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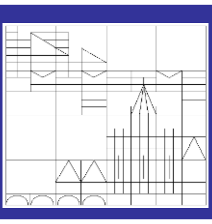

Risk Premiums in the Cross-Section of Commodity Convenience Yields

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Risk Premiums in the Cross-Section of Commodity Convenience Yields

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Abstract

This paper investigates risk premiums embedded in commodity convenience yields, i.e., returns on convenience-claim investments. The analysis is conducted in two steps. First, monthly convenience yields are extracted from a broad sample of commodity futures by using a three-factor model. Second, a multi-factor asset pricing model with conditional betas is estimated to determine risk premiums embedded in convenience-claim returns. The empirical analysis is carried out on monthly cross-sections of 22 commodities in the period from January 1991 to December 2011. It reveals the existence of significant premiums embedded in convenience yields for systematic risk factors typically related to other asset classes. While the predictability of the risk premiums via instrumental variables is limited, changes in conditional betas are found to forecast variations in convenience yields.

JEL Classification: G12; G13; E44

Keywords:
Commodity Futures, Convenience Yield, Term Structure, Risk Premiums

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1. Introduction

Commodity processors, such as oil refineries, metallurgical plants, and food manufacturers, require physical availability of raw materials to sustain their business activity. To avoid a costly disruption of the production process, they may be forced to purchase a commodity at a spot price much higher than the corresponding futures price. The theory of storage, developed by Kaldor (1939) and Working (1949), introduces the concept of convenience yield (i.e., the benefit that accrues to the owner of a physical inventory) to explain the observed discrepancy between spot and futures prices and thus the shape of the commodity term structure. As argued by Brennan (1991), the convenience yield can be interpreted as the return on a *convenience claim*, a synthetic asset consisting of a short-term leasing agreement on a physical commodity. This raises the question whether the returns of convenience claims are driven by systematic risk factors that are known to influence the returns of other asset classes, in particular stocks and bonds. The goal of this paper is to provide empirical evidence on the existence and characteristics of risk premiums in commodity futures. To this aim, we extract convenience yields from futures prices and investigate their cross-sectional exposure to risk factors common to other asset classes.

Commencing with Keynes (1930) and his theory of normal backwardation (i.e., the phenomenon of a downward sloping term structure), several scholars have investigated the market of commodity futures. While some studies focus on the risk transfers between more risk-averse hedgers and less risk-averse traders (Chang, 1985), others consider economic risk factors affecting futures returns (Miffre, 2000) or combine these two approaches (Bessembinder, 1992). A more recent strand of literature shows that the commodity term structure can forecast futures returns. While some studies (Fama and French, 1987; Roon et al., 1998; Gorton and Rouwenhorst, 2006; Erb and Harvey, 2006) employ futures bases of commodities (i.e., the normalized differences between futures and spot prices) as predictive variables, others (Bailey and Chan, 1993; Hong and Yogo, 2012; Szymanowska et al., 2014) include additional economic variables to enhance the effectiveness of related trading schemes.

The present article shares various elements with the mentioned papers but also deviates from them in several respects, thereby offering an independent contribution to the existing literature. Three aspects of this paper deserve to be emphasized. First, most of the above mentioned studies employ the slope of the commodity term structure as an input to predict futures returns. On the contrary, this paper contributes an asset-pricing analysis that relates returns of convenience-claim investments (which are directly affected by the term structure of commodity futures) to risk factors affecting stock and bond returns. Second, this paper focuses on *convenience yields* (as proxy for convenience-claim returns) and not *futures* *bases* because of three reasons: (i) While futures bases implicitly refer to a specific holding period, convenience yields capture the instantaneous shape of the term structure; (ii) The emphasis on convenience yields allows one to exploit at each point in time the information embedded in the whole maturity structure of futures prices. On the contrary, futures bases rely only on two price observations for a given date; (iii) Convenience yields are not directly affected by the maturity of the futures contract or the level of interest rates. In this respect, convenience yields represent more refined and economically meaningful variables than futures bases. Third, unlike previous work that typically focuses on time-series regressions, the empirical design adopted in this paper exploits the information embedded in the cross-section of futures[1] and thus provides new insights about risk and return of commodity investments.

The procedure for obtaining inferences about the influence of systematic risk factors on futures prices consists of two consecutive steps. First, the Schwartz (1997) reduced-form, three-factor futures pricing model is estimated by using the Kalman filter methodology. This allows one to extract and separate the convenience yield from other determinants affecting futures prices (i.e., commodity spot prices and interest rates). Second, by interpreting convenience yields as returns of convenience claims (see Brennan, 1991) we can estimate multi-factor asset pricing models in the spirit of Ferson and Harvey (1991) and can investigate the risk exposures and the existence of risk premiums in the cross-section of convenience yields. The empirical analysis is conducted on a sample of 22 commodity futures in the period from January 1991 to December 2011 and includes a total of $36,319$ monthly futures prices.

The two-stage estimation procedure of the multi-factor asset pricing model allows us to measure time-varying risk premiums embedded in convenience yields of commodity futures (or, equivalently, in convenience-claim returns). For all model specifications tested, the average risk premiums associated with the the aggregate government-bond market and the aggregate (spot) commodity market are found to be significantly different from zero on average. These findings evidence that the term structure of commodity futures is exposed to systematic economic risk factors that are common to other assets classes. The results prove to be robust with respect to the cross-sectional composition of the data sample and the specification of the asset pricing model.

The identified risk premiums are only marginally predictable by a set of commonly-used instrumental variables. However, a more promising approach for predicting

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[1] While also Bessembinder (1992) and Miffre (2000) study the cross-section of commodity futures, they focus on futures returns and thus disregard the shape of the term structure.

convenience-claim returns is to exploit the strong degrees of autocorrelation detected in their factor loadings. Selecting equally sized portfolios of commodities with high and low conditional betas with respect to the two significant risk factors (i.e., the bond and commodity spot market) results in significantly different average convenience-claim returns.

The paper is organized as follows. Section 2 outlines both the futures pricing model and the asset pricing framework. Section 3 introduces the data set consisting of futures prices, risk factors, and the set of instrumental variables used to forecast risk premiums. The empirical results are presented in Section 4. Finally, Section 5 summarizes the key findings and draws conclusions.

2. Methodology

2.1. Futures Pricing Model

To obtain accurate estimates of the convenience yield of each commodity, it is crucial to adopt a futures pricing model that is capable of matching the different shapes of the term structure of commodity futures and explaining a large part of their fluctuations. As we not aim at contributing a novel futures pricing model, we adopt generally accepted and state-of-the-art approaches to extract reliable convenience-yield measures. By following the large bulk of the empirical futures pricing literature, a reduced-form futures pricing model is implemented.[2] The most important question within this class of models lies in the choice of the state variables.

According to Schwartz (1997), a single-factor model is not suitable for accurately explaining the variations in futures prices. The inclusion of a second state variable substantially enhances the model's performance. Typically, two-factor models (see, e.g., Brennan, 1991; Gibson and Schwartz, 1990) let the price of a futures contract depend on specific dynamics of (i) the spot price and (ii) the convenience yield.[3] Conversely, two-factor models typically assume constant interest rates. Therefore, when estimating such models, fluctuations in futures prices caused by interest-rate changes are largely captured by the other two state variables (commodity spot price and convenience yield). To avoid the estimation of

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[2] Equilibrium commodity futures-pricing models as proposed by Deaton and Laroque (1992) and Routledge et al. (2000) in which the spot-futures price relation is endogenous are less tractable and thus not suitable for the empirical purpose of the present study.

[3] In this setting, the convenience yield of a certain commodity includes both the current net convenience yield (as defined by Brennan, 1991) and the negative of the instantaneous cost of carry (as mentioned by Miltersen and Schwartz, 1998).

blurred state variables (e.g., a mixture of convenience yield and interest-rate variations), several authors have suggested the inclusion of stochastic interest rates as a third state variable. Such three-factor models are discussed in Schwartz (1997), Miltersen and Schwartz (1998), and Casassus and Collin-Dufresne (2005). While all of them provide a comparably good fit to commodity futures data, we choose to implement the Schwartz (1997) three-factor model because it is widely used and comparatively parsimonious in the number of parameters to be estimated.

