Driven by Fear? The Tail Risk Premium in the Crude Oil Futures Market

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The views expressed here are those of the author and do not represent the views of the Bank of Canada.

Introduction

Background

- Oil prices difficult to reconcile with observed changes in fundamentals alone $\rightarrow$ shifts in expectations / uncertainty matter (Kilian, AER, 2009; Alquist & Kilian, JAE, 2010)
- Rare disaster framework relates asset prices to expectations (Barro, QJE, 2006; Gabaix, AER, 2008; Bollerslev & Todorov, JF, 2011)

This Paper

- What role does tail risk play in the oil market?
- What is its relationship with oil price predictability?

Implications

- Macro: aggregate outcomes in oil exporting / importing countries
- Finance: commodities as an asset class

Introduction

This paper: time-varying risk premium for large jumps

- estimate jump probabilities using futures data
  $\rightarrow$ small, symmetric
- estimate risk premia using option data
  $\rightarrow$ large, asymmetric
- oil "fear": downside - upside tail risk premia
  (Bollerslev & Todorov, JF, 2011)

Introduction

Findings:

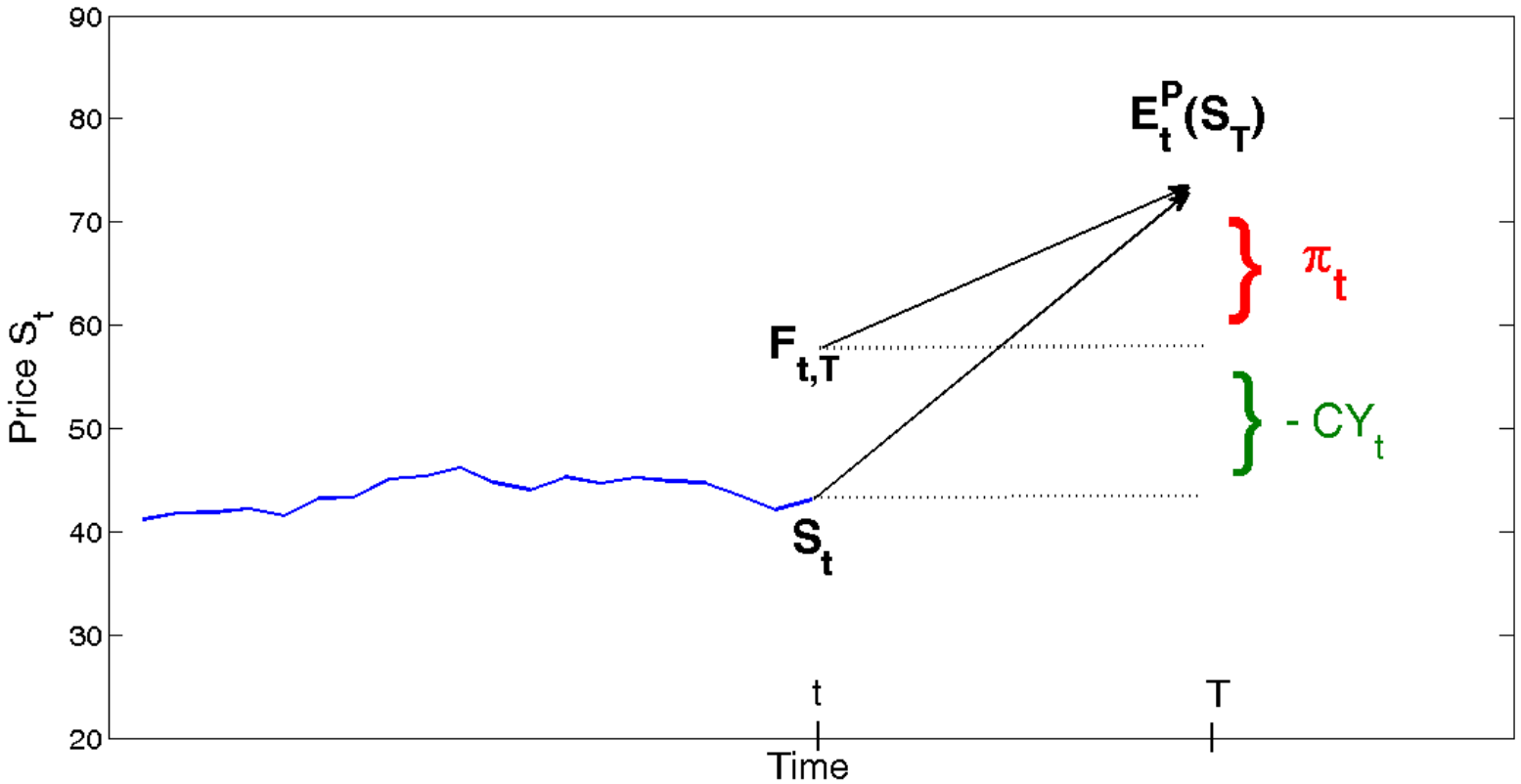
- large, time varying tail risk premia
- predict oil futures and spot returns
- tail premia closely connected to oil risk premium
  (similar to equity risk premium: Bollerslev, Todorov & Xu , JFE, 2015)
- $\rightarrow$ time varying risk matters for oil futures / spot price variations
- $\rightarrow$ ... to some extent also for aggregate stock returns

