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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.

for energy. When economic conditions are strong, energy prices increase due to growing demand, even though expectations may point to economic slowdown. Therefore, we expect pro-cyclical variation in expected returns of energy commodities. We test the following hypothesis:

Hypothesis 2. The state of the economy influences expected spot returns of energy commodities. The expected returns increase in period of high economic activity and fall in a recession.

3. Data and key variables

We use daily and weekly spot and three-month futures prices for crude oil, gasoline, and heating oil for the period from 1/02/1987 to 5/02/2014.[7] Prices for natural gas begin in 1997 and prices for propane are available from 1994 to 2009. The futures prices for energy commodities are from the New York Mercantile Exchange. We match spot and three-month futures prices observed on the same day. We also use available weekly inventory data for the same five energy commodities. Missing observations are excluded from the sample in order to have a continuous series. The data for energy prices and inventories are obtained from the website of the U.S. Department of Energy. Table 1 provides the description of futures prices and inventory data. We also use the three-month Treasury constant maturity rate from the FRED database of the Federal Reserve Bank of St. Louis.

We use daily and weekly data to compute the three-month interest-adjusted basis (in percent) for commodities following Fama and French (1988) as:

$$\left(F_{t,T}-S_t\right)/S_t \ -r_{t,T} \quad (5)$$

where S_t is the spot price at time t, $F_{t,T}$ is the three-month futures price at t, and $r_{t,T}$ is the three-month Treasury constant maturity yield.[8]

We also use daily price data to construct realized spot returns over a three-month horizon (expressed in percent) as:

$$(S_T-S_t)/S_t \quad (6)$$

where S_T is the spot price observed three months after day t.

In order to divide the sample periods into periods of low and high inventories, we calculate the long-term averages of the physical stock for each energy commodity for each week of the year using the prior five years of weekly estimates. Thus, the physical stock below (above) the five-year averages for each week determines the low (high) inventory levels.

For regression tests, we compute log normalized detrended inventory following Gorton et al. (2013) as (I_t/I_t^*), where I_t is the inventory at the end of the week t and I_t^* is the trend in inventory estimated with the Hodrick–Prescott filter. Gorton et al. (2013) indicate that Hodrick–Prescott filter and other methods of calculating normalized inventory levels yield similar estimates of unit-free detrended inventory.

Table 2 presents the descriptive statistics for interest-adjusted bases, returns, conditional return volatilities estimated with GARCH (1,1) model, and detrended inventories for five energy commodities. Panel A of the table shows that the daily three-month interest-adjusted bases are moderately volatile, with standard deviations ranging from 4% to 8% for petroleum products and of about 14% for natural gas. The bases of crude oil, heating oil, natural gas and propane are positively correlated. Panel B of Table 2 shows that returns over a three-month horizon are at least twice as volatile as the bases, and are more correlated across energy commodities. Similar to interest-adjusted bases, energy returns have low skewness and moderate kurtosis.

Panel C of Table 2 shows that the detrended normalized inventory has a distribution close to normal. Inventories for heating oil, propane, and natural gas are positively correlated and negatively correlated with crude oil and gasoline inventory. The conditional standard deviation of daily spot returns shown in Panel D of Table 2 is moderately volatile, positively skewed, and moderately correlated across the five energy commodities. Natural gas return volatility has the highest standard deviation and is less correlated with the conditional volatilities of petroleum commodities. Overall, the statistics for the bases, returns and conditional return volatility for natural gas and gasoline differ from those for other energy commodities. Such differences arise from different supply and demand fundamentals, seasonalities in consumption and production, and different storage technologies.

We use two proxies for general economic conditions. The first proxy is the ADS business conditions index designed by Aruoba, Diebold, and Scotti (2009) and published by the Federal Reserve Bank of Philadelphia. The second proxy is the Chicago Fed National Activity Index (CFNAI). The CFNAI is a principal component of 85 economic indicators. Similar to Basistha and Kurov (2008), we use the three-month moving average of the CFNAI. The historical values of the CFNAI are obtained from the website of the Federal Reserve Bank of Chicago. We also use two proxies for the U.S. recession, including the National Bureau of Economic Research (NBER) recession dummy and the real time probability of recession index constructed by Chauvet and Piger (2008) at monthly intervals using a Markov switching model. The NBER recession timing is based on information that is unavailable to market participants in real time. In contrast, the recession probability index indicates the probability that the U.S. economy is in recession in real time.

Fig. 1 shows time variation of the macroeconomic activity and business cycle proxies. Positive values of the ADS index and of the three-month moving average of the CFNAI imply better-than-average economic conditions, and negative values imply worse-than-average economic conditions. The ADS and the three-month moving average of the CFNAI positively correlate with each other and negatively correlate with the recession probability index. Large declines in the economic conditions proxies coincide with NBER recessions.

4. Empirical results

We begin by analyzing statistics for energy interest-adjusted bases and spot returns at high and low levels of inventory and in different stages of the business cycle. We then use regression analysis to examine the effect of the state of the economy on interest-adjusted basis and returns, while controlling for other determinants predicted by theory.[9]

4.1. Relative variability of spot and futures prices

The theory of storage predicts that demand and supply shocks have a larger effect on spot prices than on futures prices for commodities, generating negative interest-adjusted bases when inventory is low. Fig. 2 shows that interest-adjusted basis for heating oil is negative at low inventory levels. As inventory increases, the basis increases at a gradually decreasing rate. Fig. 2 also shows that equal changes in inventory lead to much larger changes in the basis when inventory is low than when inventory is high. Thus, consistent with the theory of storage, the relation between interest-adjusted basis and inventory appears to be non-linear.

