Commodity Futures Returns: Limits to Arbitrage and Hedging

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Commodity futures risk premiums

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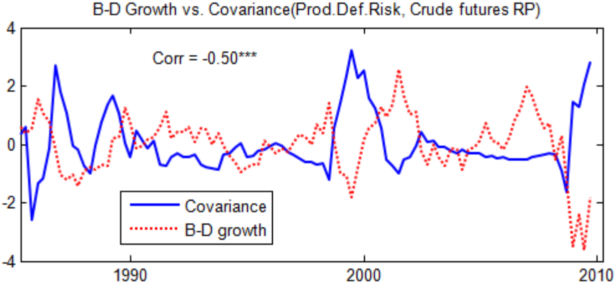
- Our paper:
  - Use instrument (producer default risk) for 'true' hedging demand of producers
  - Interaction with arbitrage capital/speculator risk appetite

Limits-to-arbitrage and hedging pressure

- Measure of employed arbitrage capital versus sensitivity of the Crude Oil futures risk premium to producer hedging pressure



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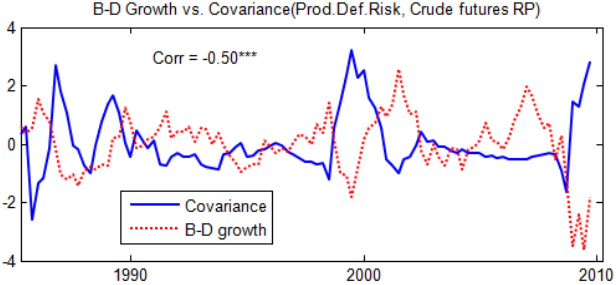
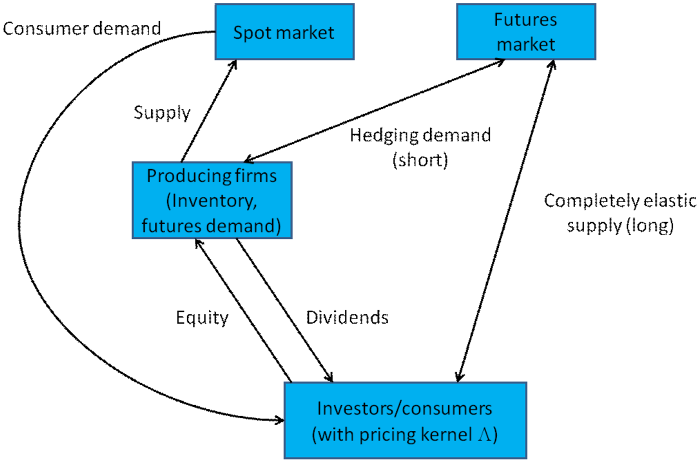


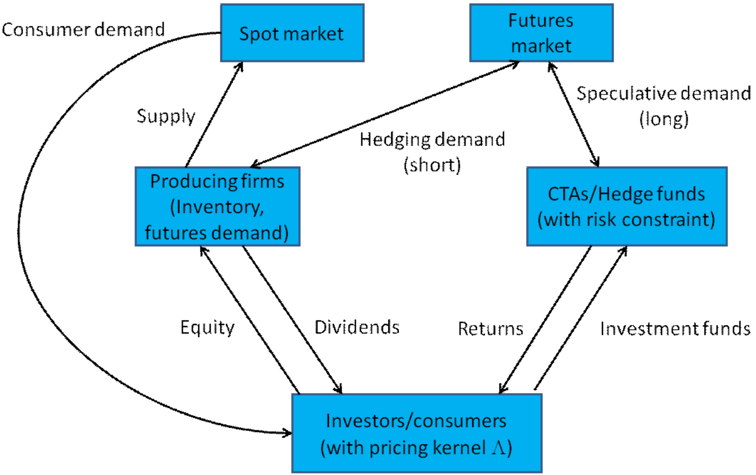
- Do limits to arbitrage cause corporate hedging activity to matter for asset price determination?
- Do limits to arbitrage change producer hedging behavior?
- Through this channel, do limits to arbitrage affect spot prices?

