(2.59)	-0.0075	(-1.68)	-0.0007	(-0.25)	0.0034	(1.20)	-0.0014	(-0.55)	0.0145	(3.91)	0.0134	(3.26)	0.0086	(2.77)
R=12	0.0124	(2.83)	-0.0076	(-1.80)	-0.0008	(-0.28)	0.0037	(1.27)	-0.0005	(-0.19)	0.0152	(4.03)	0.0125	(3.13)	0.0050	(1.67)
EW (R=3, 6, 12)	0.0116	(2.46)	-0.0070	(-1.58)	-0.0006	(-0.20)	0.0034	(1.22)	-0.0018	(-0.69)	0.0141	(3.87)	0.0131	(3.22)	0.0078	(2.92)

The table presents averages of the prices of risk λ estimated from second-stage cross-sectional regressions using 100 size and *B/M* sorted portfolios as base assets. The estimation period spans January 1980–December 2003; the break point of December 2003corresponds to the end of the pre-CFMA period of Boons *et al*. (2012). λ_0 is a constant. ERM, *SMB*, *HML*, *UMD*, *LRP* and *EW* are the excess returns on the market, the size, value, momentum and liquidity risk premia and the long-only equally-weighted portfolio of all 27 commodities. λ_{Roll} stands for the price of risk associated with the backwardated (contangoed and term structure (*TS*), respectively) risk factors after the latter have been orthogonalized with respect to *EW*. The backwardated, contangoed and *TS* portfolios are formed by taking the 25% most backwardated or/and most contangoed commodities based on roll-yields averaged over the previous *R* months. *EW (R=3, 6, 12)* stands for the excess returns of a portfolio that equally weights and monthly rebalances the backwardated (contangoed and *TS*, respectively) portfolios with *R*=3, 6 and 12 months. Shanken-corrected *t*-statistics are in parentheses.

Table 6. Cross-sectional pricing of commodity and traditional risk factors – Late sub-sample: 2004–2012

	λ_0		λ_{ERM}		λ_{SMB}		λ_{HML}		λ_{UMD}		λ_{LRP}		λ_{EW}		λ_{Roll}	
Panel A: Backwardation																
R=3	0.0011	(0.15)	0.0126	(1.85)	0.0015	(0.51)	0.0021	(0.52)	0.0006	(0.08)	0.0153	(2.20)	0.0081	(1.15)	0.0052	(1.13)
R=6	0.0010	(0.14)	0.0127	(1.84)	0.0015	(0.51)	0.0020	(0.50)	0.0003	(0.04)	0.0156	(2.28)	0.0073	(1.07)	0.0048	(0.94)
R=12	0.0006	(0.08)	0.0133	(1.95)	0.0014	(0.45)	0.0019	(0.47)	-0.0009	(-0.11)	0.0159	(2.28)	0.0068	(0.96)	0.0090	(1.44)
EW (R=3, 6, 12)	0.0005	(0.07)	0.0133	(1.95)	0.0014	(0.48)	0.0019	(0.49)	0.0006	(0.08)	0.0157	(2.26)	0.0079	(1.12)	0.0061	(1.41)
Panel B: Contango																
R=3	0.0018	(0.23)	0.0118	(1.70)	0.0017	(0.56)	0.0020	(0.51)	-0.0004	(-0.06)	0.0151	(2.11)	0.0068	(1.00)	-0.0022	(-0.40)
R=6	0.0012	(0.16)	0.0124	(1.79)	0.0017	(0.56)	0.0020	(0.50)	-0.0007	(-0.09)	0.0140	(1.98)	0.0046	(0.68)	-0.0090	(-1.41)
R=12	0.0011	(0.14)	0.0126	(1.79)	0.0016	(0.54)	0.0018	(0.46)	-0.0003	(-0.04)	0.0145	(2.12)	0.0066	(0.98)	-0.0067	(-1.21)
EW (R=3, 6, 12)	0.0015	(0.20)	0.0121	(1.74)	0.0017	(0.58)	0.0019	(0.48)	-0.0002	(-0.03)	0.0141	(2.00)	0.0050	(0.76)	-0.0070	(-1.35)
Panel C: Term structure																
R=3	0.0010	(0.14)	0.0127	(1.85)	0.0015	(0.50)	0.0020	(0.51)	0.0006	(0.08)	0.0161	(2.27)	0.0082	(1.14)	0.0044	(0.95)
R=6	0.0013	(0.18)	0.0125	(1.80)	0.0015	(0.50)	0.0019	(0.48)	-0.0002	(-0.03)	0.0151	(2.19)	0.0059	(0.88)	0.0061	(1.42)
R=12	0.0003	(0.05)	0.0136	(1.96)	0.0013	(0.44)	0.0018	(0.46)	-0.0009	(-0.11)	0.0152	(2.20)	0.0066	(0.96)	0.0073	(1.49)
EW (R=3, 6, 12)	0.0008	(0.11)	0.0131	(1.89)	0.0014	(0.46)	0.0019	(0.47)	0.0002	(0.03)	0.0156	(2.24)	0.0068	(0.98)	0.0059	(1.54)