(Almost) model free:

- results rely on non-arbitrage conditions

Risk Premium No-Arbitrage

$\rightarrow$ relates current futures price to expected spot price

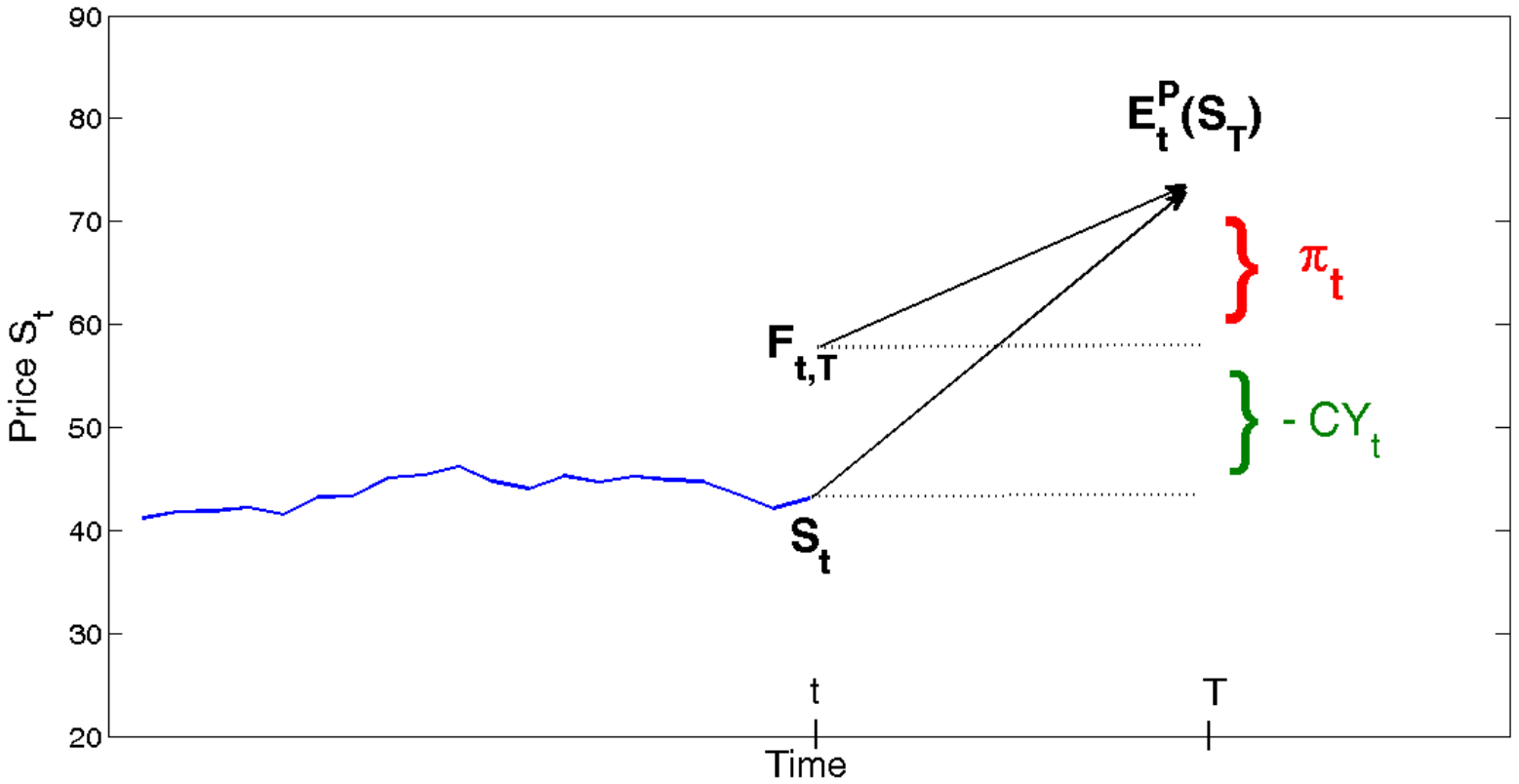