Model I: No frictions, BUT managerial hedging demand



- Managers maximize firm value BUT also want to minimize variance
  - a role for futures market
  - hedging has, however, *no* impact on commodity spot or futures prices

Model II: Limits-to-arbitrage and managerial hedging demand



- Real-world markets have frictions. An important one: Limits to Arbitrage.
  - Shleifer and Vishny, 1997; Gromb and Vayanos, 2002; Brunnermeier and Pedersen, 2009.

Paper summary

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- Novel empirical analysis
  - Propose measures of producers' default risk as proxies for managers' desire to hedge price risk:

- Confirm model predictions in U.S. Crude Oil, Heating Oil, Gasoline, and Natural Gas commodity markets
  - Key result: a 1 st.dev. increase in aggregate producer fundamental hedging demand -> a *4%* increase in the *quarterly* futures risk premium

The model

- Two periods (empirical analysis focuses on short-term futures):
  1. Supply of commodity, g_t, pre-determined
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- Consumers' inverse demand function:

$$S_t = \omega \left(\frac{A_t}{Q_t} \right)^{1/\varepsilon},$$

where: $Q_t = g_t - I_t + (1 - d) I_{t-1}$

I_t is inventory, d is cost of storage

$\ln A_t - \ln A_{t-1} \sim N(\mu, \sigma^2)$ is demand shock

- S_t is the commodity spot price

  ω and ε are positive constants.

Producers

Competitive, price-takers. Representative firm:

$$\max_{\{I, h_p\}} \quad S_0 \left(g_0 - I\right) + E\left[\Lambda\left\{S_1\left(\left(1-d\right)I + g_1\right) + h_p\left(F - S_1\right)\right\}\right] \ ...$$
$$- \frac{\gamma_p}{2} Var\left[S_1\left(\left(1-d\right)I + g_1\right) + h_p\left(F - S_1\right)\right]$$

subject to

$$I \geq 0,$$

where γ_p governs the degree of aversion to variance in future earnings.

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Note: if $E \left[\Lambda \left(S_1 - F \right) \right] > 0$, costly in terms of firm value to hedge by going short

Representative Speculator Objective Function

- Capital constraints (e.g., due to VaR constraint as in Danielsson, Shin, and Zigrand (2008)) in the form of variance penalty:

$$\max_{h_S} h_s E\left[\Lambda\left(S_1 - F\right)\right] - \frac{\gamma_s}{2} Var\left[h_s\left(S_1 - F\right)\right]$$

- Equilibrium: Futures and spot market clears, producer and speculator FOCs hold ($\sigma_f = \sigma_S / F$):

$$E\left[\frac{S_1 - F}{F}\right] = -\underbrace{Corr\left(\Lambda, S_1\right) Std\left(\Lambda\right) \sigma_f}_{\text{usual risk term}} + \underbrace{\frac{\gamma_p \gamma_s}{\gamma_p + \gamma_s} \sigma_f^2 F Q_1}_{\text{price pressure}}$$

Comparative Statics and Empirical Predictions

1. Increasing producer risk aversion (fundamental hedging demand), γ_p:
    1. Increases optimal number of short futures contracts (hedging)
    2. Increases futures risk premium
    3. Decreases inventory
    4. Decreases current spot price and increases expected future spot price

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    1. Decreases futures risk premium
    2. Increases inventory
    3. Increases current spot price
3. Interaction between speculator risk tolerance and effect of hedging demand on risk premium, spot price, and inventory.

Overview of Empirical Approach

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3. Construct commodity sector average default risk measures from firm-level data and test model's pricing implications
4. Control for other possible omitted determinants of futures risk premium
   1. Controls: Standard predictive variables, covariances with equity pricing factors
   2. Volatility interaction (implied by model)
   3. Arbitrage capital interaction (implied by model)
   4. Hedgers versus non-hedgers
   5. Managerial risk aversion

Firm-level evidence

Firm-level (SIC code 1310, 1311; gas, oil producers) default risk proxies

1. Zmijewski-score (Zmijewski, 1984):

$$\begin{aligned} \textit{Zmijewski-score} &= -4.3 - 4.5 * \textit{NetInc} / \textit{TotAssets} + 5.7 * \textit{TotDebt} / \textit{TotAssets} \\ &\quad -0.004 * \textit{CurrentAssets} / \textit{CurrentLiabilities}. \end{aligned}$$