The table presents averages of the prices of risk λ estimated from second-stage cross-sectional regressions using 100 size and *B/M* sorted portfolios as base assets. The estimation period spans January 2004–December 2012; the break point of January 2004 corresponds to the beginning of the post-CFMA period of Boons *et al*. (2012). λ_0 is a constant. ERM, *SMB*, *HML*, *UMD*, *LRP* and *EW* are the market, size, value, momentum and liquidity risk premia and the excess returns on the long-only equally-weighted portfolio of all 27 commodities. λ_{Roll} stands for the price of risk associated with the backwardated (contangoed and term structure (*TS*), respectively) risk factors after the latter have been orthogonalized with respect to *EW*. The backwardated, contangoed and *TS* portfolios are formed by taking the 25% most backwardated or/and most contangoed commodities based on roll-yields averaged over the previous *R* months. *EW (R=3, 6, 12)* stands for the excess returns of a portfolio that equally weights and monthly rebalances the backwardated (contangoed and *TS*, respectively) portfolios with *R*=3, 6 and 12 months. Shanken-corrected *t*-statistics are in parentheses.

Table 7. The impact of crude oil

	λ_0		λ_{ERM}		λ_{SMB}		λ_{HML}		λ_{UMD}		λ_{LRP}		$\lambda_{EW\text{-}No\ crude}$		$\lambda_{Roll\text{-}No\ crude}$	
Panel A: Backwardation																
R=3	0.0066	(1.97)	-0.0020	(-0.65)	-0.0005	(-0.23)	0.0035	(1.77)	0.0002	(0.11)	0.0131	(4.60)	0.0107	(3.75)	0.0043	(1.67)
R=6	0.0070	(2.00)	-0.0024	(-0.76)	-0.0011	(-0.53)	0.0037	(1.82)	0.0009	(0.43)	0.0134	(4.75)	0.0120	(4.02)	0.0046	(1.94)
R=12	0.0074	(2.23)	-0.0026	(-0.83)	-0.0007	(-0.37)	0.0035	(1.74)	0.0028	(1.24)	0.0137	(4.85)	0.0108	(3.78)	0.0007	(0.30)
EW (R=3, 6, 12)	0.0069	(2.02)	-0.0024	(-0.76)	-0.0009	(-0.46)	0.0037	(1.82)	0.0010	(0.45)	0.0132	(4.71)	0.0118	(4.02)	0.0038	(1.92)
Panel B: Contango																
R=3	0.0074	(2.17)	-0.0027	(-0.85)	0.0005	(0.26)	0.0023	(1.27)	0.0013	(0.60)	0.0114	(4.52)	0.0106	(3.57)	-0.0070	(-2.64)
R=6	0.0079	(2.38)	-0.0030	(-0.96)	0.0003	(0.16)	0.0023	(1.28)	0.0019	(0.86)	0.0123	(4.52)	0.0100	(3.58)	-0.0066	(-2.40)
R=12	0.0076	(2.36)	-0.0029	(-0.96)	0.0003	(0.13)	0.0029	(1.53)	0.0017	(0.77)	0.0137	(4.61)	0.0097	(3.47)	-0.0055	(-1.88)
EW (R=3, 6, 12)	0.0074	(2.22)	-0.0026	(-0.84)	0.0006	(0.32)	0.0023	(1.29)	0.0017	(0.77)	0.0124	(4.56)	0.0098	(3.49)	-0.0063	(-2.66)
Panel C: Term structure																
R=3	0.0066	(1.92)	-0.0021	(-0.66)	0.0001	(0.06)	0.0029	(1.57)	0.0001	(0.06)	0.0127	(4.61)	0.0107	(3.78)	0.0064	(2.77)
R=6	0.0074	(2.16)	-0.0028	(-0.87)	-0.0006	(-0.29)	0.0031	(1.62)	0.0008	(0.38)	0.0130	(4.67)	0.0111	(3.82)	0.0057	(2.52)
R=12	0.0075	(2.29)	-0.0028	(-0.93)	-0.0006	(-0.28)	0.0034	(1.70)	0.0015	(0.66)	0.0140	(4.82)	0.0107	(3.72)	0.0038	(1.66)
EW (R=3, 6, 12)	0.0070	(2.05)	-0.0024	(-0.76)	-0.0003	(-0.15)	0.0031	(1.61)	0.0007	(0.31)	0.0130	(4.69)	0.0110	(3.83)	0.0052	(2.55)