$F_{t,T} = E_t^{\mathbb{P}}(S_T) - \pi_{t,T}$ (note: $S_T = F_{T,T}$)

S_T spot price, $F_{t,T}$ futures price, $\pi_{t,T}$ risk premium

Storage No-Arbitrage

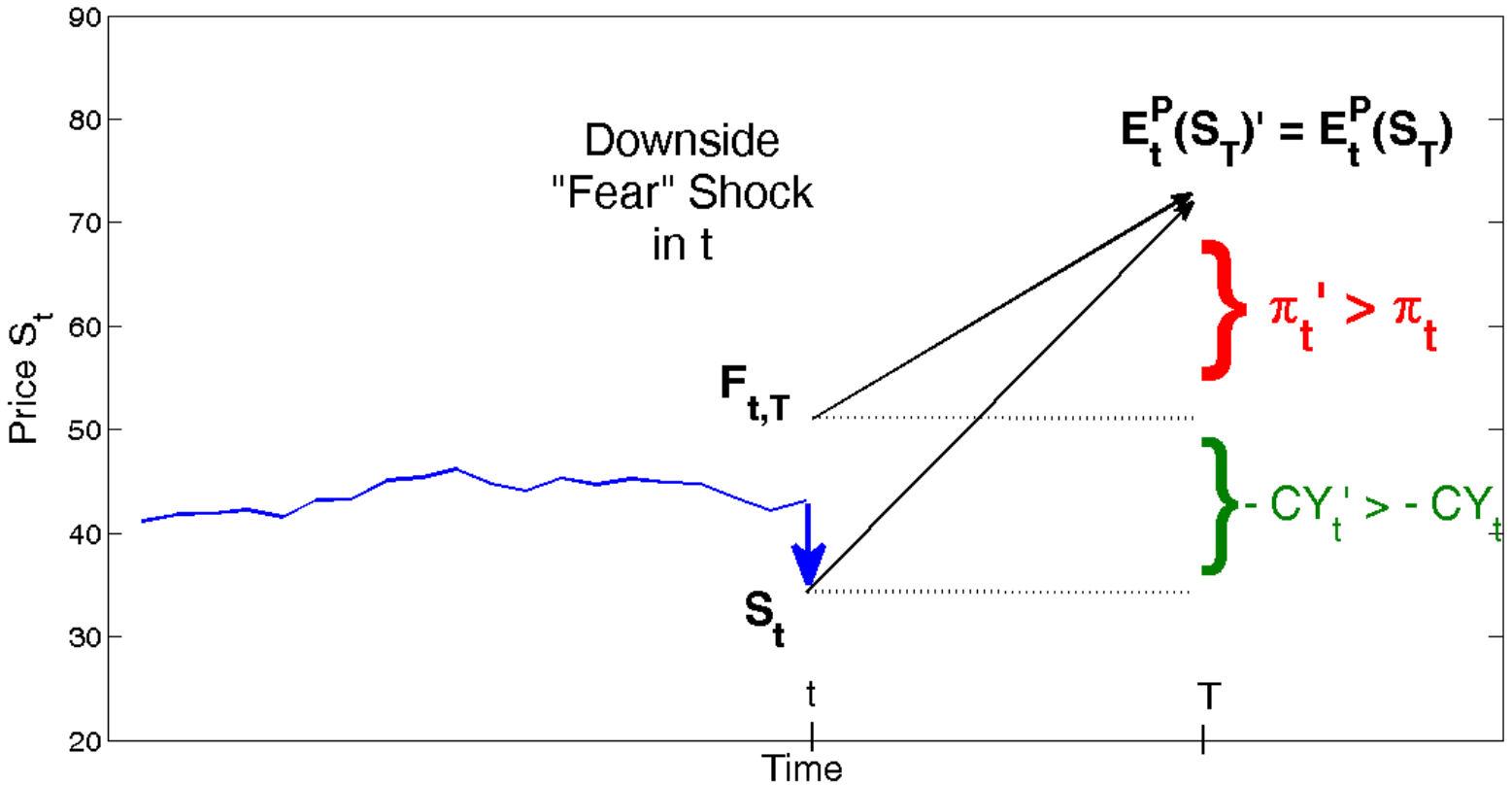
$\rightarrow$ relates current futures price to current spot price