Serletis and Hulleman (1994) and Serletis and Shahmoradi (2006) analyze energy commodities using indirect test proposed by Fama and

7 Our sample period begins in 1987 because spot prices of petroleum commodities are available from the U.S. Department of Energy starting in 1987. Spot price for crude oil is available starting in 1986.

8 The three-month futures contracts are sufficiently liquid, and their maturity matches the three-month Treasury maturity rate available from the FRED database. Contract rollovers introduce some noise in our measure of the basis. This noise may create a bias against finding significant results.

9 Granger causality tests show that the state of the economy predicts changes in daily crude oil and heating oil interest-adjusted bases and returns, while there is no evidence of the reverse predictive relation. For the other energy commodities, we do not find evidence of Granger causality between the state of the economy and the bases, and returns.

Table 1
Energy commodity futures prices and inventory data.
Three-month futures prices and inventory data are from the Energy Information Administration of the U.S. Department of Energy. The futures contracts are traded on the New York Mercantile Exchange.

Commodity	Description	Units	Starting date
A. Futures prices			
Crude oil	Light-sweet cushing, Oklahoma, West Texas Intermediate	\$/barrel	1/02/1987
Gasoline	Regular, New York Harbor	\$/gallon	1/02/1987
Heating oil	No. 2 fuel oil, New York Harbor	\$/gallon	1/02/1987
Natural gas	Henry Hub Gulf Coast	\$/million BTU	1/07/1997
Propane	Mont Belvieu, Texas	\$/gallon	2/08/1994
B. Inventory			
Crude oil	U.S. ending stocks excluding SPR of crude oil	Thousand barrels	1/01/1987
Gasoline	U.S. ending stocks of total gasoline	Thousand barrels	1/04/1990
Heating oil	Weekly U.S. ending stocks of distillate fuel oil	Thousand barrels	1/01/1987
Natural gas	Lower 48 states natural gas working underground storage	Billion cubic feet	12/30/1993
Propane	U.S. ending stocks of propane and propylene	Thousand barrels	3/04/1993

French (1988). This test uses positive and negative interest-adjusted bases as a proxy for high and low inventories. We apply the indirect test for daily energy prices. In addition, we analyze weekly energy price variation based on a direct measure of inventory levels. Table 3 reports the results for both of these tests.

Panels A and B of the table demonstrate that three-month interest-adjusted bases are negative when inventory is low and the bases are positive when inventory is high. Consistent with Serletis and Hulleman (1994), the standard deviations of petroleum interest-adjusted bases are higher when the basis is negative than when the basis is positive except for crude oil and natural gas. Similar results are obtained for weekly interest-adjusted bases with the sample partitioned by the level of inventory. Likewise, results in Panel C show that the ratios of standard deviations of futures and spot price changes are lower when the basis is negative or inventory is low than when the basis is positive or inventory is high. These results are consistent with the prediction of Fama and French (1988) based on the theory of storage that spot prices are more volatile than futures prices when inventory is low, but the futures and spot volatilities are roughly equal when inventory is high. These findings are also consistent with our hypotheses regarding variation of futures and spot energy prices over the business cycle.

4.2. Evidence on spot and futures prices over the business cycle

The theory of storage predicts that permanent demand and supply shocks around business cycle peaks decrease inventories, which causes spot prices to increase more than futures prices.[10] Fama and French (1988) find that interest-adjusted bases for metals are negative around business cycle peaks. In the analysis that follows, we describe relative spot prices, interest-adjusted bases and expected returns for energy commodities around business cycle peaks and during recessions.

Table 4 shows a sharp increase in the relative spot energy prices around the NBER business cycle peaks and a strong decline in the relative prices during recessions.[11] As expected, energy prices rise in good economic times, reaching their maximum around the business cycle peak or at the beginning of a recession, and fall in periods of economic decline. Consider the increase in energy prices around the NBER business cycle peaks of July 1990, March 2001, and December 2007. Based on the monthly maximum price levels, the increase in energy prices from their levels of about two years before the business cycle peak ranges from about 70% to 190%. Prices fall considerably in late recessions, presumably due to a decrease in demand. During the recessions of 1990–91 and 2001, energy prices fell by over 40% from their previous highs, and the decline sometimes continued after the recession was over. During the recent recession, spot energy prices declined by over two-thirds from their 2008 highs.

Panel A of Table 5 demonstrates that three-month interest-adjusted bases except natural gas are negative around business cycle peaks, when spot prices increase as shown in Table 4. These results support the prediction of the theory of storage that permanent demand and supply shocks around business cycle peaks generate negative bases. Conversely, the bases for all energy commodities except heating oil are positive during recessions, when spot prices decline. A possible explanation is that excess supply shocks in recessions are absorbed by inventory, generating positive interest-adjusted bases in recessions.

Panel B of Table 5 shows that the energy spot returns over a three-month horizon are pro-cyclical: they are positive around business cycle peaks and negative during recessions. The average returns around business cycle peaks range from 4.7% for propane to 8.7% for natural gas. In recessions, the average energy commodity returns range from −1.2% for crude oil to −13.1% for natural gas. For all commodities, the standard deviations of the basis and returns tend to be larger around business cycle peaks and during recessions than in other periods, implying that volatility in energy markets is driven by supply and demand shocks. In sum, consistent with our hypotheses, the evidence shows that the bases and returns of energy commodities are influenced by business conditions.