The table tests the robustness of the results presented in Table 4 to the exclusion of crude oil futures. It presents averages of the prices of risk λ estimated from second-stage cross-sectional regressions using 100 size and *B/M* sorted portfolios as base assets. λ_0 is a constant. *ERM*, *SMB*, *HML*, *UMD*, *LRP* and *EW-No crude* are the market, size, value, momentum and liquidity risk premia and the excess returns on a long-only equally-weighted portfolio of commodities excluding crude oil. $\lambda_{Roll\text{-}No\ crude}$ stands for the price of risk associated with the backwardated (contangoed and term structure (*TS*), respectively) risk factors after the latter have been orthogonalized with respect to *EW-No crude*. The backwardated, contangoed and *TS* portfolios exclude crude oil from the available cross-section of contracts and consider the 25% most backwardated or/and most contangoed commodities based on roll-yields averaged over the previous *R* months. *EW (R=3, 6, 12)* stands for the excess returns of a portfolio that equally weights and monthly rebalances the backwardated (contangoed and *TS*, respectively) portfolios with *R*=3, 6 and 12 months. Estimation period: January 1980–December 2012. Shanken *t*-statistics are in parentheses.

Table 8. Cross-sectional pricing of commodity, financial and macroeconomic risk factors

	λ_0		λ_{IP}		λ_{DEI}		λ_{UI}		λ_{UDS}		λ_{UTS}		λ_{EW}		λ_{Roll}	
Panel A: Backwardation																
R=3	0.0058	(2.28)	-0.0069	(-0.32)	0.0002	(0.04)	-0.0049	(-0.86)	-0.0673	(-1.34)	0.3477	(2.67)	0.0067	(2.54)	0.0053	(1.52)
R=6	0.0054	(2.12)	-0.0112	(-0.50)	0.0001	(0.01)	-0.0033	(-0.57)	-0.0628	(-1.25)	0.3626	(2.73)	0.0066	(2.49)	0.0078	(2.12)
R=12	0.0061	(2.36)	-0.0018	(-0.08)	0.0005	(0.12)	-0.0030	(-0.51)	-0.0649	(-1.27)	0.3682	(2.79)	0.0076	(2.80)	0.0117	(3.48)
EW (R=3, 6, 12)	0.0056	(2.17)	-0.0043	(-0.20)	0.0000	(-0.01)	-0.0049	(-0.87)	-0.0660	(-1.31)	0.3623	(2.75)	0.0072	(2.61)	0.0082	(2.57)
Panel B: Contango																
R=3	0.0065	(2.53)	-0.0158	(-0.71)	0.0008	(0.19)	-0.0043	(-0.72)	-0.0672	(-1.36)	0.3676	(2.86)	0.0067	(2.52)	-0.0096	(-3.09)