$F_{t,T} = S_t - CY_{t,T}$ (note: $S_T = F_{T,T}$)

convenience yield $CY_{t,T} \equiv$ net benefit from holding physical oil

"Fear" Shock (mean preserving)



Tail Risk Measures - Intution I

- Futures price dynamics under the "objective" $\mathbb{P}$-distribution:

$$\frac{dF_t}{F_{t-}} = \underbrace{\alpha_t dt}_{Drift} + \underbrace{\sigma_t dW_t}_{Br.Motion} + \underbrace{\int_{\mathbb{R}} (e^x - 1)\tilde{\mu}(dt, dx)}_{Jumps},$$

- Absence of arbitrage $\rightarrow$ corresponding risk-neutral distribution $\mathbb{Q}$
- Variance Risk Premium (VRP):

$$E_t^{\mathbb{Q}}(QV_{t+1}) > E_t^{\mathbb{P}}(QV_{t+1})$$

- VRP time varying, forecasts future SPX / crude oil futures return (Bollerslev, Tauchen & Zhou, RFS, 2009; Kang & Pan, WP, 2013)

Details

Tail Risk Measures - Intution II

- Quadratic Variation QV of log price:

  $$QV_{[t,T]} = QV_{[t,T]}\text{Br.Motion} + QV_{[t,T]}\text{small Jumps} + QV_{[t,T]}\text{large Jumps}$$