The state variables in the Schwartz (1997) three-factor model are the spot price, S, the instantaneous convenience yield, δ, and the risk-free interest rate, r. The spot price process follows a geometric Brownian motion, while the other two state variables are described by an Ornstein-Uhlenbeck process. Thus, the three stochastic processes under the equivalent martingale measure are specified as

$$dS = (r - \delta)Sdt + \sigma_1 S dz_1^*, \tag{1}$$

$$d\delta = [\kappa(\alpha - \delta) - \lambda]dt + \sigma_2 dz_2^*, \tag{2}$$

$$dr = a\left(m^* - r\right)dt + \sigma_3 dz_3^*, \tag{3}$$

where dz_1, dz_2, and dz_3 are instantaneous Gaussian innovations with instantaneous correlation coefficients $dz_1^* dz_2^* = \rho_1$, $dz_2^* dz_3^* = \rho_2$, and $dz_1^* dz_3^* = \rho_3$. The volatilities of the state variables are denoted by σ_1 (spot price), σ_2 (convenience yield), and σ_3 (interest rate). The speed and the level of mean reversion of the convenience yield are denoted by κ and α, respectively, and λ is the market price of convenience-yield risk. Since the processes are presented under the risk-neutral probability measure (and not the statistical measure), the drift of the spot price process is equal to the risk-free rate, r (and not μ). The risk-adjusting for the interest rate is embedded in the risk-neutral mean reversion level m^*. Finally, a denotes the speed of mean reversion of the interest rate. Letting τ be the time-to-maturity of the futures contract, the logarithm of the futures price can be expressed as follows:

$$\ln F(S, \delta, r, \tau) = \ln S - \delta\,\frac{1 - e^{-\kappa\tau}}{\kappa} + r\,\frac{1 - e^{-a\tau}}{a} + C\left(\tau\right), \tag{4}$$

where

$$
\begin{aligned}
C(\tau) = & \frac{(\kappa\alpha - \lambda + \sigma_1\sigma_2\rho_1)\left((1 - e^{-\kappa\tau}) - \kappa\tau\right)}{\kappa^2} \\
& - \frac{\sigma_2^2\left(4\left(1 - e^{-\kappa\tau}\right) - \left(1 - e^{-2\kappa\tau}\right) - 2\kappa\tau\right)}{4\kappa^3} \\
& - \frac{(am^* + \sigma_1\sigma_3\rho_3)\left((1 - e^{-a\tau}) - a\tau\right)}{a^2} \\
& - \frac{\sigma_3^2\left(4\left(1 - e^{-a\tau}\right) - \left(1 - e^{-2a\tau}\right) - 2a\tau\right)}{4a^3} \\
& + \sigma_2\sigma_3\rho_2\left(\frac{(1 - e^{-\kappa\tau}) + (1 - e^{-a\tau}) - \left(1 - e^{-(\kappa+a)\tau}\right)}{\kappa a\,(\kappa + a)}\right. \\
& \qquad \left. + \frac{\kappa^2\left(1 - e^{-a\tau}\right) + a^2\left(1 - e^{-\kappa\tau}\right) - \kappa a^2\tau - a\kappa^2\tau}{\kappa^2 a^2\,(\kappa + a)}\right).
\end{aligned}
\tag{5}
$$

In Equation (4) an important feature of the model becomes apparent. The log futures price is a linear function of the three state variables. Their dynamics, as described by Equations (1) to (3), follow a Markov process with Gaussian innovations and thus the state variables are stationary. These properties ensure that Kalman filtering can be used for estimation purposes.

The implementation of the model follows Schwartz (1997) and Barlow et al. (2004). In particular, the latter authors suggest that a derivative-free optimization approach, such as the direct search method of Nelder and Mead (1965), can avoid problems of numerical instability associated with the complex target function. The state-space formulation of the model and the corresponding application of the Kalman filter are outlined in Appendix A. The point estimates of the parameters are obtained by maximizing the conditional log-likelihood function that captures the fit between forecasted log futures prices and the observed market data. Once the parameters are estimated, the recursive structure of the Kalman filter method allows one to extract the historical series of conditional (posterior) forecasts of the convenience yields.

According to Schwartz (1997), the estimation of the parameters of the futures pricing model is obtained in three consecutive steps. First, the two-factor specification of his model (which assumes constant interest rates) is estimated by maximum likelihood and both the spot price and the convenience yield are extracted using Kalman filtering. As starting values for the recursion, the proxies from Gibson and Schwartz (1990) are used.[4] Second, the commodity spot prices thus obtained

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[4] The spot price is set equal to the closest-to-delivery futures price and the convenience

are used to calculate the correlation coefficients between spot prices and interest rates (three-month T-bill yields), ρ_3. The correlation coefficient between convenience yields and interest rates, ρ_2, is set equal to zero.[5] Third, the remaining parameters of the three-factor model are estimated by maximum likelihood. The test statistics are calculated by the approach of Berndt et al. (1974) which relies on the outer product of gradients of the information matrix of the underlying log-likelihood function. Finally, the Kalman filter is used again to extract the ex post forecasts of all three state variables.

2.2. Asset Pricing Model

A convenience yield can be interpreted as a return on a particular asset, termed "convenience claim" by Brennan (1991). This asset consists of a short position in a commodity futures combined with a spot purchase of the related underlying. Convenience claims thus correspond to a short-term leasing contract of one unit of inventory, or, in other words, a calendar spread. Hence, investments in convenience claims allow one to receive convenience yield as compensation for the temporary physical provision of an underlying commodity. More precisely, since convenience yields are known in advance, the returns of the convenience claim correspond to the negative convenience yield in the previous month: $r_t \equiv -\delta_{t-1}$. Because convenience yields can be interpreted as returns from investing in convenience claims (or, equivalently, calendar spreads), it is natural to use asset pricing models to explain their variations.

The asset pricing models used in this study are motivated by the intertemporal capital asset pricing model of Merton (1973) and the arbitrage pricing model of Ross (1976). More precisely, the analysis relies on multi-factor models as proposed by Ferson and Harvey (1991) and applied by Bessembinder (1992) in the context of commodity markets. Equation (6) outlines the ex ante formulation of the model with J risk factors:

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yield is determined using the two closest futures prices. An approximation for the annualized convenience yield for a given date is thus: $\delta_{approx} = r - \frac{1}{\tau_2 - \tau_1} \ln \left[\frac{F(\tau_2)}{F(\tau_1)} \right]$. Bailey and Chan (1993) also use this approximation for their empirical analysis.

[5] While Schwartz (1997) calculates ρ_2 as the the correlation between the convenience yields as extracted from the two-factor model and interest rates, we set $\rho_2 = 0$ for all commodities. In our opinion, this procedure is appropriate since the convenience yields that are extracted from the two-factor model unavoidably capture a large portion of the interest-rate variation and are not suitable for calculating an accurate correlation coefficient between the convenience yield and the interest rate.

$$\mathbb{E}\left[r_{it}|\boldsymbol{Z}_{t-1}\right] = \gamma_0\left(\boldsymbol{Z}_{t-1}\right) + \sum_{j=1}^{J} b_{ij,t-1}\gamma_j\left(\boldsymbol{Z}_{t-1}\right). \tag{6}$$

The expected return of the convenience claim on commodity i in period t is explained by a constant, $\gamma_0\left(\boldsymbol{Z}_{t-1}\right)$, and a summation of risk premiums, $b_{ij,t-1}\gamma_j\left(\boldsymbol{Z}_{t-1}\right)$. The expected premium $\gamma_j\left(\boldsymbol{Z}_{t-1}\right)$ for one unit of risk related to factor j is conditional on the publicly available information set $\boldsymbol{Z}_{t-1}$. The conditional beta $b_{ij,t-1}$ is the sensitivity (or loading) of the convenience-claim return relative to the jth risk factor.