4.3. Interest-adjusted basis, inventory, and state of the economy

To test Hypothesis 1, we estimate the following regression of interest-adjusted basis on proxies for the state of the economy EM_t, log normalized detrended inventory I_{nvt}, conditional standard deviation of spot returns σ_t, and monthly seasonal dummies d_m:

$$\left(F_{t,T}-S_t\right)/S_t-r_{t,T}=\alpha+\beta_1 EM_t+\beta_2 Inv_t+\beta_3\sigma_t+\sum\delta_m d_m+\varepsilon_t. \quad (7)$$

The proxies for the state of the economy include two measures of business conditions and two recession proxies. Based on Hypothesis 1, we expect the estimate of β_1 to be negative when the business conditions proxies are used and positive when recession proxies are used. The inventory variable is a proxy for the convenience yield. This variable is used by Gorton et al. (2013) in a similar context. According to the theory of storage, the relation between the basis and inventories should be positive at low inventory levels, and close to zero at high inventory levels.

The conditional standard deviation of spot returns is included to capture the relation between price volatility and the basis suggested by Pindyck (2001).[12] When price volatility increases, the convenience

[10] Kilian and Murphy (2014) find that demand shocks have little effect on inventories.
[11] The business cycle patterns observed for relative nominal and real energy prices are similar.
[12] Pindyck (2001) considers spot price volatility to be a proxy for general volatility of consumption and production, which affects the demand for storage and convenience yield, and thereby can explain the basis.

Table 2
Statistics for interest-adjusted basis, returns, inventory and return volatility.

	Mean	St. Dev.	Skewness	Kurtosis	Obs.	Correlation with				
						Crude oil	Gasoline	Heating oil	Natural gas	Propane
A. 3-mo interest-adjusted basis (daily data), %										
Crude oil	−1.19	4.42	0.69	12.31	6797	1	0.30	0.51	0.17	0.41
Gasoline	0.02	7.85	−0.14	3.93	6797	0.30	1	0.01	−0.13	−0.07
Heating oil	−0.53	6.46	−2.33	12.91	6794	0.51	0.01	1	0.42	0.72
Natural gas	6.17	14.26	2.42	18.45	4292	0.17	−0.13	0.42	1	0.39
Propane	−2.17	6.38	−2.59	12.00	3879	0.41	−0.07	0.72	0.39	1
B. 3-mo spot returns (daily data), %										
Crude oil	3.12	17.93	1.04	9.93	6781	1	0.84	0.84	0.26	0.69
Gasoline	3.31	18.41	0.28	4.51	6781	0.84	1	0.74	0.23	0.62
Heating oil	3.21	18.30	1.15	9.65	6781	0.84	0.74	1	0.35	0.76
Natural gas	4.35	27.34	1.15	9.52	4239	0.26	0.23	0.35	1	0.53
Propane	3.26	19.01	0.22	5.14	5377	0.69	0.62	0.76	0.53	1
C. Log normalized inventory (weekly data)										
Crude oil	−0.001	0.03	0.11	2.70	1428	1.00	−0.12	−0.31	−0.29	−0.21
Gasoline	−0.0009	0.04	0.11	3.05	1270	−0.12	1.00	−0.02	−0.37	−0.43
Heating oil	−0.006	0.09	−0.47	2.73	1428	−0.31	−0.02	1.00	0.68	0.70
Natural gas	−0.06	0.33	−0.64	2.64	1062	−0.29	−0.37	0.68	1.00	0.94
Propane	−0.05	0.30	−0.58	2.27	604	−0.21	−0.43	0.70	0.94	1.00
D. Spot return conditional volatility (weekly data), %										
Crude oil	3.96	1.23	2.50	11.77	1428	1.00	0.57	0.53	0.08	0.32
Gasoline	4.66	1.16	2.25	11.51	1428	0.57	1.00	0.49	0.18	0.21
Heating oil	4.19	1.68	3.49	20.86	1428	0.52	0.49	1.00	0.20	0.48
Natural gas	7.43	2.97	3.36	20.85	901	0.08	0.18	0.20	1.00	0.50
Propane	4.41	2.41	3.61	23.88	1139	0.33	0.21	0.48	0.50	1.00

Note: The statistics are for the three-month interest-adjusted basis (Panel A), the spot returns over a three-month horizon (Panel B), weekly log normalized inventory (Panel C), and weekly conditional volatility of spot returns (Panel D). The sample period is 1987–5/02/2014 for crude oil and heating oil; 1990–5/02/2014 for gasoline; 1997–5/02/2014 for natural gas; and February 11, 1994 to September 18, 2009 for propane.

yield and demand for storage should increase, leading to a decline in the basis. The model also includes seasonal dummies, as in Fama and French (1987). Energy inventories typically increase during summer and decline in winter. Thus, the impact of seasonal dummies on energy bases is expected to be positive during summer and negative during winter.

We estimate regressions for interest-adjusted basis shown in Eq. (7) using daily and weekly data, so that the regression coefficients can be compared, and robustness of results can be verified. The first five columns of Table 6 report daily regression results for interest-adjusted basis with the ADS index used as the state of the economy proxy.[13] The last five columns report the daily results with the NBER recession dummy. These regressions do not include the inventory variable, because daily inventory data are not available.

Columns 1, 3, and 4 of Table 6 show that interest-adjusted bases for crude oil, heating oil, and propane are related to the state of the economy proxies. Specifically, these bases have a strong negative relation with the economic conditions proxies and positive relation with the recession proxies. This finding supports Hypothesis 1. For example, in the daily regression, the coefficient estimate of the ADS business conditions index for crude oil is about −1.6. For heating oil, this coefficient estimate is about −0.9. These negative coefficients show that interest-adjusted bases of energy commodities are counter-cyclical. The coefficient estimates of the NBER recession dummy are positive and significant for the same three commodities. Based on these estimates, interest-adjusted basis increases by about 2% on average for crude oil and heating oil and by about 4% on average for propane when the U.S. economy is in recession.