R=6	0.0070	(2.73)	-0.0059	(-0.26)	0.0014	(0.37)	-0.0046	(-0.77)	-0.0774	(-1.65)	0.3579	(2.82)	0.0066	(2.53)	-0.0057	(-1.71)
R=12	0.0068	(2.65)	-0.0097	(-0.43)	-0.0005	(-0.13)	-0.0058	(-0.99)	-0.0647	(-1.42)	0.3286	(2.59)	0.0062	(2.28)	-0.0099	(-2.76)
EW (R=3, 6, 12)	0.0070	(2.71)	-0.0095	(-0.42)	0.0006	(0.16)	-0.0056	(-0.95)	-0.0690	(-1.47)	0.3392	(2.68)	0.0063	(2.37)	-0.0085	(-2.82)
Panel C: Term structure																
R=3	0.0063	(2.44)	-0.0087	(-0.40)	0.0004	(0.09)	-0.0058	(-1.02)	-0.0641	(-1.30)	0.3616	(2.77)	0.0066	(2.49)	0.0076	(2.64)
R=6	0.0063	(2.47)	-0.0108	(-0.49)	0.0005	(0.12)	-0.0047	(-0.82)	-0.0674	(-1.39)	0.3523	(2.73)	0.0061	(2.33)	0.0065	(2.13)
R=12	0.0064	(2.51)	-0.0063	(-0.29)	-0.0008	(-0.21)	-0.0053	(-0.92)	-0.0627	(-1.33)	0.3369	(2.67)	0.0068	(2.48)	0.0101	(3.18)
EW (R=3, 6, 12)	0.0063	(2.45)	-0.0084	(-0.38)	-0.0001	(-0.02)	-0.0064	(-1.12)	-0.0662	(-1.37)	0.3458	(2.68)	0.0064	(2.37)	0.0081	(2.91)

The table presents averages of the prices of risk λ estimated from second-stage cross-sectional regressions using 100 size and *B/M* sorted portfolios as base assets. λ_0 is a constant. *IP*, *DEI*, *UI*, *UDS* and *UTS* are the monthly growth in industrial production, changes in expected inflation, unexpected inflation, shocks to default and term spreads, respectively. *EW* stands for the excess returns of an equally-weighted portfolio that is long all 27 commodities. λ_{Roll} stands for the price of risk associated with the backwardated (contangoed and term structure (*TS*), respectively) risk factors after the latter have been orthogonalized with respect to *EW*. The backwardated, contangoed and *TS* portfolios are formed by taking the 25% most backwardated or/and most contangoed commodities based on roll-yields averaged over the previous *R* months. *EW (R=3, 6, 12)* stands for the excess returns of a portfolio that equally weights and monthly rebalances the backwardated (contangoed and *TS*, respectively) portfolios with *R*=3, 6 and 12 months. Estimation period: January 1980–December 2012. Shanken-corrected *t*-statistics are in parentheses.

Table 9. Cross-sectional pricing of commodity, financial and macroeconomic risk factors and of a composite leading indicator