3. Data

3.1. Commodity Futures

To ensure the reliability of the empirical investigation, we require the sample of commodity contracts to meet two criteria. First, the sample should be representative of the commodity-futures market and thus provide sufficient contract diversity. To this end, energy products, metals, and agricultural products are included in the sample, which results in a more heterogeneous composition of the sample if compared to Fama and French (1987) and Bailey and Chan (1993). Second, commodity futures are required to be (i) sufficiently liquid and (ii) traded without interruptions throughout the sample period.[6] The choice of a constant cross-section stands in contrast to the approaches chosen by Fama and French (1987) and Gorton and Rouwenhorst (2006) who employ a varying number of contracts over time. The sample covers the period from January 1991 to December 2011. This choice achieves a satisfying balance between the range of traded contracts and the length of the observation period. As shown in Table 1, the final composition of the sample includes 22 commodities. The representativeness of the sample is underpinned by the high degree of similarity with the most common

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[6] Unleaded gasoline futures contracts represent the only formal exception to this requirement. Their contract specifications have changed due to a regulatory modification by the U.S. government concerning the compounds of fuels (the new gasoline no longer contains the additive *methyl tertiary-butyl*). Since both contracts were simultaneously traded between February 2006 and December 2006, we use the contracts based on the old blend until October 2006 and the new ones since November 2006. This corresponds to the date when the aggregate trading volume of the new contracts started to exceed the trading volume of the original contracts. It must be noted that the correlation between the two contracts during the period of time when both were traded was very high, amounting to 0.988 for the front contracts.

commodity indexes. For instance, according to the information provided by Erb and Harvey (2006), in 2004 at least 75% of the composition of each of the three leading commodity indexes includes contracts also present in our sample: 16 out of 17 for the Commodity Research Bureau CRB index, 18 out of 24 for the Goldman Sachs Commodity Index GSCI, and 15 out of 20 for the Dow Jones AIG Commodity Index DJ-AIGCI.

[INSERT TABLE 1 ABOUT HERE]

For all 22 commodities, the end-of-month prices of all contracts with maturities up to one year enter the empirical analysis.[7] As can be seen in Table 1, column three, the number of contract maturities varies among commodities. For instance, while all energy products (Panel B) have contract maturities ending in each month, agricultural products (Panel C) have contract maturities for selected months only. All prices used in the empirical analysis stem from actual transactions. Hence, closing prices for a contract enter the sample only if there is at least one trade at the observation date. The different number of contract maturities and (to a minor extent) the lack of liquidity leads to a varying number of observations for each commodity (see Table 1, column 4). In total, $36,319$ traded futures prices are used in the empirical analysis.

3.2. Risk Factors and Instrumental Variables

In the spirit of multi-factor asset pricing models, economic variables should describe the state of the economy. The five economic variables used in this paper (see Table 2) represent plausible economy-wide risk factors that are commonly used in the empirical asset pricing literature by Ferson and Harvey (1991), Bessembinder (1992), Bailey and Chan (1993), and Miffre (2000). SPEXR, BONDTR, and GSCI represent returns of the S&P 500 index, the Citigroup world government bond index, and the Goldman Sachs commodity index, respectively.[8] Furthermore, GIP and UI denote the growth rates of the U.S. industrial production and the unexpected inflation based on a first-order moving-average MA(1) model.

[INSERT TABLE 2 ABOUT HERE]

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[7] Monthly data are used because many of the economic and instrumental variables are available only with this frequency. Calculations show that convenience yields extracted from futures price series with monthly frequency are almost identical to end-of-month convenience yields extracted from daily futures series.

[8] By employing a commodity index based on spot prices (not futures prices) potential endogeneity issues in explaining convenience yields are mitigated.

Instrumental variables are used to predict changes of risk premiums associated to each risk factor. The four instrumental variables used in this paper are listed in Table 3. They include two variables that refer to the state of the capital market: SPDY(-1) is the lagged dividend yield of the S&P 500 index and JUNK(-1) is the average lagged spread of yields between Baa-rated and Aaa-rated corporate bonds. These two instrumental variables are well established in the empirical asset pricing literature, beginning with Keim and Stambaugh (1986) and Campbell and Shiller (1988). The other two instrumental variables we consider are the capacity utilization rate of all industries, CUR(-1), and the level of new orders in the economy, NORD(-1). Both variables are closely related to the industrial production and are widely used in economic forecasting. CUR(-1) measures the current (relative) level of production and thus captures the demand side of the commodity market. NORD(-1) is published in the Reports on Business by the Institute for Supply Management ISM and captures the expected demand for commodities in the forthcoming periods.

[INSERT TABLE 3 ABOUT HERE]

4. Empirical Results

4.1. Estimation of the Futures Pricing Model

This subsection presents the estimation results of the Schwartz (1997) three-factor futures pricing model as obtained by implementing the procedure described in Section 2.1 in the period between January 1991 and December 2011. The Vasicek (1977) interest-rate dynamics is governed by three parameters: the mean-reversion level, m^*, the mean-reversion speed, a, and the interest-rate volatility, σ_3. The maximum-likelihood estimates of these parameters are 0.01, 0.89, and 0.01, respectively. Since the interest-rate process is estimated separately from the convenience-yield and spot-price dynamics, the interest-rate parameters are identical for all commodities. All the remaining parameters of the three-factor model are obtained by Kalman filtering. Their estimates with the corresponding t-statistics are reported in Table 4. In the following, we discuss the most important estimation results by dividing the whole sample of commodity futures into metals (Panel A), energy products (Panel B), and agricultural products (Panel C).

[INSERT TABLE 4 ABOUT HERE]

Metal futures are characterized by comparatively low mean-reversion levels (α) and volatilities (σ_2) of convenience yields. None of the metal futures considered in this study exhibit a mean-reversion level of the convenience yield that significantly differs from zero. In the case of gold, not even the volatility of the convenience yield is found to be significantly different from zero. However, all other metals seem to be exposed to temporary physical shortages which cause fluctuations in the convenience yields. Finally, the positive drift of the spot price process (μ) reflects the fact that all metals gained value during the observation period.

The spot-price and convenience-yield processes of energy futures show some distinctive features. First, the volatility of the spot-price process (σ_1) is very high, being consistently above 30%. Second, the convenience yield is characterized by even higher volatilities (σ_2; 76% and 100% for natural gas and unleaded gasoline, respectively) and a high speed of mean-reversion (κ).

Agricultural products show a very heterogeneous picture. For instance, wheat differs from the other grains and oilseeds by displaying a particularly low speed of mean reversion ($\kappa = 0.30$). Lumber, on the other hand, shows the highest volatility ($\sigma_2 = 80\%$) and the highest speed of mean reversion of the convenience yield ($\kappa = 2.28$). Finally, unlike all other commodities, corn, wheat, cotton, and orange juice have zero or negative values in the spot-price drift (μ) because their values stagnated or decreased between January 1991 and December 2011.

4.2. Estimation of Asset Pricing Model

For the empirical implementation of the multi-factor asset pricing model laid out in Equation (6) we follow the well-established two-step approach of Fama and MacBeth (1973) and Fama and French (1997). In the first step, time-varying betas are obtained by rolling time-series regressions of the convenience-claim returns on the five risk factors based on the preceding 60 monthly observations. This procedure provides a simple and straightforward conditioning of the betas on the available information set. It is repeated for each of the 192 dates from January 1996 to December 2011 and for all 22 commodities in the sample. In the second step, betas are used as explanatory variables in cross-sectional regressions:

$$r_{it} = \zeta_{0t} + \sum_{j=1}^{J} \zeta_{jt}\beta_{ij,t-1} + \varepsilon_{it}, \quad t = 1, \ldots, T. \tag{7}$$

At each date t, the cross-sectional regression (7) estimates premiums ζ_{jt} for each of the J risk factors that can drive convenience-claim returns.

Table 5 shows for each commodity the time-series average of the loading on each risk factor. While 63 out of the 110 estimated factor loadings are statistically significant at the 5% confidence level,[9] the majority of them (65%) are in fact negative. In particular, many commodities have a negative and significant exposure to

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[9] To account for autocorrelation due to rolling regressions in estimation of beta, the t-

the aggregate stock market (SPEXR, 12 out of 22) and unexpected inflation (UI, 13 out of 22). The loadings on the bond market (BONDTR), commodity market (GSCI), and industrial production (GIP) vary substantially across commodities unveiling a very heterogeneous risk profile toward those factors.

