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Risk premia in crude oil futures prices☆

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ABSTRACT

If commercial producers or financial investors use futures contracts to hedge against commodity price risk, the arbitrageurs who take the other side of the contracts may receive compensation for their assumption of nondiversifiable risk in the form of positive expected returns from their positions. We show that this interaction can produce an affine factor structure to commodity futures prices, and develop new algorithms for estimation of such models using unbalanced data sets in which the duration of observed contracts changes with each observation. We document significant changes in oil futures risk premia since 2005, with the compensation to the long position smaller on average in more recent data. This observation is consistent with the claim that index-fund investing has become more important relative to commerical hedging in determining the structure of crude oil futures risk premia over time.

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1. Introduction

Volatile oil prices have been drawing a lot of attention in recent years, with Hamilton (2009) for example suggesting that the oil price spike was a contributing factor in the recession of 2007–2009. There has been considerable interest in whether there is any connection between this volatility and the flow of dollars into commodity-index funds that take the long position in crude oil futures contracts. Recent empirical investigations of a possible link include Kilian and Murphy (2013), Tang and Xiong (2012), Buyuksahin and Robe (2011), Alquist and Gervais (2011), Mou (2010), Singleton (2011), Irwin and Sanders (2012), and Fattouh et al. (2013).

A separate question is the theoretical mechanism by which such an effect could arise in the first place. Keynes (1930) theory of normal backwardation proposed that if producers of the physical commodity want to hedge their price risk by selling futures contracts, then the arbitrageurs who take the other side of the contract may be compensated for assuming that risk in the form of a futures price below the expected future spot price. Empirical support for this view has come from Carter et al. (1983), Chang (1985), and De Roon et al. (2000), who interpreted the compensation as arising from the nondiversifiable component of commodity price risk, and from Bessembinder (1992), Etula (2013) and Acharya et al. (2013), who attributed the effect to capital limitations of potential arbitrageurs. In the modern era, buying pressure from commodity-index funds could exert a similar effect in the opposite direction, shifting the receipt of the risk premium from the long side to the short side of the contract.

In this paper we show that if arbitrageurs care about the mean and variance of their futures portfolio, then hedging pressure from commodity producers or index-fund investors can give rise to an affine factor structure to commodity futures prices. We do so by extending the models in Vayanos and Vila (2009) and Hamilton and Wu (2012a), which were originally used to describe how bond supplies affect relative yields, but are adapted in the current context to summarize how hedging demand would influence commodity futures prices. The result turns out to provide a motivation for specifications similar to the class of Gaussian affine term structure models originally developed by Vasicek (1977), Duffie and Kan (1996), Dai and Singleton (2002), Duffee (2002), and Ang and Piazzesi (2003) to characterize the relation between yields on bonds of different maturities. Related affine models have also been used to describe commodity futures prices by Schwartz (1997), Schwartz and Smith (2000), and Casassus and Collin-Dufresne (2006), among others.

In addition, this paper offers a number of methodological advances for use of this class of models to study commodity futures prices. First, we develop the basic relations directly for discrete-time observations, extending the contributions of Ang and Piazzesi (2003) to the setting of commodity futures prices. This allows a much more transparent mapping between model parameters and properties of observable OLS regressions. Second, we show how parameter estimates can be obtained directly from unbalanced data in which the remaining duration of observed contracts changes with each new observation, developing an alternative to the Kalman filter methodology used for this purpose by Cortazar and Naranjo (2006). Third, we show how the estimation method of Hamilton and Wu (2012b) provides diagnostic tools to reveal exactly where the model succeeds and where it fails to match the observed data.

We apply these methods to prices of crude oil futures contracts over 1990–2011. We document significant changes in risk premia in 2005 as the volume of futures trading began to grow significantly. While traders taking the long position in near contracts earned a positive return on average prior to 2005, that premium decreased substantially after 2005, becoming negative when the slope of the futures curve was high. This observation is consistent with the claim that historically commercial producers paid a premium to arbitrageurs for the privilege of hedging price risk, but in more recent periods financial investors have become natural counterparties for commercial hedgers. We also uncover seasonal variation of risk premia over the month, with changes as the nearest contract approaches expiry that cannot be explained from a shortening duration alone.

The plan of the paper is as follows. Section 2 develops the model, and Section 3 describes our approach to empirical estimation of parameters. Section 4 presents results for our baseline specification, while Section 5 presents results for a model allowing for more general variation as contracts near expiration. Conclusions are offered in Section 6.