	λ_0		λ_{IP}		λ_{DEI}		λ_{UI}		λ_{UDS}		λ_{UTS}		λ_{UCLI}		λ_{EW}		λ_{Roll}	
Panel A: Backwardation																		
R=3	0.0076	(3.03)	0.0006	(0.03)	-0.0011	(-0.27)	-0.0041	(-0.75)	-0.0763	(-1.61)	0.4106	(2.91)	0.0504	(2.19)	0.0074	(2.84)	0.0035	(1.00)
R=6	0.0071	(2.84)	-0.0044	(-0.20)	-0.0013	(-0.33)	-0.0032	(-0.57)	-0.0747	(-1.56)	0.4210	(2.95)	0.0515	(2.18)	0.0075	(2.82)	0.0058	(1.61)
R=12	0.0075	(2.94)	0.0039	(0.17)	-0.0009	(-0.21)	-0.0030	(-0.54)	-0.0748	(-1.50)	0.4159	(2.93)	0.0593	(2.41)	0.0084	(3.11)	0.0113	(3.48)
EW (R=3, 6, 12)	0.0072	(2.86)	0.0026	(0.12)	-0.0014	(-0.34)	-0.0044	(-0.80)	-0.0773	(-1.60)	0.4180	(2.95)	0.0540	(2.25)	0.0079	(2.94)	0.0068	(2.21)
Panel B: Contango																		
R=3	0.0083	(3.30)	-0.0045	(-0.20)	-0.0006	(-0.14)	-0.0041	(-0.74)	-0.0747	(-1.62)	0.4296	(3.10)	0.0554	(2.39)	0.0077	(2.89)	-0.0077	(-2.51)
R=6	0.0088	(3.56)	0.0003	(0.01)	0.0001	(0.01)	-0.0043	(-0.77)	-0.0793	(-1.82)	0.4063	(2.94)	0.0571	(2.43)	0.0070	(2.68)	-0.0044	(-1.33)
R=12	0.0085	(3.44)	0.0010	(0.05)	-0.0017	(-0.43)	-0.0058	(-1.05)	-0.0733	(-1.72)	0.3929	(2.85)	0.0546	(2.32)	0.0070	(2.61)	-0.0082	(-2.28)
EW (R=3, 6, 12)	0.0088	(3.52)	0.0008	(0.03)	-0.0007	(-0.17)	-0.0053	(-0.97)	-0.0745	(-1.71)	0.3984	(2.90)	0.0565	(2.41)	0.0070	(2.67)	-0.0069	(-2.28)
Panel C: Term structure																		
R=3	0.0081	(3.21)	0.0006	(0.03)	-0.0008	(-0.20)	-0.0048	(-0.86)	-0.0727	(-1.58)	0.4233	(3.01)	0.0528	(2.32)	0.0074	(2.80)	0.0057	(2.03)
R=6	0.0079	(3.22)	-0.0043	(-0.19)	-0.0008	(-0.20)	-0.0044	(-0.81)	-0.0770	(-1.69)	0.4139	(2.96)	0.0492	(2.16)	0.0069	(2.62)	0.0047	(1.55)
R=12	0.0080	(3.19)	0.0020	(0.09)	-0.0019	(-0.47)	-0.0051	(-0.92)	-0.0762	(-1.67)	0.3939	(2.87)	0.0532	(2.27)	0.0076	(2.83)	0.0089	(2.83)
EW (R=3, 6, 12)	0.0080	(3.20)	0.0007	(0.03)	-0.0013	(-0.33)	-0.0056	(-1.03)	-0.0768	(-1.67)	0.4059	(2.91)	0.0521	(2.25)	0.0072	(2.70)	0.0065	(2.40)

The table presents averages of the prices of risk λ estimated from second-stage cross-sectional regressions using 100 size and *B/M* sorted portfolios as base assets. λ_0 is a constant. *IP*, *DEI*, *UI*, *UDS*, *UTS* and *UCLI* are the monthly growth in industrial production, changes in expected inflation, unexpected inflation, shocks to default and term spreads and the unexpected changes in the OECD composite leading indicator, respectively. *EW* stands for the excess returns of an equally-weighted portfolio that is long all 27 commodities. λ_{Roll} stands for the price of risk associated with the backwardated (contangoed and term structure (*TS*), respectively) risk factors after the latter have been orthogonalized with respect to *EW*. The backwardated, contangoed and *TS* portfolios are formed by taking the 25% most backwardated or/and most contangoed commodities based on roll-yields averaged over the previous *R* months. *EW (R=3, 6, 12)* stands for the excess returns of a portfolio that equally weights and monthly rebalances the backwardated (contangoed and *TS*, respectively) portfolios with *R*=3, 6 and 12 months. Estimation period: January 1980–December 2012. Shanken-corrected *t*-statistics are in parentheses.