[INSERT TABLE 5 ABOUT HERE]

The behavior of the cross-sectional average of conditional betas over time is displayed in Figure 1. The average exposures vary substantially and assume both positive and negative values. In particular, the financial crisis of 2008 seems to have a different impact on the five average factor loadings. While the exposures of convenience-claim returns toward SPEXR, GSCI, and UI appear to be only temporarily dragged away from the initial levels, the shock on the loadings of BONDTR and GIP seem to be more persistent.

[INSERT FIGURE 1 ABOUT HERE]

4.3. Risk Premiums

The premiums ζ_{jt} related to the J risk factors in the multi-factor asset pricing model (see Equation 7) are estimated using the cross sections of factor loadings described in the previous section. Table 6 shows the average risk premiums for different model specifications and data sets. In particular, the analysis is conducted on three different data sets: (i) the full sample of 22 commodities, (ii) all commodities but gold, and (iii) all commodities except the two contracts from the Intercontinental Exchange, ICE, (i.e., Brent Crude Oil and Gasoil). The exclusion of gold is motivated by the lack of variability of its convenience yield. In the third data set, ICE contracts are excluded because of their similarity with (US) Crude Oil and Heating Oil contracts traded on the NYMEX. Panel A shows the results for one-factor asset pricing models (i.e., the convenience yields are cross-sectionally regressed on each of the five economic variables in a univariate setting). In Panel B the model is estimated in its multivariate specification with all five risk factors.

Overall, the results indicate that the exposure toward some of the economy-wide risk factors are rewarded. More specifically, convenience claims that load on the bond (BONDTR) and the commodity spot market (GSCI) earn a statistically significant premium. This finding is reasonably robust as it holds for all three samples and for both one-factor and multi-factor asset pricing models. Both in the

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statistics rely on heteroscedasticity and autocorrelation consistent (HAC) standard errors as proposed by Newey and West (1987). As in Ferson and Harvey (1991), the HAC standard errors are calculated with moving average terms up to eleven lags.

univariate and multivariate analysis, convenience-claims are not found to provide systematic reward for exposure toward the equity market (SPEXR) and the growth of industrial production (GIP). The premium associated with unexpected inflation (UI) is positive, although statistical significance is only given in the univariate setting.

The dynamic properties of the risk premiums are depicted in Figure 2. All risk premiums change over time and occasionally assume negative values. Further, their paths unveil significant levels of autocorrelation.

[INSERT TABLE 6 ABOUT HERE]

The analysis conducted in this section shows that the cross-section of commodity convenience-claim returns is exposed in a non-trivial way to economy-wide risk factors which drive the returns of other asset classes. Since variations in the convenience yield (and, equivalently, in the basis) are driven by systematic factors, the roll gains in commodity trading strategies cannot be seen as purely idiosyncratic return components of commodity investments. Thereby, the results complement the discussion on the contribution of commodity investments to the diversification of traditional portfolios (Jensen et al., 2000; Erb and Harvey, 2006; Gorton and Rouwenhorst, 2006). This finding is particularly valuable in light of the fact that many studies (Erb and Harvey, 2006; Hong and Yogo, 2012; Szymanowska et al., 2014) employ convenience yields as a selection criterion for commodity-futures investments.

[INSERT FIGURE 2 ABOUT HERE]

4.4. Predictability of Risk Premiums

This section focuses on the predictability of the estimated risk premiums. In particular, we investigate whether the risk premiums can be predicted by a set of instrumental variables in the following empirical regression model:

$$\zeta_{jt} = \psi_0 + \sum_{k=1}^{K} \psi_{j,k} h_{k,t-1} + \eta_{jt}, \quad j = 1, \dots, J. \tag{8}$$

Each of the five previously estimated risk premiums ζ_{jt} are regressed against K lagged instrumental variables $h_{k,t-1}$. The set of instrumental variables used includes the dividend yield of the S&P 500 index (SPDY), the credit spread between corporate bonds with Baa and Aaa (JUNK), the capacity utilization rate of the US industries (CUR), and the level of new orders (NORD). A significant parameter $\psi_{j,k}$ indicates that the premium of risk factor j is predicted by the instrumental variable k. To account for the possible autocorrelation in the estimated risk premiums, the calculations rely on heteroscedasticity and autocorrelation consistent (HAC) standard errors.

[INSERT TABLE 7 ABOUT HERE]

Table 7 displays the results for the period from 1996 to 2011. Significant coefficients of the instrumental variables are only found for the risk premium of the S&P 500 (SPDY, JUNK, and CUR). This is the only case in which a substantial explanatory power (R^2_{adj}) of the instrumental variables is found (23.7%). For the other four risk premiums, no regression coefficients of any instrumental variables is statistically significant. Thus, unlike comparable studies on equity markets (see, e.g., Ferson and Harvey, 1991), the majority of risk premiums in commodity markets do not seem to be predictable by instrumental variables.

4.5. Implications for Investment Strategies

By selecting convenience-claim investments with high (low) loadings toward risk factors with positive (negative) premiums, one would expect to obtain high average returns as a reward for bearing high levels of systematic risk. To test this simple relation, we construct for each of the five risk factors portfolio pairs consisting of the 11 commodities with the highest (lowest) conditional betas. Each portfolio is rebalanced at the beginning of each month according to the betas measured for the previous month. Given this construction, both the high-beta and the low-beta beta portfolios can include commodities with positive and negative factor loadings.

As can be seen in Table 8, statistically significant differences between portfolio pairs are detected when sorting according to BONDTR loadings and GSCI loadings. In both cases, the return differential exceeds four percentage points per annum and the high-beta portfolios returns are significantly larger than zero.

[INSERT TABLE 8 ABOUT HERE]

Erb and Harvey (2006), Hong and Yogo (2012), and Szymanowska et al. (2014) emphasize the importance of futures bases, or, equivalently, convenience yields, as conditioning variables for investing in commodity futures. The empirical results presented in this paper indicate that convenience yields are themselves related to common systematic risk factors. In this respect, a promising venue of futures research could investigate whether the high returns generated by active investments in commodity futures can be (partially) explained by exposures toward systematic risk factors. From a practitioners perspective, it could be interesting to study whether the active trading strategies in commodity futures developed by Erb and Harvey (2006), Hong and Yogo (2012), and Szymanowska et al. (2014) could be further enhanced by considering as additional conditioning variables the exposures toward risk factors.

5. Summary and Conclusion

In this paper risk premiums embedded in commodity convenience yields are investigated. The analysis consists of two steps. First, time series of monthly convenience yields are extracted from a broad sample of 22 commodity futures in the period between January 1991 and December 2011 by estimating a three-factor futures pricing model via Kalman filtering. For all commodities except some precious metals, clear evidence of stochastic and mean-reverting convenience yields is found. The so-obtained convenience yields represent returns of a particular asset called convenience-claim, a short-term leasing contract of the physical commodity. Second, multi-factor asset pricing models with conditional betas and risk premiums embedded in the cross-section of convenience-claim returns are estimated. The five risk factors considered in the study include the S&P 500 index, the world government bond index, the Goldman Sachs commodity index, the industrial-production growth, and unexpected inflation.

Supportive evidence of significant premiums in the cross-section of convenience-claim returns is found for risk factors associated with bond and commodity investments. The existence of risk premiums in convenience yields means that the reward paid to physical suppliers of storage and investors depends on systematic risk factors that also drive the returns of other asset classes. However, the level of predictability of the detected risk premiums based on a set of commonly-used instrumental variables is moderate. The finding that common economic factors affect the term-structure of commodity futures could be a promising starting point for explaining the high returns achieved by recently-developed active trading strategies in the market for commodity futures (Erb and Harvey, 2006; Hong and Yogo, 2012; Szymanowska et al., 2014).