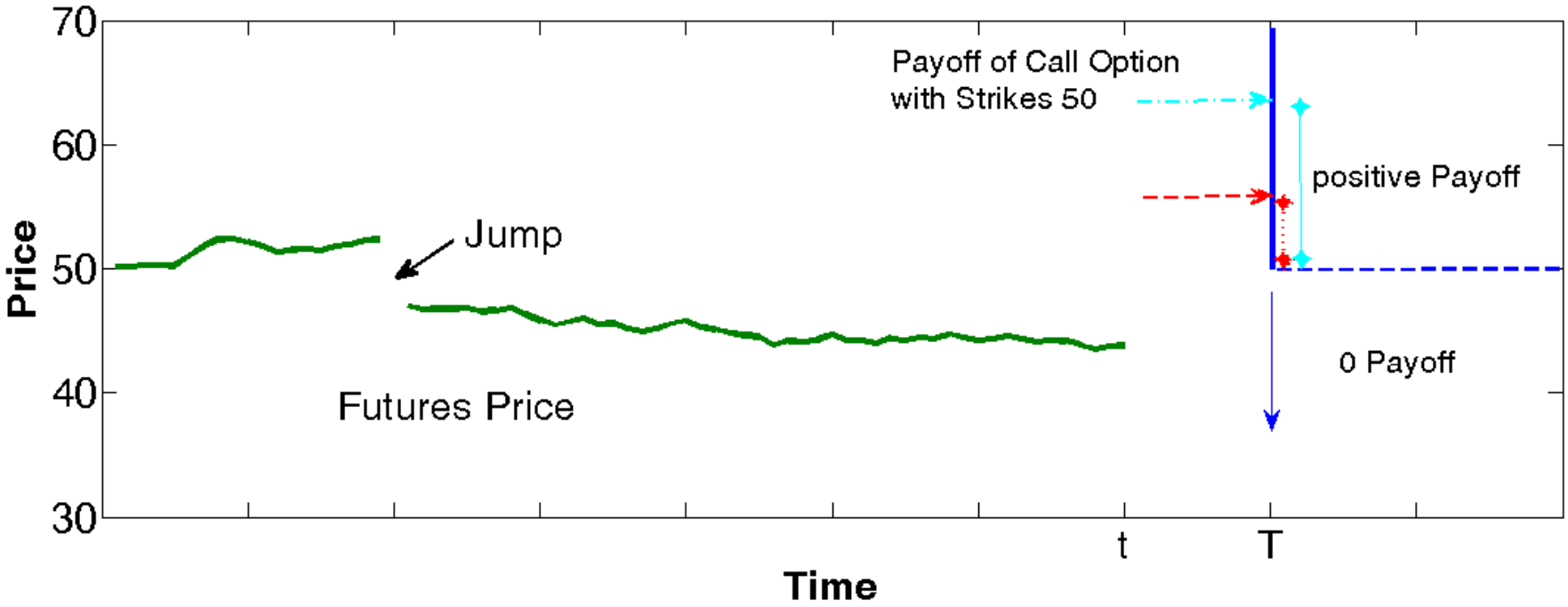
- Tail risk premia: part of the VRP that is due to large jumps

  $\rightarrow$ difference between left and right tail premia "fear"
  (Bollerslev & Todorov, JF, 2011; Bollerslev, Todorov & Xu , JFE, 2015)

- Fear Index FI_t = Right Tail VRP_t - Left Tail VRP_t

Details

Estimation based on Options and Futures: Intuition



Empirical Implementation

West Texas Intermediate, Cushing, OK

- For NYMEX Crude Oil Options (LO) - $E_t^{\mathbb{Q}}(\cdot)$
  - Sample Period: 1987 - 2013, pooled monthly data
  - daily End-of-Day settlement prices
  - Maturities 9-40 days, standard cleaning procedures
  - OTM options: calls (puts) with
    $|\text{log-moneyness}| > (-)2\times$ at-the-money implied volatility
    $\rightarrow \approx 300$ obs. per month
  - threshold for large jumps
    $|k_t| = 3\times$ at-the-money implied volatility

Graph

- For NYMEX Crude Oil Futures (CL) - $E_t^{\mathbb{P}}(\cdot)$
  - 5-min intraday data for realized measures

Estimation Results

- **P**-measure jump variations small, symmetric
- **Q**-measure jump variations large, asymmetric

Est. Details

Realized and Risk Neutral Variation Measures

- Summary statistics
  (324 monthly observations, annualized, in %)

