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Business cycle, storage, and energy prices

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ABSTRACT

This study examines the effect of the state of the economy and inventory on interest-adjusted bases and expected returns for five energy commodities. We find that interest-adjusted bases and returns have a business cycle pattern. Consistent with the theory of storage, demand shocks near business cycle peaks generate negative interest-adjusted bases and positive returns. In recessions, the bases become positive, and the average returns are negative. Our regression results also show that the interest-adjusted bases of energy commodities are counter-cyclical and the expected returns are pro-cyclical. For petroleum commodities, inventory has a significant effect on interest-adjusted bases at low levels of inventory, whereas at high inventory levels the effect of inventory on the bases is weak. Finally, we find that the bases and economic conditions predict spot returns in energy commodity markets.

1. Introduction

This study examines the variation of spot and futures prices of energy commodities over the business cycle. According to the modern view of the theory of storage (Fama & French, 1987, 1988), when commodity inventory is low and the marginal benefit of holding inventory (known as convenience yield) is high, the basis tends to be negative, i.e. the futures price is below the spot price. This market condition is known as backwardation.[1] In contrast, when inventory rises and the convenience yield falls, the basis tends to be positive, i.e. the futures price is above the spot price. This condition is called contango.[2]

Understanding the relation between spot and futures prices of energy commodities is crucial to economic agents in energy markets. For example, if the crude oil market is in backwardation, oil companies are likely to increase production (Litzenberger & Rabinowitz, 1995). A shift to contango increases the benefits of holding inventory. Furthermore, when crude oil market is in backwardation, commodity futures investors and speculators with long futures positions earn positive returns from rolling over their positions. Erb and Harvey (2006a) show that this so-called "roll return" is a crucial determinant of commodity futures returns. The roll return becomes negative when prices exhibit contango. Erb and Harvey (2006b) find that most of the time series variation in commodity futures returns is driven by spot return variation. Energy futures carry large weights in most commodity futures indices.[3] Therefore, it is important to understand what determines the basis and expected spot returns of energy commodities.

We examine the effect of the state of the economy on interest-adjusted basis (the basis net of the interest rate) and expected returns for energy commodities, also incorporating determinants predicted by the theory of storage. Several studies examine the link between the basis, returns, and business conditions. Fama and French (1988) find negative interest-adjusted bases for metals around business cycle peaks, suggesting that metal prices are affected by general business conditions. Bailey and Chan (1993) provide evidence that commodity bases reflect the macroeconomic risks premiums. Gorton, Hayashi, and Rouwenhorst (2013) find that commodity bases are affected by inventory levels. Hong and Yogo (2012) find that open interest in commodity futures predicts commodity returns. They use open interest as a proxy for economic activity. Gargano and Timmermann (2014) find that macroeconomic variables, including inflation, production, and money supply growth predict commodity price movements during recessions. Gospodinov and Ng (2013) argue that commodity convenience yield reflects future economic conditions and find a significant relation between convenience yields and commodity price changes. Our analysis is different from the previous research in that we directly examine the energy bases and short-term expected spot returns in relation to four measures of the state of the economy.

Our paper makes several contributions to the literature. First, we find that the state of the economy has a significant effect on interest-

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[1] Backwardation is consistent with the theory of normal backwardation, which states that futures price of a commodity should be below the expected spot price by "the amount of normal backwardation" (Keynes, 1930).

[2] Contango in energy commodities market is also consistent with the theory of Hotelling (1931), which states that the net price of exhaustible resources rises over time at the rate of interest under certainty.

[3] For example, the total weight of energy commodities in the popular S&P Goldman Sachs Commodity Index is about 79%.

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adjusted bases and expected returns of energy commodities. Consistent with the theory of storage, interest-adjusted bases for all energy commodities except natural gas are negative around business cycle peaks. We also show that the energy interest-adjusted bases tend to be positive in recessions. Expected spot returns of energy commodities over a three-month horizon are positive around business cycle peaks and negative during recessions. Regression results show that three-month interest-adjusted bases for petroleum commodities tend to decrease and expected returns over three months tend to increase when economic conditions are strong. Conversely, the petroleum bases increase and expected returns fall in recessions. We also find that the bases of oil, oil products and natural gas are useful predictors of spot returns.

Second, this is the only study to directly examine the variation of spot and futures prices for five energy commodities in periods when the inventory is low or high. Prior studies (e.g. Serletis & Hulleman, 1994; Serletis & Shahmoradi, 2006; Stronzik, Rammerstorfer, & Neumann, 2009) analyze crude oil and natural gas markets using an indirect test proposed by Fama and French (1988). This indirect test relies on using the sign of the interest-adjusted basis as a proxy for inventory. In contrast, we use a direct measure of inventory based on reported the U.S. physical stock.[4] We partition the sample by the level of inventory based on whether the physical stock for energy is below and above its five-year average for the same week. The new evidence is that the direct measure of inventory levels has a clear effect on the energy spot and futures price variation. When inventory is low, spot prices change more than futures prices, generating negative interest-adjusted bases. When inventory is high, changes in spot and future prices are similar, and interest-adjusted bases are positive.