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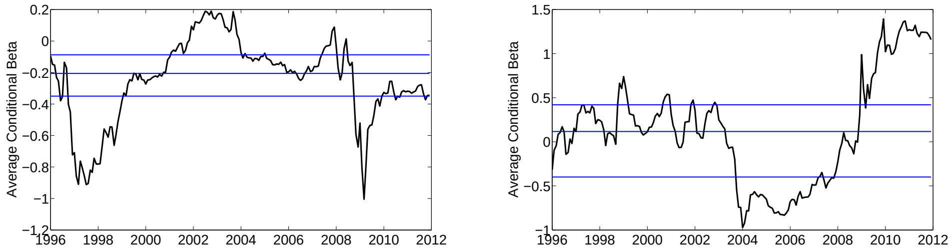
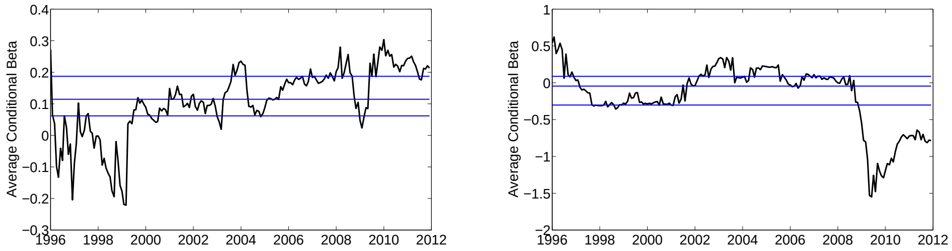
Figure 1: Average Conditional Betas

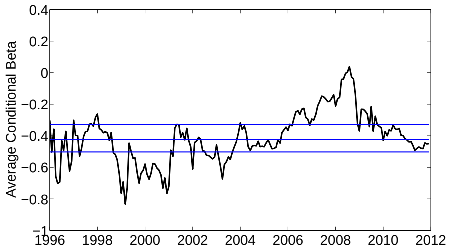
These figures show the evolutions of the cross-sectional average of conditional betas for the five risk factors based on the full sample of 22 commodities. SPEXR is the excess return of the S&P 500 Index return, BONDTR indicates the total return of the World Government Bond Index from Citigroup, GSCI indicates the return of the Goldman Sachs Commodity Index, GIP refers to the growth in the U.S. industrial production, and UI indicates unexpected inflation. The graphs cover the period from 1996 to 2011 (192 observations) and the betas are conditional on the past five years (60 monthly observations). The horizontal lines indicate the median as well as the top and bottom quartile of the respective factor loadings.



(a) SPEXR Factor Loadings (b) BONDTR Factor Loadings



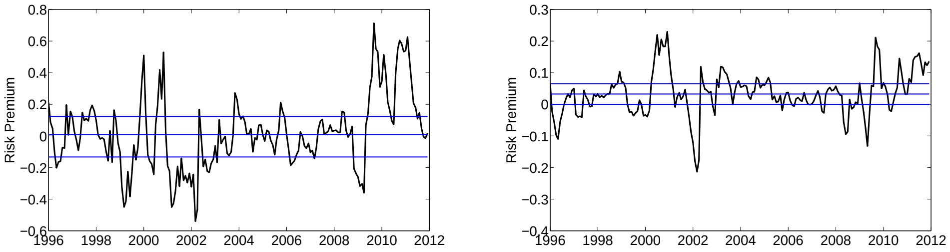
(c) GSCI Factor Loadings (d) GIP Factor Loadings



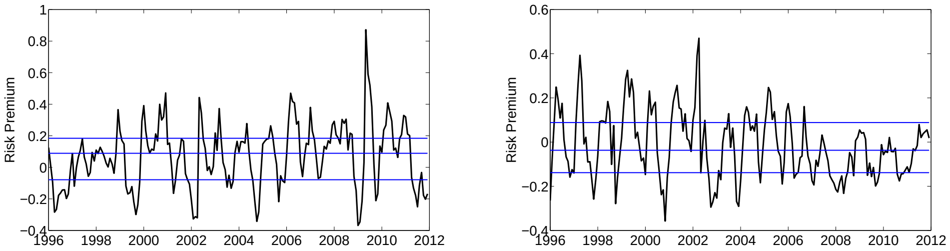
(e) UI Factor Loadings

Figure 2: Variations of Risk Premiums

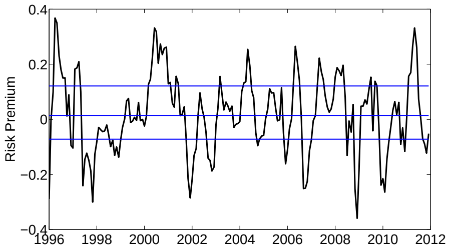
These figures show the evolution of risk premiums for the five risk factors based on the full sample of 22 commodities. SPEXR is the excess return of the S&P 500 Index return, BONDTR indicates the total return of the World Government Bond Index from Citigroup, GSCI indicates the return of the Goldman Sachs Commodity Index, GIP refers to the growth in the U.S. industrial production, and UI indicates unexpected inflation. The graphs cover the period from 1996 to 2011 (192 observations). The horizontal lines indicate the median, the upper quartile, and the lower quartile, respectively.



(a) SPEXR Risk Premium (b) BONDTR Risk Premium



(c) GSCI Risk Premium (d) GIP Risk Premium



(e) UI Risk Premium

Table 1: Commodity Futures Contracts

This table lists all commodities used in the empirical analysis. ‘Commodity’ indicates the exact contract terminology as it is used in the respective exchange. For clarity, an indication of the quality is reported, if necessary (e.g., Sugar no. 11). ‘Exchange’ indicates the institution where the respective commodity future is traded: ‘NYMEX’ indicates the New York Mercantile Exchange; ‘ICE’ refers to the Intercontinental Exchange; ‘CME’ denotes the Chicago Mercantile Exchange; ‘CBOT’ refers to the Chicago Board of Trade; ‘NYBOT’ indicates the New York Board of Trade. ‘Contract Maturities’ denotes all the months in which futures contracts mature. ‘Observations’ provides the total number of actually traded monthly futures prices available for a particular commodity in the period from January 1991 to December 2011.

Commodity	Exchange	Contract Maturities	Observations
		Panel A: Metals	
Copper High Grade	NYMEX	Jan-Dec	2,406
Gold	NYMEX	Jan-Dec	1576
Palladium	NYMEX	Mar, Jun, Sep, Dec	625
Platinum	NYMEX	Jan, Apr, Jul, Oct	701
Silver	NYMEX	Jan-Dec	1,415
		Panel B: Energy Products	
Light Sweet Crude Oil	NYMEX	Jan-Dec	2,933
Heating Oil	NYMEX	Jan-Dec	2,832
Natural Gas	NYMEX	Jan-Dec	2,981
Unleaded Gasoline	NYMEX	Jan-Dec	2,431
Brent Oil	ICE	Jan-Dec	2,346
Gas Oil	ICE	Jan-Dec	2,347
		Panel C: Agricultural Products	
Corn	CBOT	Mar, May, Jul, Sep, Dec	1,265
Oats	CBOT	Mar, May, Jul, Sep, Dec	1,018
Soybeans	CBOT	Jan, Mar, May, Jul, Aug, Sep, Nov	1,718
Wheat	CBOT	Mar, May, Jul, Sep, Dec	1,225
Live Cattle	CME	Feb, Apr, Jun, Aug, Oct, Dec	1,491
Lumber	CME	Jan, Mar, May, Jul, Sep, Nov	1,129
Cocoa	NYBOT	Mar, May, Jul, Sep, Dec	1,211
Coffee type C	NYBOT	Jan, Mar, May, Jul, Sep, Dec	1,228
Cotton no. 2	NYBOT	Mar, May, Jul, Aug, Oct, Dec	1,212
Orange Juice	NYBOT	Jan, Mar, May, Jul, Sep, Nov	1,273
Sugar no. 11	NYBOT	Mar, May, Jul, Oct	956

Table 2: Risk Factors

The variables are calculated on a month-to-month basis and are not seasonally adjusted. Consumer price index data are obtained from Bureau of Labor Statistics, all other data are taken from Thomson Reuters Datastream. MA(1) stands for a first-order moving-average model. Observations cover the period from January 1991 to December 2011.