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2. KMV's Expected Default Frequency (EDF)

$$EDF \approx \Phi\left(-\left(\frac{\ln(V/F) + (\mu - 0.5\sigma_V^2)T}{\sigma_V\sqrt{T}}\right)\right)$$

Firm-level evidence (cont'd)

From EDGAR quarterly and annual reports 2000 – 2010

Panel A: Summary statistics on micro-hedging

For each quarter and firm:	# Firm-quarter obs.	Fraction "yes"
Use derivatives?	2,400	88.0%
Futures or forwards?	547	47.7%
Swaps?	1,781	80.6%
Options?	1,800	81.8%
Significant short crude?	1,738	69.8%
Significant long crude?	964	1.0%

Firm-level evidence (cont'd)

From EDGAR quarterly and annual reports 2000 – 2010

- Is hedging positively related to default risk? Yes!

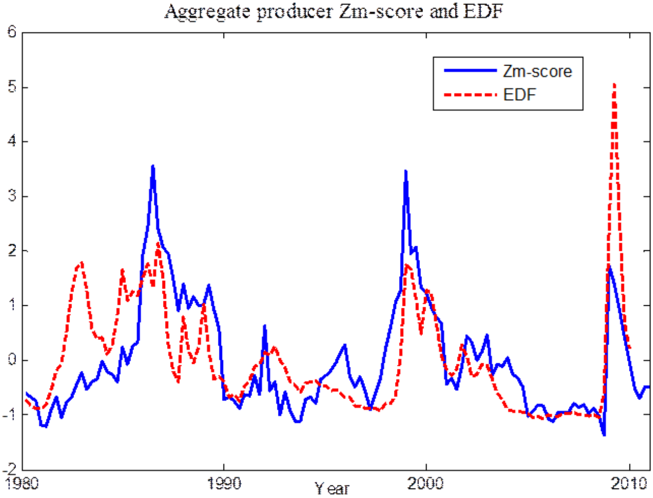
Panel B: Crude oil hedging vs. firm-level default risk measures

Dependent variable: "significant short crude?" (0 or 1 for each firm-quarter)

	Indep.var: Firm-quarter Zm-score					Indep.var: Firm-quarter log EDF-score				
	β	$(S.E.)$	Fixed effect	R^2_{adj}	N	β	$(S.E.)$	Fixed effect	R^2_{adj}	N
dprobit	0.053^{***}	(0.014)	Time *f.e.*	6.1%	926	0.057^{***}	(0.009)	Time *f.e.*	7.3%	1,100
	0.055^{***}	(0.019)	Firm *f.e.*	18.6%	548	0.022^{***}	(0.008)	Firm *f.e.*	20.6%	660
	0.058^{***}	(0.020)	Time & firm *f.e.*	25.2%	548	0.058^{***}	(0.016)	Time & firm *f.e.*	26.8%	660
OLS	0.055^{***}	(0.014)	Time *f.e.*	5.0%	926	0.057^{***}	(0.009)	Time *f.e.*	6.0%	1,100
	0.034^{***}	(0.011)	Firm *f.e.*	29.8%	926	0.011^{**}	(0.004)	Firm *f.e.*	31.6%	1,100
	0.041^{***}	(0.011)	Time & firm *f.e.*	32.7%	926	0.036^{***}	(0.009)	Time & firm *f.e.*	34.7%	1,100