The volatility of spot returns is negatively related to interest-adjusted bases for all energy commodities, although this coefficient estimate is statistically significant only for heating oil and propane. For example, based on the daily regression, a 1% increase in the conditional volatility of returns decreases the interest-adjusted basis by over 2% for heating oil and by about 1.4% for propane. These results are consistent with the hypothesis of Pindyck (2001) that the convenience yield increases and the basis declines when price volatility increases.

The coefficient estimates of monthly seasonal dummies are mostly significant for all energy commodities except crude oil. For heating oil, propane, and natural gas, the coefficients of the dummies for summer and fall months are typically positive and those for winter months are negative. Since the demand for heating oil, propane, and natural gas is very high during the heating season and inventory accumulation occurs during summer, this evidence is consistent with the theory of storage. On the other hand, for gasoline, the seasonal dummy coefficients are positive for winter months and negative for summer and fall months. Demand for gasoline increases during the summer driving season and declines in winter. The absence of seasonal pattern in the crude oil basis is likely to be due to a lack of seasonality in the demand for crude oil.

Table 7 presents the weekly regression results with the log detrended inventory variable at times of low and high levels of inventory. The theory of storage predicts that demand and supply shocks have a larger effect on interest-adjusted basis at low inventory levels than at high inventory levels. To test these predictions we estimate the linear regression for interest-adjusted basis under low and high inventory levels. Linear model specification is appropriate because at high inventory levels the interest-adjusted basis function is almost flat, whereas at low inventory levels the basis increases with increase in inventory.

Consistent with the theory of storage, the results show a large positive and significant effect of log normalized inventory on interest-adjusted bases when inventory is low for all energy commodities except natural gas. In contrast, at high inventory levels, the response of interest-adjusted basis is smaller and statistically insignificant, implying that the relation between inventory and the basis is almost flat when the inventory is high. For example, the inventory coefficient estimates for gasoline are over four times as large when inventory is low as when inventory is high. The coefficient of log normalized inventory in the low-inventory subsample ranges from 0.11 for propane to 0.70 for

[13] Regression results for interest-adjusted bases using weekly data are quantitatively similar to the reported daily results. The results based on monthly data with the three-month moving average of the CFNAI and with the probability of recession are also similar. These results are available upon request.

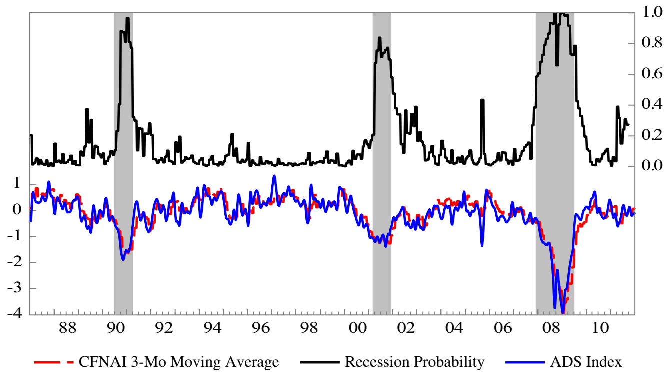

Fig. 1. Business cycle measures. The Aruoba–Diebold–Scotti (ADS) business conditions index and three-month moving average of the Chicago Fed National Activity Index (CFNAI) on the left axis, and the probability of recession index on the right axis. Shaded areas are NBER recessions.

Table 3
The relative variability of spot and futures prices.

	Daily data			Weekly data		
	Positive basis	Negative basis	All	High inventory	Low inventory	All
Averages of the interest-adjusted basis (%)						
Crude oil	2.34	−3.79	−1.19	0.75	−3.47	−1.21
Gasoline	5.91	−6.09	0.02	3.55	−1.49	0.01
Heating oil	2.85	−6.27	−0.53	2.37	−3.06	−0.31
Natural gas	9.91	−5.45	6.17	8.77	−0.08	6.09
Propane	1.65	−5.46	−2.17	−2.50	−5.68	−2.27
Standard deviation of the interest-adjusted basis (%)						
Crude oil	3.27	3.17	4.41	3.97	3.47	4.30
Gasoline	4.88	5.25	7.85	6.28	6.86	7.75
Heating oil	2.19	7.20	6.45	3.46	7.48	6.40
Natural gas	13.77	8.19	14.26	14.61	8.29	13.59
Propane	1.40	7.09	6.36	5.40	9.12	6.30
Ratios of standard deviation of futures changes to standard deviation of spot price changes						
Crude oil	0.83	0.77	0.80	0.81	0.82	0.82
Gasoline	0.80	0.70	0.76	0.84	0.65	0.75
Heating oil	0.88	0.67	0.77	0.87	0.67	0.76
Natural gas	0.66	0.50	0.61	0.71	0.51	0.64
Propane	0.93	0.68	0.81	0.90	0.70	0.81

Statistics are for all days (All), when the interest-adjusted basis is positive and negative and when the inventory is high and low. Spot and three-month futures energy prices are from the U.S. EIA. Spot and futures price changes are expressed as percentage changes. Inventory levels are classified as high or low based on comparison of the weekly physical stock estimates with the average inventory for the same week in the previous five years. The sample period is 1/02/1987–5/02/2014 for crude oil and heating oil; 1/06/1995–5/02/2014 for gasoline; 1/10/1997–5/02/2014 for natural gas; and 29/08/2003–5/02/2014 for propane.

gasoline. This implies that a 1% increase in inventories increases the basis by about 0.11% for propane and by about 0.7% for gasoline when the corresponding inventory is low. For natural gas, the inventory coefficients are not statistically significant at low inventory and marginally significant at high inventory level, implying a weak relation between inventory and the basis.