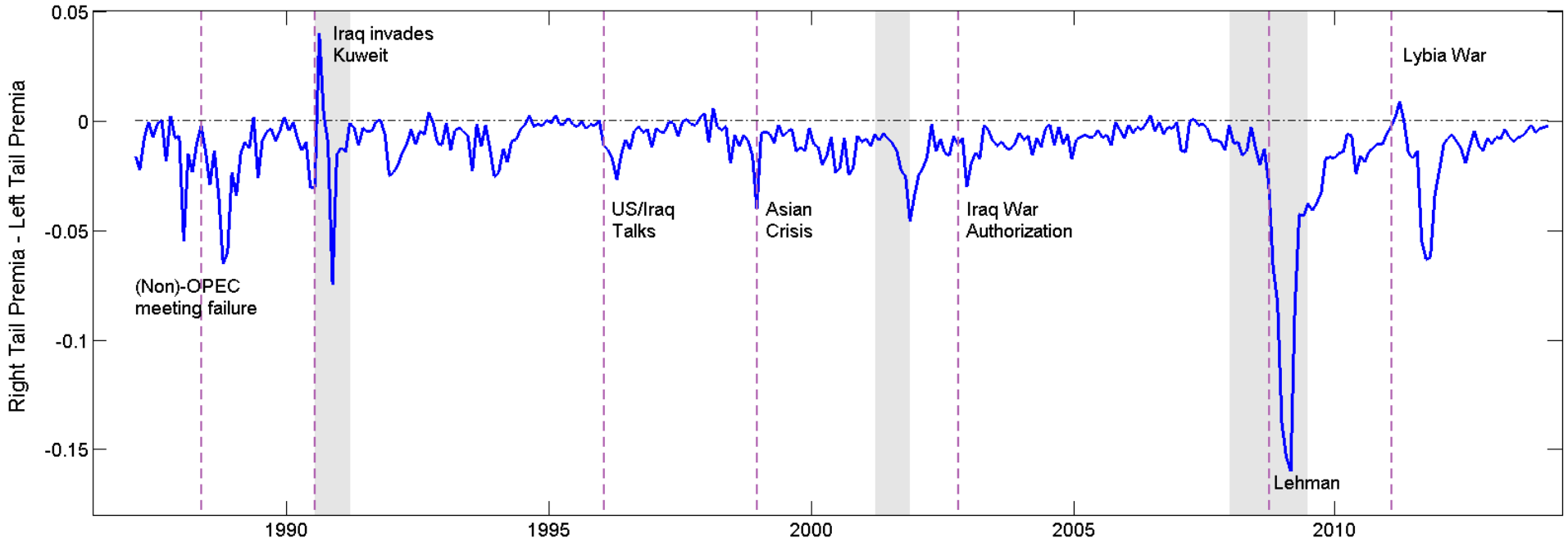
	Mean	SD	AR(1)
$LJV^{\mathbb{Q}}_{t,T}$	2.33	2.53	0.84
$RJV^{\mathbb{Q}}_{t,T}$	0.81	1.01	0.77
$LJV^{\mathbb{P}}_{t,T}$	0.01	0.01	0.67
$RJV^{\mathbb{P}}_{t,T}$	0.02	0.02	0.71
FI_t	-1.52	1.89	0.81
OILVIX2_t	13.53	12.93	0.84
VRP_t	2.44	7.41	0.19

- VRP in oil market attributed to tail risk
- Negative jump premium dominates positive jump premium