Symbol	Definition
SPEXR	S&P 500 index return less 1 month US interbank offered rate
BONDTR	Total return of World Government Bond Index (G7 countries, all maturities) from Citigroup
GSCI	Return of Goldman Sachs Commodity (spot price) Index
GIP	Growth in the US Industrial Production volume
UI	Unexpected Inflation according to MA(1) model on US consumer price index (urban, all items)

Table 3: Instrumental Variables

The variables are calculated on a month-to-month basis. The notation (-1) indicates a time lag of the respective variable of one month. Data are taken from Thomson Reuters Datastream. Observations cover the period from January 1991 to December 2011.

Symbol	Definition
SPDY(-1)	Dividend yield of S&P 500 index
JUNK(-1)	Difference in yields of corporate bonds rated Baa and Aaa by Moody's Investor Services
CUR(-1)	Capacity Utilization Rate of all industries (seasonally adjusted)
NORD(-1)	New Orders according to the Report on Business from the Institute for Supply Management ISM (not seasonally adjusted)

Table 4: Parameter Estimates for the Three-Factor Futures Pricing Model

This table presents the results of the parameter estimation with the Kalman filter for the Schwartz (1997) three-factor model (Equations (1)-(5) in the text). Monthly data from January 1991 to December 2011 (204 observation dates) is included in the estimation process. The parameter μ denotes the spot price drift, κ the speed, and α the level of mean reversion of the convenience yield. The market price of convenience yield risk is λ, while ρ_1 is the correlation between the spot price and the convenience yield. The volatilities of the spot price and the convenience yield are denoted with σ_1 and σ_2, respectively. The correlation coefficient between the spot price and the interest rate is ρ_3. The t-statistics of the estimated parameters are in brackets.

Commodity	Parameter							
	μ	κ	α	λ	ρ_1	σ_1	σ_2	ρ_3
Panel A: Metals								
Copper High Grade	0.13	0.35	0.02	-0.01	0.57	0.28	0.09	0.15
	(2.03)	(3.99)	(0.39)	(-0.61)	(10.7)	(29.92)	(15.64)	(2.35)
Gold	0.08	0.77	0.00	0.03	-0.05	0.15	0.01	-0.04
	(2.22)	(0.62)	(0.11)	(0.95)	(-0.07)	(27.28)	(0.66)	(-0.67)
Palladium	0.18	0.56	0.02	0.02	0.40	0.34	0.05	0.17
	(2.26)	(1.86)	(0.45)	(0.56)	(1.28)	(25.81)	(4.28)	(2.76)
Platinum	0.12	0.44	0.04	0.02	0.45	0.21	0.03	0.14
	(2.12)	(1.10)	(0.96)	(0.57)	(1.56)	(34.77)	(2.62)	(2.24)
Silver	0.13	0.24	0.00	0.01	0.46	0.29	0.01	0.03
	(1.93)	(0.68)	(-0.04)	(0.48)	(1.44)	(26.09)	(2.88)	(0.54)
Panel B: Energy Products								
Crude Oil	0.18	1.28	0.04	0.05	0.81	0.33	0.31	0.16
	(2.32)	(34.09)	(0.75)	(0.69)	(38.00)	(23.95)	(21.43)	(2.53)
Heating Oil	0.14	0.82	0.00	-0.02	0.76	0.34	0.4	0.15
	(1.58)	(13.40)	(-0.02)	(-0.12)	(25.35)	(24.26)	(15.55)	(2.39)
Natural Gas	0.03	1.48	-0.13	-0.09	0.79	0.51	1.00	0.00
	(0.24)	(19.98)	(-0.52)	(-0.24)	(24.42)	(21.06)	(17.27)	(-0.05)
Unleaded Gasoline	0.19	1.77	0.03	0.07	0.79	0.39	0.76	0.12
	(2.05)	(20.86)	(0.28)	(0.31)	(29.81)	(23.53)	(14.11)	(1.84)
Brent Crude	0.18	1.07	0.04	0.04	0.79	0.32	0.28	0.15
	(2.42)	(29.56)	(0.63)	(0.61)	(37.53)	(30.29)	(24.10)	(2.34)
Gasoil	0.16	0.71	0.02	0.03	0.75	0.33	0.34	0.16
	(1.95)	(14.19)	(0.12)	(0.32)	(23.86)	(23.82)	(23.95)	(2.52)
Panel C: Agricultural Products								
Corn	-0.02	0.52	-0.09	-0.08	0.76	0.29	0.19	0.05
	(-0.25)	(8.30)	(-0.74)	(-1.02)	(19.23)	(20.13)	(14.58)	(0.83)
Oates	0.05	0.96	-0.04	0.05	0.73	0.33	0.36	-0.01
	(0.60)	(8.48)	(-0.38)	(0.46)	(16.64)	(22.39)	(13.22)	(-0.22)
Soybeans	0.10	0.76	0.03	0.04	0.70	0.27	0.20	0.09
	(1.41)	(12.47)	(0.42)	(0.57)	(16.42)	(21.45)	(20.81)	(1.47)

Table 4: continued.

Commodity	Parameter							
	μ	κ	α	λ	ρ_1	σ_1	σ_2	ρ_3
Wheat	0.00	0.30	-0.09	-0.08	0.71	0.31	0.23	-0.09
	(0.03)	(2.63)	(-0.38)	(-0.96)	(13.93)	(21.17)	(9.55)	(-1.45)
Live Cattle	0.07	1.32	0.03	0.07	0.88	0.18	0.33	0.11
	(1.28)	(8.66)	(0.29)	(0.55)	(53.01)	(20.74)	(8.17)	(1.67)
Lumber	-0.02	2.28	-0.13	-0.20	0.84	0.41	0.80	0.09
	(-0.17)	(25.83)	(-1.48)	(-1.04)	(38.32)	(17.28)	(16.24)	(1.47)
Cocoa ’C’	0.03	0.65	-0.04	0.01	0.71	0.31	0.09	-0.06
	(0.36)	(5.56)	(-1.29)	(0.46)	(18.31)	(24.47)	(10.52)	(-1.00)
Coffee	0.07	0.98	-0.05	0.05	0.68	0.39	0.23	0.11
	(0.76)	(16.77)	(-0.84)	(0.86)	(28.73)	(24.53)	(26.55)	(1.73)
Cotton	0.00	0.39	-0.09	-0.04	0.77	0.32	0.26	0.07
	(0.03)	(7.66)	(-0.52)	(-0.57)	(23.82)	(19.84)	(19.71)	(1.1)
Orange Juice	0.00	0.74	-0.06	0.01	0.67	0.31	0.20	0.12
	(-0.01)	(10.72)	(-0.93)	(0.2)	(15.27)	(23.56)	(14.74)	(1.88)
Sugar No 11	0.16	1.29	0.04	0.05	0.86	0.39	0.46	0.11
	(1.56)	(11.02)	(0.36)	(0.37)	(43.37)	(20.65)	(10.67)	(1.75)

Table 5: Average Factor Loadings of Convenience Claim Returns

This table presents the results of the rolling multivariate time-series regressions of convenience-claim returns on the five risk factors SPEXR, BONDTR, GSCI, GIP, and UI. The regressions are based on monthly data from January 1991 to December 2011 with a conditioning period of 60 months. The t-statistics of the average conditional betas (in brackets) are heteroscedasticity and autocorrelation consistent (HAC). Significant parameters at the 10%, 5%, and 1% significance level are marked with *, **, and ***, respectively.