Table 7 also demonstrates that price volatility affects interest-adjusted basis for energy commodities when inventory is low. The coefficient estimates for the response of interest-adjusted basis to return volatility are negative and statistically significant when inventory is low. This result implies that interest-adjusted bases of energy commodities decrease when volatility increases, because higher volatility increases the demand for storage, leading to higher convenience yield. At the same time, the volatility coefficient estimates for natural gas and gasoline are positive and significant when inventory is high. This positive effect of volatility on the basis may be due to market expectations of future conditions in the cash and storage market (Pindyck, 2001). For instance, an increase in price volatility of natural gas is expected to increase the level of inventory, which in turn positively affects the basis.

The effect of the state of the economy proxies is statistically significant for crude oil, gasoline, propane and natural gas at low inventory levels. Interest-adjusted basis tends to decline in periods of economic growth. The coefficients of the three-month moving average of the CFNAI are consistently negative for all commodities, ranging from about −0.5 for heating oil to about −1.3 for crude oil when inventory is low. Conversely, the coefficient estimates for the probability of recession are positive, ranging from about 1.9 for heating oil to 5.4 for crude oil. These results support the hypothesis that interest-adjusted basis is likely to be positive in recessions.

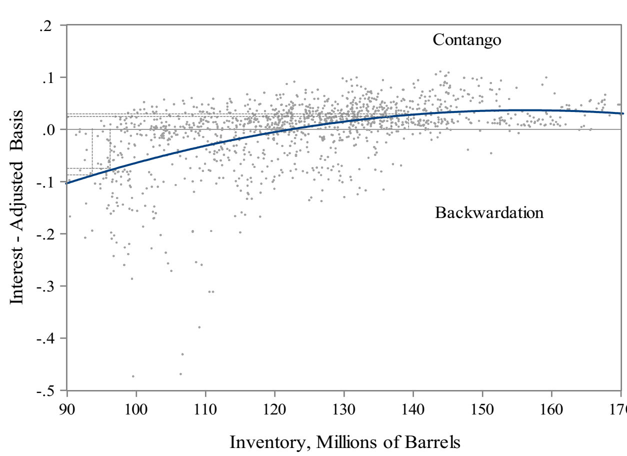

Fig. 2. Interest-adjusted basis as a function of inventory. Scatter plot of the three-month interest-adjusted basis of New York Harbor No. 2 heating oil and weekly U.S. ending stock of distillate fuel oil. The thick curve represents the second-order polynomial regression line, which resembles the inventory-basis relation predicted by the theory of storage. The estimated regression: *Int.-Adjusted Basis* = −0.74 + 0.01 ∗ *Inventory* − 3.20e−05 ∗ (*Inventory*^{2}), R^2 = 0.27, N = 1427. The sample period is 1/02/1987–5/02/2014.

4.4. Expected returns and state of the economy

To test hypothesis 2, we estimate a regression of expected returns on proxies for the state of the economy and the basis. The basis can be decomposed into the expected change in spot prices and the risk premium, as in Eq. (4). The expected spot price at expiration is unobservable and has to be replaced with the realized spot price S_T. We estimate the following regressions for energy commodities:

$$(S_T - S_t)/S_t = \alpha + \beta_1 Basis_t + \beta_2 EM_t + u_t \tag{8}$$

$$\left(F_{t,T} - S_T\right)/S_t = \delta + \gamma_1 Basis_t + \gamma_2 EM_t + v_t. \tag{9}$$

The coefficients β_1 and γ_1 should sum up to one because the left-hand sides of Eqs. (8) and (9) add up to basis.[14] Thus, changes in the basis should be related to variation in expected returns, the risk premium, or their mix. Proxies for economic conditions are included in the regressions to examine whether the state of the economy predicts future

[14] Fama and French (1987) find that β_1 and γ_1 are positive for some commodities, indicating that the basis is related to expected returns and time-varying futures risk premiums. However, their sample did not include energy commodities.

Table 4
Relative spot prices around business cycle peaks and recessions.

	Before peak	Around peak	Peak	Recession				After trough
A. 1990–91								
	Jan-88	Jan-90	Jul-90	Maximum (Mo.)		Minimum (Mo.)		Jan-92
Crude oil	1	1.33	1.08	2.10	(Oct-90)	1.16	(Mar-91)	1.10
Gasoline	1	1.42	1.44	2.22	(Sep-90)	1.47	(Feb-91)	1.18
Heating oil	1	1.37	1.03	1.82	(Oct-90)	1.19	(Mar-91)	1.00
B. 2000–01								
	Jan-98	Jan-00	Mar 01	Maximum (Mo.)		Minimum (Mo.)		Jan-02
Crude oil	1	1.63	1.63	1.71	(May-01)	1.17	(Nov-01)	1.18
Gasoline	1	1.47	1.64	1.98	(Apr-01)	1.08	(Nov-01)	1.14
Heating oil	1	1.96	1.59	1.68	(Apr-01)	1.18	(Nov-01)	1.15
Natural gas	1	1.16	2.50	2.50	(Mar-01)	1.12	(Nov-01)	1.11
Propane	1	1.84	1.85	1.85	(Mar-01)	1.10	(Nov-01)	0.96
C. 2007–09								
	Jan-05	Jan-07	Dec-07	Maximum (Mo.)		Minimum (Mo.)		Jan-10
Crude oil	1	1.16	1.96	2.86	(Jun-08)	0.83	(Feb-09)	1.67
Gasoline	1	1.15	1.88	2.65	(Jun-08)	0.77	(Dec-08)	1.64
Heating oil	1	1.16	1.96	2.89	(Jun-08)	0.97	(Mar-09)	1.55
Natural gas	1	1.07	1.16	2.06	(Jun-08)	0.62	(Jun-09)	0.95
Propane	1	1.21	2.07	2.53	(Jul-08)	0.83	(Dec-08)	1.78