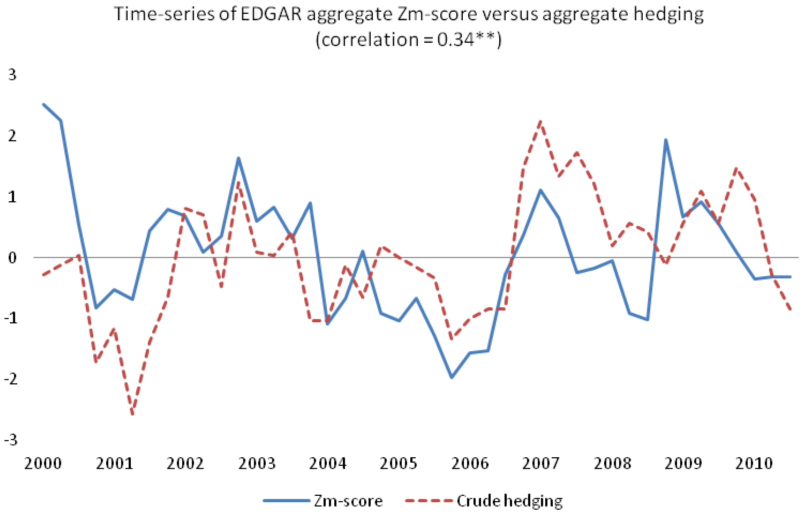
Aggregate producer default risk

Equal weight default risk measures each quarter for SIC code 1310, 1311



Aggregate producer default risk

Correlation average Edgar-based short crude exposure of producers vs Aggregate Default Measures



Futures Forecasting Regressions

- From the model:

$$E\left[\frac{S-F}{F}\right] = -R_f\, Cov\left(\Lambda, S/F\right) + R_f \frac{\gamma_p \gamma_s}{\gamma_p + \gamma_s} \sigma^2_{S/F} FQ$$

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- Forecasting regressions:

$$FuturesReturns_{t+1} = \beta DefRisk_t + ControlVariables_t + \varepsilon_{t+1}$$

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- Forecasting regressions:

$$FuturesReturns_{t+1} = \beta DefRisk_t + ControlVariables_t + \varepsilon_{t+1}$$

	Crude Oil		Heating Oil		Gasoline		Natural Gas		All	
	EDF	Zm	EDF	Zm	EDF	Zm	EDF	Zm	EDF	Zm
Dependent variable: next-quarter futures return ($r^i_{t,t+1}$)										
$DefRisk_t$	0.058**	0.045***	0.047**	0.035**	0.040*	0.031	0.061*	0.058	0.046**	0.038**
	(0.023)	(0.017)	(0.021)	(0.017)	(0.026)	(0.024)	(0.035)	(0.039)	(0.019)	(0.016)
Controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	10.6%	9.7%	9.6%	8.5%	15.2%	13.4%	10.0%	11.0%	7.6%	7.1%
N	107	110	122	125	100	103	79	82	408	420

Identification: Hedger vs Non-Hedger

Classification based on EDGAR quarterly reports on hedging activity (crude oil returns 2000-2011)

Hedgers vs. non-hedgers

	Zm-score		EDF-score	
Hedger default risk (β_H)	0.052**	0.096***	0.069***	0.081***
	(0.022)	(0.028)	(0.024)	(0.023)
Non-hedger default risk (β_{NH})	−0.017	−0.004	−0.032	−0.021
	(0.013)	(0.020)	(0.029)	(0.037)
Controls?	No	Yes	No	Yes
R^2	5.6%	11.9%	10.3%	13.9%
N	172	172	160	160

Identification: Volatility interaction

Hedging pressure should have larger price impact when futures return volatility is high:

Dependent variable: next quarter futures return $\left(r^i_{t,t+1}\right)$		
	Joint regression across commodities	
	EDF	Zm
RV_t	-0.002	-0.007
	(0.013)	(0.012)
$DefRisk_t$	0.036^{**}	0.033^{*}
	(0.016)	(0.018)
$RV \times DefRisk$	0.022^{**}	0.015^{**}
	(0.010)	(0.007)
controls?	yes	yes
R^2	8.6%	7.7%
N	404	416

Identification: Managerial risk aversion

ExecuComp (2000-2011): risk averse mgrs have high company stock holding, low option holdings

Panel A: Crude oil hedging vs. managerial risk-aversion

Indep.var: Indicator for top half firm equity and bottom half options / salary

Specification	β_{execu}	$(S.E.)$	β_{size}	$(S.E.)$	Time fixed effect?	R^2_{adj}	N
1	0.187**	(0.092)	−0.086**	(0.038)	No	23.1%	291
2	0.206**	(0.104)	−0.084**	(0.042)	Yes	29.2%	291