Commodity	Risk Factor				
	SPEXR	BONDTR	GSCI	GIP	UI
	β_1	β_2	β_3	β_4	β_5
Panel A: Metals					
Copper High Grade	-0.41	-0.40	-0.15	-0.50	-0.12
	***(-3.63)	**(-2.48)	***(-2.83)	***(-5.38)	**(-2.48)
Gold	-0.02	-0.02	0.00	-0.02	0.01
	***(-5.74)	(-1.63)	(0.74)	***(-4.00)	***(3.82)
Palladium	-0.06	-0.45	0.08	-0.23	0.09
	*(-1.86)	***(-3.13)	***(2.86)	***(-3.82)	*(1.92)
Platinum	-0.06	-0.57	-0.07	-0.12	0.02
	(-1.26)	***(-7.64)	***(-2.82)	***(-2.80)	(0.78)
Silver	0.02	0.11	-0.01	0.01	-0.01
	(0.98)	***(3.10)	*(-1.94)	(0.52)	(-0.61)
Panel B: Energy Products					
Crude Oil	-0.39	-1.14	0.15	-0.29	-1.14
	**(-1.98)	**(-2.48)	**(2.18)	*(-1.82)	***(-7.36)
Heating Oil	-0.42	-0.57	0.16	0.49	-0.15
	**(-2.36)	(-0.98)	**(2.40)	***(3.32)	(-1.10)
Natural Gas	-0.8	-0.26	1.81	0.87	1.43
	***(-3.77)	(-0.29)	***(11.23)	***(4.29)	***(4.76)
Unleaded Gasoline	-0.02	0.15	0.38	-1.60	-2.78
	(-0.10)	(0.27)	***(3.20)	***(-5.58)	***(-8.45)
Brent Crude	-0.38	-0.77	0.09	-0.31	-0.95
	**(-2.05)	**(-2.02)	(1.58)	*(-1.96)	***(-7.24)
Gasoil	-0.35	-0.12	0.15	0.5	-0.83
	**(-2.03)	(-0.22)	***(2.72)	***(3.44)	***(-5.44)

Table 5: continued.

Commodity	Risk Factor				
	SPEXR	BONDTR	GSCI	GIP	UI
	β_1	β_2	β_3	β_4	β_5
Panel C: Agricultural Products					
Corn	-0.03	2.16	0.10	0.06	-0.72
	(-0.26)	***(17.55)	(0.80)	(0.55)	***(-8.50)
Oates	-0.32	1.50	-0.23	-0.40	-0.64
	***(-3.11)	***(2.70)	*(-1.86)	*(-1.94)	***(-2.86)
Soybeans	-0.41	-0.21	-0.09	-0.11	-0.01
	***(-4.68)	(-1.11)	(-0.88)	(-0.90)	(-0.11)
Wheat	-0.08	0.60	-0.13	0.35	-0.45
	(-0.55)	**(2.50)	(-1.22)	***(3.99)	***(-3.26)
Live Cattle	-0.66	-1.08	-0.22	0.08	-0.58
	***(-3.65)	**(-2.51)	**(-2.33)	(0.54)	**(-2.59)
Lumber	0.16	2.70	-0.07	-1.52	-1.13
	(0.52)	***(4.47)	(-0.39)	***(-2.95)	***(-9.08)
Cocoa 'C'	0.19	0.05	0.04	0.43	0.05
	***(5.49)	(0.18)	(1.45)	***(5.37)	(0.94)
Coffee	-0.99	0.27	0.33	-1.05	0.48
	***(-3.27)	(0.43)	***(3.20)	***(-2.99)	*(1.89)
Cotton	-0.31	0.05	0.23	-0.16	-0.65
	**(-2.54)	(0.09)	***(3.37)	(-0.97)	***(-5.74)
Orange Juice	0.22	1.32	-0.20	-0.21	-0.44
	(1.47)	***(7.69)	*(-1.91)	(-0.82)	***(-5.69)
Sugar No 11	-0.29	-0.37	0.02	-0.29	-0.60
	(-1.22)	(-1.03)	(0.38)	(-1.02)	***(-2.84)

Table 6: Average Risk Premiums

This table presents the results of the following cross-sectional regression: (Equation (7) in the text). 'SPEXR' is the excess return of the S&P 500 Index over the U.S. interbank offered rate; 'BONDTR' is the total return of the World Government Bond Index from Citigroup; 'GSCI' is the return of the Goldman Sachs Commodity Index; 'GIP' is the growth in the U.S. industrial production; and 'UI' is the unexpected inflation calculated with a first-order moving average model, MA(1). The regression constants are estimated but not reported. The regression is performed with monthly data from January 1996 to December 2011 (192 observations). In Panel A all explanatory variables are estimated separately in an univariate version of the model, while in Panel B the model is estimated as a whole (hence multivariate). The t-statistics of the estimated parameters (in brackets) are heteroscedasticity and autocorrelation consistent (HAC). Significant parameters at the 10%, 5%, and 1% significance level are marked with *, **, and ***, respectively. The sample 'All Commodities' includes all 22 contracts from Section 3.1. The sample 'Without Gold' consists of 21 contracts, and the sample 'Without ICE Contracts' consists of 20 contracts, where Brent crude oil and gas oil from the Intercontinental Exchange are excluded from the original sample.

Sample	Economic Variables				
	SPEXR	BONDTR	GSCI	GIP	UI
	ζ_1	ζ_2	ζ_3	ζ_4	ζ_5
Panel A: Univariate Models					
All Commodities	-0.016	0.029	0.076	0.013	0.020
	(-0.701)	***(4.056)	***(3.867)	(1.220)	*(1.941)
Without Gold	-0.015	0.029	0.076	0.014	0.020
	(-0.665)	***(4.056)	***(3.908)	(1.296)	*(1.971)
Without ICE Contracts	-0.014	0.03	0.069	0.014	0.014
	(-0.664)	***(4.208)	***(3.414)	(1.243)	(1.243)
Panel B: Multivariate Model					
All Commodities	0.016	0.034	0.07	-0.015	0.021
	(0.408)	***(3.217)	***(3.009)	(-0.845)	(1.108)
Without Gold	0.017	0.034	0.07	-0.015	0.021
	(0.424)	***(3.236)	***(3.009)	(-0.833)	(1.147)
Without ICE Contracts	0.013	0.036	0.069	-0.012	0.023
	(0.296)	***(3.343)	***(2.907)	(-0.641)	(1.223)

Table 7: Regression of the Risk Premiums on the Instrumental Variables

This table presents the results of the time-series regression set out in Equation (8). The risk premiums are taken from the model with conditional betas (Panel A) and the one with unconditional beta (Panel B). The explained risk premiums include the following economic variables: ‘SPEXR’ is the excess return of the S&P500 Index over the U.S. interbank offered rate; ‘BONDTR’ is the total return of the World Government Bond Index from Citigroup; ‘GSCI’ is the return of the Goldman Sachs Commodity Index; ‘GIP’ is the growth in the U.S. industrial production; and ‘UI’ is the unexpected inflation calculated with a first-order moving average model, MA(1). The instrumental variables are: ‘SPDY(-1)’ is the lagged dividend yield of the S&P 500 Index. ‘JUNK(-1)’ is the lagged credit spread between corporate bonds with Baa and Aaa ratings from Moody’s Investor Services. ’CUR(-1)’ is the capacity utilization rate of all U.S. industries. ‘NORD(-1)’ is the level of new orders. The estimation is performed with monthly data from January 1996 to December 2011 (192 observations). The calculations in both panels are based on the multivariate model specification for all 22 commodities. The t-statistics of the estimated parameters (in brackets) are heteroscedasticity and autocorrelation consistent (HAC). Significant parameters at the 10%, 5%, and 1% significance level are marked with *, **, and ***, respectively.