Note: The spot price for each commodity in Panels A, B, and C is divided by the spot price of January 1988, January 1998, and January 2005, respectively. The maximum price ratio in Panels A, B and C is the highest ratio around business cycle peaks and in recessions. The minimum price ratio is the lowest ratio during recessions. The business cycle peaks and recessions are dated by the NBER. The dates before peak and around peak are one month prior to about two years, and five months before the NBER peaks, respectively. The dates after trough are one month after the end of recession.

spot prices. Based on Hypothesis 2, we expect a positive relation between the state of the economy and expected returns.

Table 8 shows the estimation results for the expected returns regression in Eq. (8). The results show that basis positively predicts expected returns for energy commodities. All coefficient estimates of basis are positive and statistically significant at the 1% level. The results (not provided) for the risk premium regression in Eq. (9) are statistically unreliable. Fama and French (1987) argue that variation in the basis is low compared to variation in realized risk premium, leading to imprecise estimates of the relation between the basis and the premium. The predictable behavior of the expected returns through the variation in the basis is consistent with the predictions of the theory of storage, and it could be of help to forecast changes in spot prices.

Table 5
Averages and standard deviations of interest-adjusted bases and spot returns over the business cycle (daily data).

	Around peaks		Recessions		Excluding dates around peaks and recessions	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
A. 3-mo basis, %						
Crude oil	−2.47	4.81	0.17	7.24	−1.31	3.81
Gasoline	−2.95	7.77	0.02	8.73	0.17	7.63
Heating oil	−5.20	7.23	−0.98	6.87	0.08	6.11
Natural gas	3.78	15.82	6.34	10.49	6.31	14.67
Propane	−5.71	9.66	0.50	3.10	−2.39	6.32
B. 3-mo returns, %						
Crude oil	7.07	29.64	−1.21	32.87	3.51	13.67
Gasoline	7.79	18.83	−2.55	28.69	4.00	16.24
Heating oil	4.54	26.52	−4.06	27.50	4.42	15.55
Natural gas	8.73	35.93	−13.05	24.85	6.99	25.88
Propane	4.65	20.82	−7.69	24.21	4.59	17.65

Note: Statistics are for daily three-month interest-adjusted basis in Panel A and spot returns over a three-month horizon in Panel B for days around business cycle peaks (around peaks): 1/01/1990–6/30/1990, 9/01/2000–2/28/2001, and 6/01/2007–11/30/2007 and during recessions (recessions): 7/01/1990–3/31/1991, 3/01/2001–11/28/2001, and 12/01/2007–6/30/2009. Business cycle peaks and recessions are dated by the NBER. The periods around peaks are six-month periods prior to the NBER business cycle peaks.

Table 8 also shows that the state of economy predicts returns of energy commodities. Coefficient estimates of the ADS index and the NBER recession dummy are statistically significant in the daily regression. These results imply that expected returns over a three-month horizon increase in good economic times and decline in recessions. The expected price decline over a three-month horizon in recessions ranges from about 8.1% for gasoline to about 20.9% for natural gas. Conversely, the ADS index positively predicts returns, with coefficient estimates ranging from about 3.3 for crude oil to about 6.3 for natural gas. The weekly regression results (not provided) are somewhat weaker, but similar to those based on daily data. The finding that the state of the economy predicts future spot price changes supports Hypothesis 2 and it is consistent with the evidence in Tables 4 and 5.

4.5. Robustness checks

Our regressions for bases and expected returns are estimated with OLS using Newey–West autocorrelation and heteroskedasticity-consistent standard errors (Newey & West, 1987). These regressions are subject to possible small sample biases in the coefficient estimators and standard errors. Stambaugh (1999) shows that the OLS coefficient estimator is biased in a small sample when the predictor variable is persistent and its innovations are strongly correlated with returns. Amihud and Hurvich (2004) propose a correction for this bias that involves estimating a VAR(1) model for the persistent predictors and using (bias-corrected) residuals in the predictive regression. We performed this procedure for our bases and return regressions. The coefficients were similar to those reported in Tables 6 and 8.

The expected return regressions use overlapping observations. It is well known that the standard errors are biased downward in finite samples when overlapping observations are used (e.g., Nelson & Kim, 1993). Britten-Jones, Neuberger, and Nolte (2011) show in Monte-Carlo

Table 6
Regression results for interest-adjusted bases (daily data).