Panel B: Managerial risk aversion and default risk

	Zm-score		EDF-score	
Risk-averse managers' default risk (β_{RA})	0.048*	0.044*	0.016	0.032**
	(0.026)	(0.026)	(0.022)	(0.014)
Risk-tolerant managers' default risk (β_{RT})	−0.007	0.009	0.004	0.027
	(0.038)	(0.040)	(0.039)	(0.034)
Controls?	No	Yes	No	Yes
R^2	7.7%	11.0%	6.0%	11.6%
N	272	272	272	272

Spot Forecasting Regressions

$$SpotReturns_{t+1} = \beta DefRisk_t + ControlVariables_t + \varepsilon_{t+1}$$

	Crude Oil		Heating Oil		Gasoline		Natural Gas		All	
	EDF	Zm	EDF	Zm	EDF	Zm	EDF	Zm	EDF	Zm
Panel B: Dependent variable: next-quarter log spot price change ($\Delta s^i_{t,t+1}$)										
$DefRisk_t$	0.056**	0.043**	0.038**	0.033**	0.051**	0.045**	0.063**	0.059*	0.045**	0.038**
	(0.023)	(0.018)	(0.019)	(0.016)	(0.023)	(0.022)	(0.027)	(0.034)	(0.016)	(0.016)
Controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	18.0%	16.9%	19.2%	19.1%	17.7%	17.0%	14.4%	15.4%	10.4%	10.1%
N	107	110	122	125	100	103	79	82	408	420

- Common component in futures risk premium and expected spot price change
  - Due to inventory arbitrage
  - I.e., basis not good predictor of time-series of futures returns

Speculator capital

Measure of Speculator Risk Tolerance:

- Adrian and Shin (2008), Etula (2009): growth in Broker-Dealer assets relative to Household Assets
  - Scaled by ratio of Broker-Dealer assets to Household assets (Flow of Funds data)

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Dependent variable: next quarter futures return $\left(r^i_{t,t+1}\right)$ (joint test across commodities)	EDF	Zm
BD_t	-0.046^{***}	-0.041^{**}
	(0.011)	(0.015)
$DefRisk_t$	0.032^{**}	0.024
	(0.015)	(0.020)
$BD \times DefRisk$	-0.028^{***}	-0.015^{**}
	(0.007)	(0.006)
controls?	yes	yes
R^2	13.7%	10.9%
N	408	420

Hedging Pressure vs. Arbitrage Activity

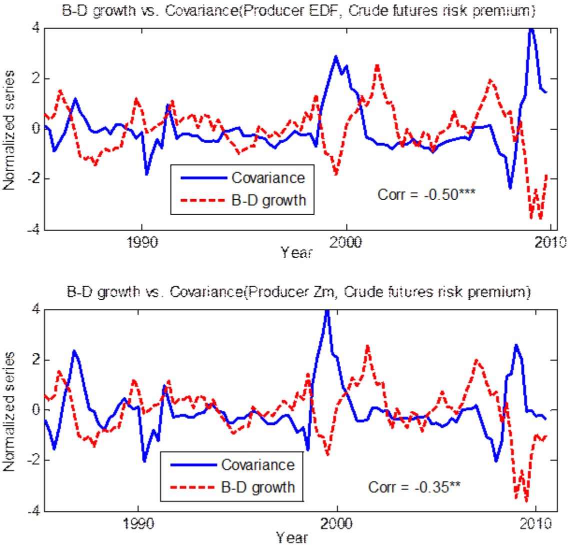
- Already showed interaction effect in quarterly regressions

- Lower frequency relation striking:
  - Arb capital as source of covariation between futures risk premium and hedging demand:
    - ★ Annual overlapping quarterly: $\sum_{j=0}^{3} r_{t+1+j} * DefRisk_{t+j}$ vs. $\sum_{j=0}^{3} BD_{t+j}$

- Arb capital predicted to be inversely related to effect of hedging pressure on the risk premium.

Hedging Pressure vs. Arbitrage Activity (cont'd)

- Producers EDF and Crude oil returns



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  - economically significant effect: predictability in commodity futures and spot returns, inventory

- Support for limits-to-arbitrage / market segmentation
  - interaction with producer hedging demand
  - speculator capital supply in the futures market has real effects
  - *recent debate:* increased risk appetite of speculators decreases cost of hedging, which increases inventory, which increases spot prices. However, risk-sharing arguments unlikely to explain magnitude of historical price gyrations