

Commodity Futures Returns: Limits to Arbitrage and Hedging

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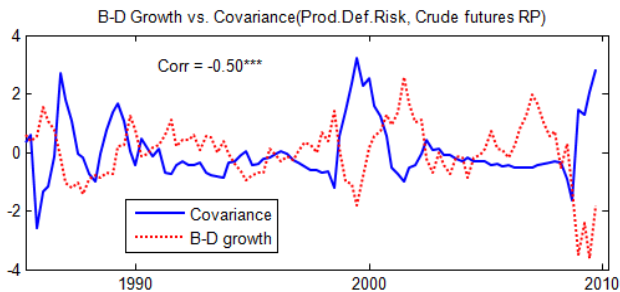
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 - ▶ Chen and Xiong (2012): speculators *consume* liquidity during financial crisis
 - ▶ Kang, Rouwenhorst, and Tang (2013): hedgers sell to momentum traders and profit on reversal over next days

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 - ▶ Kang, Rouwenhorst, and Tang (2013): hedgers sell to momentum traders and profit on reversal over next days
- Our paper:
 - ▶ Use instrument (producer default risk) for 'true' hedging demand of producers
 - ▶ Interaction with arbitrage capital/speculator risk appetite

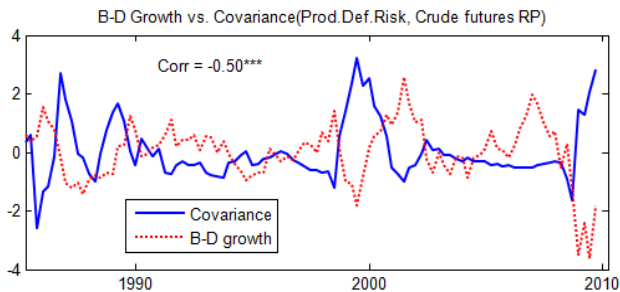
Limits-to-arbitrage and hedging pressure

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



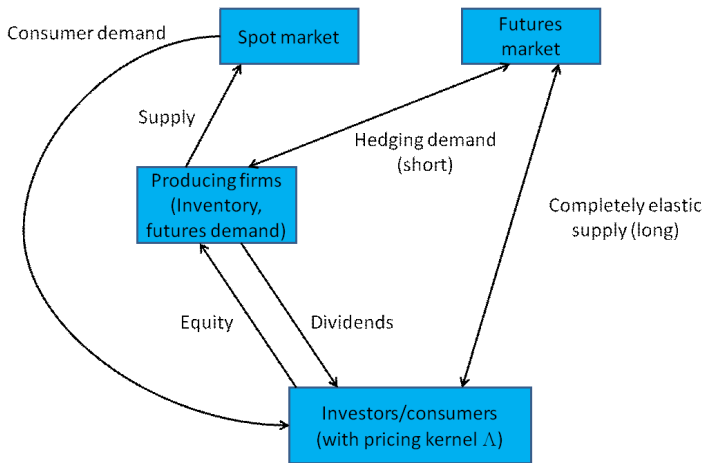
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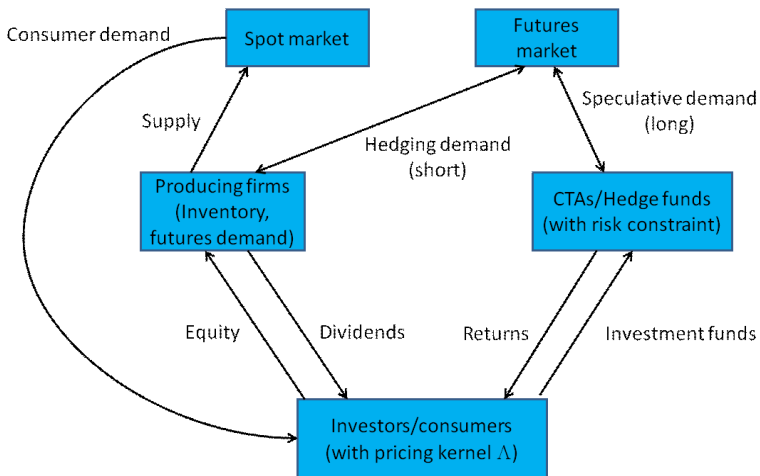
- Do limits to arbitrage cause corporate hedging activity to matter for asset price determination?
- Do limits to arbitrage change producer hedging behavior?
- Through this channel, do limits to arbitrage affect spot prices?

Model I: No frictions, BUT managerial hedging demand



- Managers maximize firm value BUT also wants 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.