	With economic conditions proxy					With recession proxy				
	Crude oil	Gasoline	Heating oil	Propane	Natural gas	Crude oil	Gasoline	Heating oil	Propane	Natural gas
ADS index (β_1)	**−1.66*****	0.23	**−0.97*****	**−1.51*****	−0.10	–				
	(0.42)	(0.41)	(0.33)	(0.25)	(0.56)					
NBER recession (β_1)						**1.75*****	0.40	**2.03****	**4.11*****	1.12
						(0.71)	(0.93)	(0.82)	(0.57)	(1.14)
Returns volatility,% (β_2)	**−0.49***	−0.05	**−2.13*****	**−1.43*****	0.57	−0.16	−0.21	**−2.13*****	**−1.41*****	1.00
	(0.26)	(0.38)	(0.37)	(0.26)	(0.53)	(0.32)	(0.34)	(0.38)	(0.26)	(0.69)
Constant	0.49	**3.45*****	**3.31*****	0.11	0.57	−0.34	**3.81*****	**3.22*****	**−3.03*****	−0.87
	(0.54)	(0.47)	(1.13)	(1.87)	(1.91)	(0.85)	(1.07)	(1.13)	(1.14)	(2.92)
N	6716	6698	6695	3879	4213	6716	6698	6695	3879	4213
R^2	0.06	0.35	0.38	0.48	0.29	0.02	0.35	0.37	0.49	0.29

Note: The table shows the estimates for the following regression: $(F_{t,T} - S_t)/S_t - r_{t,T} = \alpha_t + \beta_1 EM_t + \beta_2 \sigma_t + \sum \delta_m d_m + \varepsilon_t$. The regression is estimated using OLS with HAC standard errors (Bartlett kernel, Newey–West fixed bandwidth = 6.0). The coefficients of the seasonal dummies are not shown. The seasonal dummies have significant coefficients for gasoline from January to February (positive) and from April to November (negative); for heating oil from January to March (negative) and from June to November (positive); for propane in January (negative) and from March to November (positive); and for natural gas from January to February (negative) and from August to November (positive). The sample period is 1/02/1987–4/30/2014 for crude oil, heating oil and gasoline; 1/08/1997–4/30/2014 for natural gas; and 2/08/1994–9/18/2009 for propane. *, **, and *** indicate that the coefficient in bold is statistically significant at 10%, 5% and 1% levels, respectively. Standard errors are in parentheses.

simulations that when the overlapping horizon is short in comparison to the length of the sample, the downward bias in the Newey–West standard errors is fairly modest. For example, when the sample length is 250 and the overlapping horizon is 3, the 95% confidence interval contains the true value of the coefficient about 90% of the time when the Newey–West HAC is used. Our daily regressions contain between 3879 and 6781 observations, and the overlapping horizon is 62 days, pointing out that the downward bias in the standard errors in our regressions is likely to be small. A small increase in these standard errors would not affect our inferences.

In an attempt to reduce persistence in the bases and overlap in returns, we re-estimate the bases and returns regressions with two different proxies for the recession and the state of the economy using weekly and monthly data. The results are qualitatively similar to the corresponding estimates based on daily data reported in Tables 6 and 8.

There is a growing literature on "financialization" of commodity markets. This literature examines whether buying pressure of commodity index funds affects commodity futures prices. The results are mixed. For example, Tang and Xiong (2012) find increased correlations among commodity futures prices since 2004. Singleton (2014) provides evidence that investor flows into energy futures contributed to the boom and subsequent bust in oil prices in 2008. At the same time, Stoll and Whaley (2010) and Hamilton and Wu (2014) find that changes in the long positions of commodity index traders are not a useful predictor of futures returns. Unfortunately, data for commodity index fund positions are available from the

Table 7
Regression results for interest-adjusted bases (weekly data).

Inventory	Crude oil		Gasoline		Heating oil		Propane		Natural gas	
	Low	High	Low	High	Low	High	Low	High	Low	High
A. With CFNA Index										
CFNA Index (β_1)	**−1.30*****	**−1.44****	**−1.08****	0.35	−0.45	**−0.54***	**−1.11*****	**−1.02*****	**−0.92***	**−1.14***
	(0.40)	(0.70)	(0.47)	(0.46)	(0.76)	(0.30)	(0.42)	(0.26)	(0.51)	(0.69)
Log normalized inventory (β_2)	**0.26*****	**0.23****	**0.66*****	0.17	**0.34*****	**0.13*****	**0.11*****	0.02	0.08	**0.12***
	(0.08)	(0.12)	(0.15)	(0.17)	(0.07)	(0.04)	(0.05)	(0.02)	(0.07)	(0.07)
Returns volatility,% (β_3)	**−1.93*****	0.18	−0.12	**1.74*****	**−1.34*****	**−0.37***	0.13	−0.005	−0.15	**1.55*****
	(0.29)	(0.50)	(0.39)	(0.41)	(0.34)	(0.20)	(0.08)	(0.11)	(0.18)	(0.57)
Constant	4.56	0.88	3.57	**−3.84***	1.39	**2.61*****	**−5.01****	**−4.40*****	**−9.48***	**−13.14*****
	(1.49)	(2.04)	(2.38)	(1.95)	(1.39)	(0.93)	(1.75)	(0.86)	(5.71)	(4.86)
N	663	759	486	518	837	585	112	205	272	624
R^2	0.31	0.19	0.57	0.55	0.56	0.32	0.84	0.57	0.54	0.45
B. With probability of recession										
Probability of recession (β_1)	**5.36*****	0.64	**4.35*****	−0.60	1.28	0.70	**1.93****	**3.97*****	**1.67***	0.82
	(0.77)	(1.98)	(1.30)	(1.22)	(1.35)	(1.44)	(0.83)	(0.97)	(1.08)	(2.07)
Log normalized inventory (β_2)	**0.31*****	**0.22***	**0.70*****	0.18	**0.33*****	**0.12*****	**0.09***	0.02	0.07	**0.12***
	(0.08)	(0.13)	(0.16)	(0.17)	(0.07)	(0.04)	(0.05)	(0.02)	(0.07)	(0.07)
Returns volatility,% (β_3)	**−2.00*****	0.68	−0.14	**1.70*****	**−1.34*****	−0.27	**0.15***	0.02	−0.15	**1.55*****
	(0.27)	(0.44)	(0.40)	(0.38)	(0.24)	(0.24)	(0.08)	(0.11)	(0.17)	(0.57)
Constant	**4.51*****	−1.01	3.35	**−3.70***	**2.99*****	**2.23****	**−3.19***	**−4.91*****	**−9.43***1	**−13.01*****
	(1.36)	(1.80)	(2.34)	(1.93)	(0.65)	(1.02)	(1.31)	(0.86)	(5.57)	(4.83)
N	663	755	482	518	833	585	112	205	268	624
R^2	0.37	0.16	0.58	0.55	0.57	0.30	0.85	0.57	0.56	0.44