Finally, we examine the effects of inventory on interest-adjusted bases under low and high levels of inventory.[5] We find positive and significant effect of inventory on interest-adjusted bases at low inventory levels but small and insignificant effect at high inventory levels. We also find that conditional return volatility negatively affects the basis when inventory is low. Since we use weekly inventory data, our test is more powerful than the analysis of Gorton et al. (2013) based on monthly data.

2. The relation between futures and spot prices

The basis is typically defined as the difference between commodity futures price $F_{t,T}$ at time t for delivery of the commodity at T and the spot price S_t. The theory of storage predicts that the basis depends on the foregone interest $S_t r_{t,T}$, marginal cost of storage $W_{t,T}$ and the convenience yield $C_{t,T}$. Fama and French (1988) state this relation as follows:

$$F_{t,T} - S_t = S_t r_{t,T} + W_{t,T} - C_{t,T}. \tag{1}$$

Dividing by the spot price and subtracting the interest rate, the interest-adjusted basis is expressed as a percentage of the spot price:

$$\left(F_{t,T} - S_t\right)/S_t - r_{t,T} = \left(W_{t,T} - C_{t,T}\right)/S_t\,. \tag{2}$$

Eq. (2) relates interest-adjusted basis to the relative convenience yield and the physical storage cost. Because supply and demand factors change, interest-adjusted basis also varies, moving between positive and negative territory depending on the magnitude of the net marginal convenience yield $W_{t,T} - C_{t,T}$ (Pindyck, 2001). According to the theory of storage, the marginal convenience yield declines, and the basis increases, with increases in inventory.

The basis can be expressed as the sum of the expected change in the spot price and the risk premium, defined as the difference between the futures price and an unbiased forecast of the future spot price:

$$F_{t,T} - S_t = E_t[S_T - S_t] + F_{t,T} - E_t. \tag{3}$$

Dividing by the spot price, we get:

$$Basis_t = \left(F_{t,T} - S_t\right)/S_t = (E_t[S_T] - [S_t])/S_t + \left(F_{t,T} - E_t[S_T]\right)/S_t. \tag{4}$$

Eq. (4) expresses the basis in terms of the expected spot returns and the risk premium. According to the theory of normal backwardation, producers hedge their risk exposure by selling futures at prices that are below the expected spot prices. Speculators, who hold long futures positions, earn a positive risk premium. An alternative view is that variation in expected returns and the risk premium is determined by changes in costs and benefits of carrying inventory.

2.1. Hypotheses

We investigate how the state of the economy affects the basis of energy commodities. Demand and supply shocks for energy are often induced by changes in macroeconomic activity (e.g., Kilian, 2009). For example, business activity in energy-intensive sectors depends on the state of the economy. When the economy grows, spot and futures prices of energy tend to increase due to growing demand. Fama and French (1988) argue that inventory acts as a buffer absorbing demand and supply shocks. As inventory levels decline at business cycle peaks, positive demand shocks have a large effect on the spot price, leading to negative interest-adjusted bases.[6] When the economy is in recession, spot and futures prices decline due to a fall in demand. Negative demand shocks lead to an increase in inventories, lower convenience yields and higher bases. We propose the following hypothesis:

Hypothesis 1. The state of the economy influences interest-adjusted basis of energy commodities. The interest-adjusted basis tends to fall near a business cycle peak and increase in a recession.

We also examine the effect of the state of the economy on the expected spot returns of energy commodities. Theoretical literature on determinants of financial asset returns is extensive. Most theoretical studies predict counter-cyclical behavior of aggregate stock returns (e.g., Campbell & Cochrane, 1999). Pricing theory for commodities is relatively undeveloped. We are aware of no model that generates clear predictions regarding behavior of expected spot commodity returns over the business cycle.

According to Frankel and Rose (2010), storable commodities can be viewed both as *assets*, the prices of which are determined by supply and demand for stocks, and as *goods*, whose prices are driven by shocks to the current flow supply and current flow demand. The asset view predicts that changes in expectations of future supply and demand will affect the demand for inventories and result in a change in commodity prices (e.g., Kilian & Murphy, 2014). Kilian and Vega (2011) find no evidence that oil prices immediately respond to macroeconomic news. They conclude that oil prices are determined primarily by flow supply and flow demand. In contrast, stock returns are determined by expectations of corporate earnings and discount rates. Therefore, the business cycle behavior of expected returns for energy commodities is likely to differ from that of stock returns. For example, stocks have higher expected returns in recession due to higher equity risk premium. At the same time, energy prices can be expected to decline due to low demand

[4] Energy commodities are consumed and produced internationally. However, global inventory data are not available. We use weekly U.S. stocks data across five commodities, which are accurate and available since 1987. U.S. energy inventory strongly affect national benchmark prices for five energy commodities, which are produced, consumed, and traded in the United States. The correlation between monthly U.S. petroleum stocks and the OECD petroleum stocks (excluding the U.S.) for 1990–2011 is about 0.58.

[5] Gorton et al. (2013) examine the effects of inventory on futures price variation only at low levels of inventories.

[6] This effect is discussed by Fama and French (1988) in their study of industrial metal prices.