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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 \rightarrow a 4% increase in the *quarterly* futures risk premium

The model

- Two periods (empirical analysis focuses on short-term futures):
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 - 2 $r = 1/E[\Lambda] - 1$; $d \in [0, 1)$

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 - 1 Supply of commodity, g_t , pre-determined
 - 2 $r = 1/E[\Lambda] - 1$; $d \in [0, 1)$
- Consumers' inverse demand function:

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

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

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

S_t is the commodity spot price

ω and ε are positive constants.

Producers

Competitive, price-takers. Representative firm:

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

subject to

$$I \geq 0,$$

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

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Note: if $E [\Lambda (S_1 - F)] > 0$, 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:

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

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

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

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
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- ② Increasing speculator risk tolerance, γ_S :
 - ① Decreases futures risk premium
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 - ③ Increases current spot price

- ⑤ Interaction between speculator risk tolerance and effect of hedging demand on risk premium, spot price, and inventory.

Overview of Empirical Approach

- 1 Producer default risk as proxy for time-varying fundamental hedging demand (γ_p)
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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):

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

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- 2 KMV's Expected Default Frequency (EDF)

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

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!

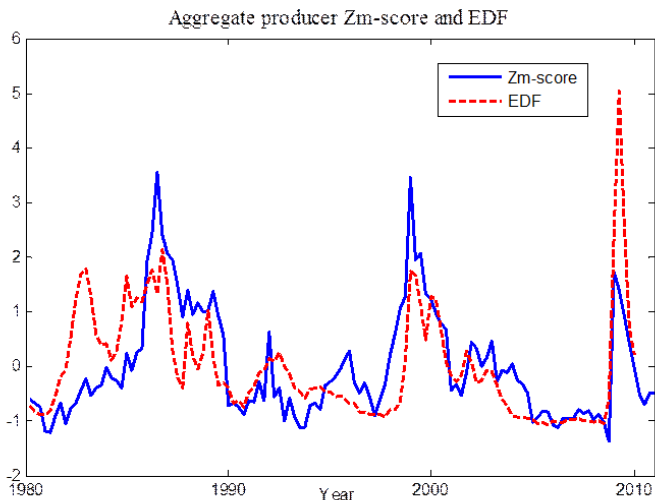
Panel B: Crude oil hedging vs. firm-level default risk measures

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 <i>f.e.</i>	6.1%	926	0.057***	(0.009)	Time <i>f.e.</i>	7.3%	1,100
	0.055***	(0.019)	Firm <i>f.e.</i>	18.6%	548	0.022***	(0.008)	Firm <i>f.e.</i>	20.6%	660
	0.058***	(0.020)	Time & firm <i>f.e.</i>	25.2%	548	0.058***	(0.016)	Time & firm <i>f.e.</i>	26.8%	660
OLS	0.055***	(0.014)	Time <i>f.e.</i>	5.0%	926	0.057***	(0.009)	Time <i>f.e.</i>	6.0%	1,100
	0.034***	(0.011)	Firm <i>f.e.</i>	29.8%	926	0.011**	(0.004)	Firm <i>f.e.</i>	31.6%	1,100
	0.041***	(0.011)	Time & firm <i>f.e.</i>	32.7%	926	0.036***	(0.009)	Time & firm <i>f.e.</i>	34.7%	1,100

Aggregate producer default risk

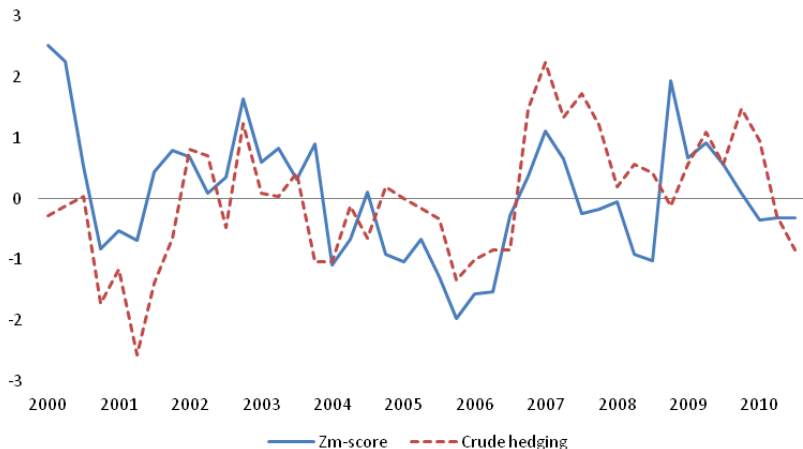
Equal weight default risk measures each quarter for SIC code 1310, 1311



Aggregate producer default risk

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

Time-series of EDGAR aggregate Zm-score versus aggregate hedging
(correlation = 0.34**)



Futures Forecasting Regressions

- From the model:

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

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$$\text{FuturesReturns}_{t+1} = \beta \text{DefRisk}_t + \text{ControlVariables}_t + \varepsilon_{t+1}$$