Note: The table shows the estimates for the following regression: $(F_{t,T} - S_t)/S_t - r_{t,T} = \alpha_t + \beta_1 EM_t + \beta_2 INV_t + \beta_3 \sigma_t + \sum \delta_m d_m + \varepsilon_t$. The regression is estimated using OLS with HAC standard errors (Bartlett kernel, Newey–West fixed bandwidth = 6.0). The coefficients of the seasonal dummies are not shown. The seasonal dummy variables have significant coefficients for gasoline from January to February (positive) and from April to November (negative), for heating oil from January to February (negative) and from May to September (positive); and for propane and for natural gas from March to October (positive). The sample period is 1/02/1987–5/02/2014 for crude oil and heating oil; 1/06/1995–5/02/2014 for gasoline; 1/10/1997–5/02/2014 for natural gas; and 29/08/2003–5/02/2014 for propane. *, **, and *** indicate that the coefficient in bold is statistically significant at 10%, 5% and 1% levels. Standard errors are in parentheses.

Table 8
Regression results for expected returns (daily data).

	With economic conditions proxy					With recession proxy				
	Crude oil	Gasoline	Heating oil	Propane	Natural gas	Crude oil	Gasoline	Heating oil	Propane	Natural gas
Basis,% (β_1)	**1.25***** (0.20)	**0.96***** (0.10)	**0.81***** (0.08)	**1.05***** (0.10)	**0.62***** (0.07)	**1.22***** (0.19)	**0.96***** (0.10)	**0.81***** (0.08)	**1.14***** (0.10)	**0.63***** (0.07)
ADS index (β_2)	**3.26**** (1.49)	1.56 (1.49)	**3.86***** (1.32)	**4.92***** (1.53)	**6.34***** (1.13)	–	–	–	–	–
NBER recession (β_2)	–	–	–	–	–	**−10.53***** (3.21)	**−8.10***** (2.98)	**−11.34***** (2.91)	**−16.29***** (3.47)	**−20.94***** (3.21)
Constant	**4.35***** (0.71)	**2.68***** (0.67)	**3.45***** (0.64)	**6.48***** (0.94)	1.39 (1.39)	**4.51***** (0.68)	**3.31***** (0.63)	**4.09***** (0.65)	**7.87***** (0.93)	**2.52*** (1.37)
N	6781	6781	6778	3909	4237	6267	6781	6778	3909	4237
R^2	0.09	0.17	0.10	0.13	0.13	0.10	0.18	0.12	0.16	0.17

Note: The table shows the estimates for the following regression: $(S_T - S_t)/S_t = \alpha + \beta_1 Basis_t + \beta_2 EM_t + v_t$, where S_T is the spot price three months after day t. The regression is estimated using OLS with HAC standard errors (Bartlett kernel, Newey–West fixed bandwidth = 6.0). The sample period is 1/02/1987–1/30/2014 for crude oil, heating oil, and gasoline; 1/07/1997–1/30/2014 for natural gas; and 2/08/1994–9/18/2009 for propane. *, **, and *** indicate that the coefficient in bold is statistically significant at 10%, 5% and 1% levels. Standard errors are in parentheses.

Commodity Futures Trading Commission (CFTC) only for agricultural futures since 2006. We use the total futures open interest as a proxy for positions of financial traders. Specifically, we add detrended and normalized total futures open interest as a control in our regressions.[15] The results show positive but insignificant effect of the open interest on the expected returns of energy commodities. The results also show insignificant effect of the open interest on the interest-adjusted bases, except for heating oil. The coefficient estimates of the state of the economy variable are qualitatively unchanged. The results of the robustness checks are not tabulated to save space but are available upon request.

5. Conclusions

We find a significant effect of the state of the economy on interest-adjusted bases and expected spot returns of major energy commodities. Interest-adjusted bases of energy commodities tend to be negative and returns over a three-month horizon tend to be positive around business-cycle peaks. The signs of interest-adjusted bases and returns reverse during recession. Regression results confirm that interest-adjusted bases tend to decrease and the expected returns increase when economic conditions are strong. Conversely, interest-adjusted bases increase and expected returns fall in contractions. Thus, our results show that variation in futures and spot energy prices has a strong business-cycle pattern.

Our direct test for petroleum commodities shows a large positive and significant effect of inventory on interest-adjusted bases at low inventory levels. In contrast, this relation is insignificant at high inventory levels. Finally, we find that basis is a useful predictor of returns in energy commodity markets. These results support the theory of storage. The results for natural gas are somewhat different, suggesting that factors other than storage and macroeconomic conditions exert a strong influence on price dynamics in the evolving natural gas market. Further research is needed to directly examine the response of energy spot and futures prices to demand and supply shocks.

Acknowledgments

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[15] This variable is computed as the natural log of the ratio of the open interest to the trend in the open interest estimated with the Hodrick–Prescott filter.

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