Premium	Instrumental Variables					
	Constant	SPDY(-1)	JUNK(-1)	CUR(-1)	NORD(-1)	
	ψ_0	ψ_1	ψ_2	ψ_3	ψ_4	R^2_{adj}
SPEXR	1.586	21.916	-27.103	-2.457	0.421	23.7%
	(1.528)	**(2.128)	***(-3.057)	**(-2.179)	(1.318)	
BONDTR	0.427	-0.636	-4.142	-0.425	-0.01	3.2%
	(1.647)	(-0.132)	(-1.385)	(-1.551)	(-0.1)	
GSCI	0.617	-8.288	2.377	-0.632	0.127	0.0%
	(1.032)	(-0.883)	(0.332)	(-0.908)	(0.484)	
GIP	-0.405	-9.946	6.479	0.517	0.17	3.0%
	(-0.974)	(-1.544)	(1.206)	(1.233)	(0.849)	
UI	-0.123	-0.758	-2.433	0.155	0.106	0.6%
	(-0.232)	(-0.104)	(-0.427)	(0.246)	(0.551)	

Table 8: Returns of Convenience Claims Conditional on Factor Loading

This table presents averages of convenience-claims returns conditional on previous period's conditional betas of the respective risk factors. Two portfolios are created at each date, one consisting of those 11 commodities with the highest betas and the other 11 commodities with the lowest betas. In addition, the difference between the two portfolios are also displayed. The results cover the sample period from 1996 to 2011 (192 observations). SPEXR is the excess return of the S&P 500 Index return, BONDTR indicates the total return of the World Government Bond Index from Citigroup, GSCI indicates the return of the Goldman Sachs Commodity Index, GIP refers to the growth in the U.S. industrial production, and UI indicates unexpected inflation. The conditional betas are estimated within the multivariate specification of the asset pricing model with a conditioning period of 60 months. The t-statistics (in brackets) are heteroscedasticity and autocorrelation consistent (HAC). Significant parameters at the 10%, 5%, and 1% significance level are marked with *, **, and ***, respectively.

Risk Factor	Previous Conditional Beta		
	High Beta	Low Beta	Difference
SPEXR	1.71%	3.19%	-1.48%
	(0.90)	(1.19)	(-0.58)
BONDTR	5.14%	-0.25%	5.39%
	**(2.16)	(-0.14)	***(3.57)
GSCI	4.52%	0.37%	4.15%
	*(1.84)	(0.20)	**(2.27)
GIP	1.81%	3.09%	-1.28%
	(0.82)	(1.40)	(-0.64)
UI	1.51%	3.39%	-1.88%
	(0.99)	(1.29)	(-1.09)

Appendix A. State-Space Model and the Kalman Filter

The estimation of the three-factor futures pricing model follows Schwartz (1997) and works in two stages. First, the one-factor, interest-rate process is autonomously estimated by maximum likelihood. Second, the estimation of the dynamics of the other two state variables (spot price and convenience yield) is obtained by applying the Kalman filtering to futures prices. In the following, this second estimation step is outlined.

The basic idea of this estimation approach consists in finding parameters values for the dynamics of the spot price (Equation 1) and convenience yield (Equation 2) that generate theoretical futures values as close as possible to the traded futures prices. To this end, the (latent) dynamics of the spot price and convenience yield are related to the vector of futures prices, $\boldsymbol{y_t}$, by using the following state-space model:

$$\boldsymbol{\xi_{t+1}} = \boldsymbol{c} + \boldsymbol{G}\,\boldsymbol{\xi_t} + \boldsymbol{v_{t+1}} \tag{A.1}$$

$$\boldsymbol{y_t} = \boldsymbol{d} + \boldsymbol{H'}\,\boldsymbol{\xi_t} + \boldsymbol{w_t}. \tag{A.2}$$

Equation (A.1) is the state equation that models the dynamics of the state variables. Equation (A.2) is the observation equation that uses the insights from the three-factor futures pricing model of Schwartz (1997) to relate the values of the state variables, $\boldsymbol{\xi_t}$, to the (log-)futures prices, $\boldsymbol{y_t}$. As shown below, the parameters governing the discretized dynamics of the state variables are embedded in the system matrices $\boldsymbol{c}$, $\boldsymbol{d}$, $\boldsymbol{G}$, $\boldsymbol{H}$, as well as in $\boldsymbol{Q}$ and $\boldsymbol{R}$.

The exact specification of the matrices governing the joint dynamics of the state variables are as follows:

$$\begin{aligned}
\underset{(2\times1)}{\boldsymbol{\xi_t}} &= \begin{bmatrix} \ln S_t & \delta_t \end{bmatrix}' \\
\underset{(2\times1)}{\boldsymbol{c}} &= \begin{bmatrix} \left(\mu - \tfrac{1}{2}\sigma_1^2\right)\Delta t & \kappa\alpha\Delta t \end{bmatrix}' \\
\underset{(2\times2)}{\boldsymbol{G}} &= \begin{bmatrix} 1 & -\Delta t \\ 0 & 1-\Delta t \end{bmatrix}
\end{aligned}$$

where the corresponding 2×1 vector of innovations $\boldsymbol{v_t}$ satisfies the following properties:

$$
\begin{aligned}
\mathbb{E}\left[\boldsymbol{v_t}\right] &= \mathbf{0} \\
\mathbb{E}\left[\boldsymbol{v_t v_s'}\right] &= \begin{cases} \boldsymbol{Q} & t=s \\ \mathbf{0} & else \end{cases} \\
\underset{(2\times 2)}{\boldsymbol{Q}} &= \begin{bmatrix} \sigma_1^2\,\Delta t & \rho\sigma_1\sigma_2\,\Delta t \\ \rho\sigma_1\sigma_2\,\Delta t & \sigma_2^2\,\Delta t \end{bmatrix}
\end{aligned}
$$

The exact specification of the matrices relating the value of the state variables to futures prices are shown here:

$$
\begin{aligned}
\underset{(N\times 1)}{\boldsymbol{y_t}} &= \begin{bmatrix} \ln F\left(\tau_1\right) & \ldots & \ln F\left(\tau_N\right) \end{bmatrix}' \\
\underset{(N\times 1)}{\boldsymbol{d}} &= \begin{bmatrix} -\frac{r_t\left(1-e^{-a\tau_1}\right)}{a} + C\left(\tau_1\right) \\ \vdots \\ -\frac{r_t\left(1-e^{-a\tau_N}\right)}{a} + C\left(\tau_N\right) \end{bmatrix} \\
\underset{(N\times 2)}{\boldsymbol{H'}} &= \begin{bmatrix} 1 & -\frac{1-e^{-\kappa\tau_1}}{\kappa} \\ \vdots & \vdots \\ 1 & -\frac{1-e^{-\kappa\tau_N}}{\kappa} \end{bmatrix}
\end{aligned}
$$

where N is the number of futures contracts with different time-to-maturities τ considered at each date τ. Since the interest-rate process is separately estimated (see Schwartz, 1997), it does not appear in $\boldsymbol{\xi_t}$, and the actually observed T-bill yield series directly enters the matrices of the observation equation in $\boldsymbol{d}$.

The error term of the observation equation, $\boldsymbol{w_t}$, captures the difference between the pricing model and the observed futures data, which can be due to the existence of bid-ask spreads, non-simultaneity of quoted prices, and model misspecifications. Thus, low pricing errors are an indicator of a good model fit. The specification of $\boldsymbol{w_t}$ is given by:

$$
\begin{aligned}
\mathbb{E}\left[\boldsymbol{w_t}\right] &= \mathbf{0} \\
\mathbb{E}\left[\boldsymbol{w_t w_s'}\right] &= \begin{cases} \boldsymbol{R} & t=s \\ \mathbf{0} & else \end{cases} \\
\underset{(N\times N)}{\boldsymbol{R}} &= \begin{bmatrix} \phi_1^2 & 0 & 0 \\ 0 & \ddots & 0 \\ 0 & 0 & \phi_N^2 \end{bmatrix}
\end{aligned}
$$

The errors of the state equation, $\boldsymbol{v_t}$, and the observation equations, $\boldsymbol{w'_s}$, are independent for all time-lags:

$$\mathbb{E}\left[\boldsymbol{v_t}\boldsymbol{w'_s}\right] = \mathbf{0} \quad \text{for} \quad \text{all} \quad t \quad \text{and} \quad s.$$

The likelihood associated with a given set of parameters that determine the dynamics of the state variables is obtained by a forward recursion that considers the difference between the futures prices as forecasted by the model and their actually observed quotes. The details of this updating procedure are described in length in Harvey (1989) and Barlow et al. (2004), among others. Thus, by maximizing the likelihood function, both a set of parameters for the stochastic processes and a series of state variables is obtained. The convenience-yield series are particularly important as their analysis within an asset pricing framework represents the core of the study.

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