	Crude Oil		Heating Oil		Gasoline		Natural Gas		All	
	EDF	Zm	EDF	Zm	EDF	Zm	EDF	Zm	EDF	Zm
<i>Dependent variable: next-quarter futures return ($r_{t,t+1}^i$)</i>										
<i>DefRisk_t</i>	0.058** (0.023)	0.045*** (0.017)	0.047** (0.021)	0.035** (0.017)	0.040* (0.026)	0.031 (0.024)	0.061* (0.035)	0.058 (0.039)	0.046** (0.019)	0.038** (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** (0.022)	0.096*** (0.028)	0.069*** (0.024)	0.081*** (0.023)
Non-hedger default risk (β_{NH})	-0.017 (0.013)	-0.004 (0.020)	-0.032 (0.029)	-0.021 (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 ($r'_{t,t+1}$)		
Joint regression across commodities		
	EDF	Zm
RV_t	-0.002 (0.013)	-0.007 (0.012)
$DefRisk_t$	0.036** (0.016)	0.033* (0.018)
$RV \times$ $DefRisk$	0.022** (0.010)	0.015** (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

Specification	β_{execu}	(S.E.)	β_{size}	(S.E.)	Time	R^2_{adj}	N
					fixed effect?		
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
<i>Panel B: Dependent variable: next-quarter log spot price change ($\Delta s_{t,t+1}^i$)</i>										
<i>DefRisk_t</i>	0.056** (0.023)	0.043** (0.018)	0.038** (0.019)	0.033** (0.016)	0.051** (0.023)	0.045** (0.022)	0.063** (0.027)	0.059* (0.034)	0.045** (0.016)	0.038** (0.016)
Controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
<i>R</i> ²	18.0%	16.9%	19.2%	19.1%	17.7%	17.0%	14.4%	15.4%	10.4%	10.1%
<i>N</i>	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 ($r_{t,t+1}^f$) (joint test across commodities)	
	EDF	Zm
BD_t	-0.046*** (0.011)	-0.041** (0.015)
$DefRisk_t$	0.032** (0.015)	0.024 (0.020)
$BD \times$ $DefRisk$	-0.028*** (0.007)	-0.015** (0.006)
controls?	yes	yes
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Hedging Pressure vs. Arbitrage Activity

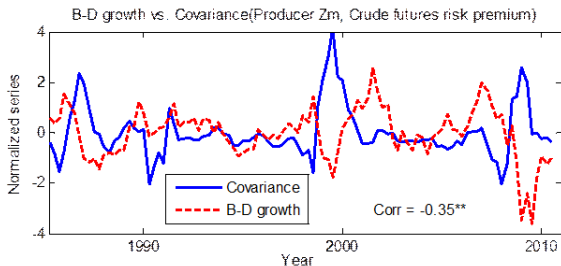
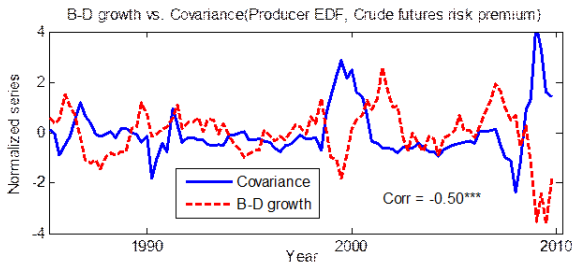
- Already showed interaction effect in quarterly regressions
- Lower frequency relation striking:
 - ▶ Arb capital as source of covariation between futures risk premium and hedging demand:

- ★ 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.

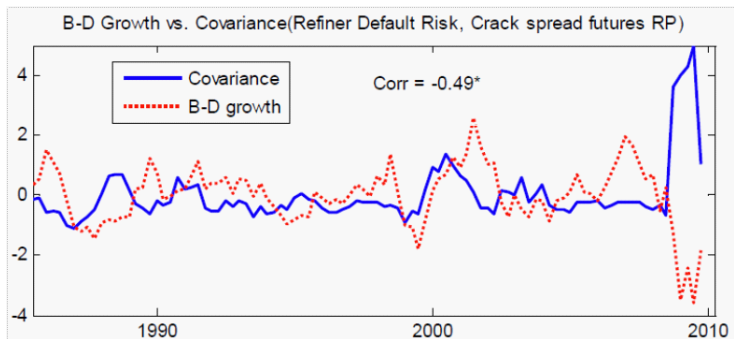
Hedging Pressure vs. Arbitrage Activity (cont'd)

- Producers EDF and Crude oil returns



Hedging Pressure vs. Arbitrage Activity (cont'd)

- Refiners EDF and Gasoline crack spread returns



Summary

- We show that a refinement of the 'old' hedging pressure story is important for understanding commodity futures risk premiums and spot price dynamics
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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