for different threshold

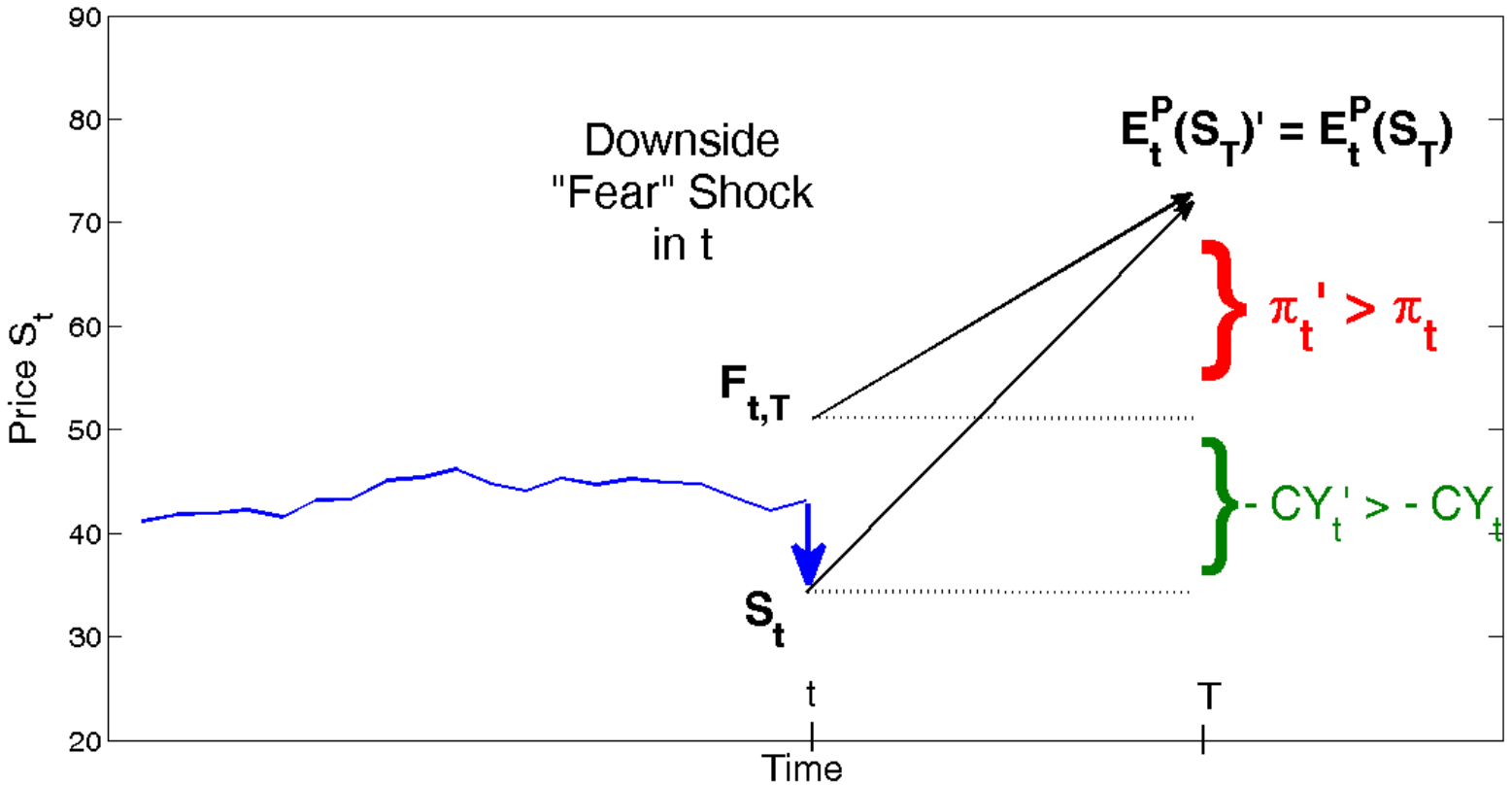
P vs Q Graph

Oil Fear Index



Individual Measures

Forecasting: Intuition



Forecasting Regression Results

Variables	(1) $r_{S,t+3}$	(2) $r_{F,t+3}$	(3) $r_{S,t+6}$	(4) $r_{F,t+6}$
L3.$RJV^{\mathbb{Q}}_{t,T}$	-7.70***	-5.27***		
	(2.044)	(1.872)		
L3.$LJV^{\mathbb{Q}}_{t,T}$	2.56***	1.59***		
	(0.510)	(0.546)		
L6.$RJV^{\mathbb{Q}}_{t,T}$			-11.03***	-9.76**
			(2.845)	(3.875)
L6.$LJV^{\mathbb{Q}}_{t,T}$			5.27***	3.47***
			(0.698)	(0.860)
Adj. R^2	0.0877	0.0374	0.1419	0.0685
Obs.	321	321	318	318
Wald test (p-value)	<0.001	0.005	<0.001	<0.001

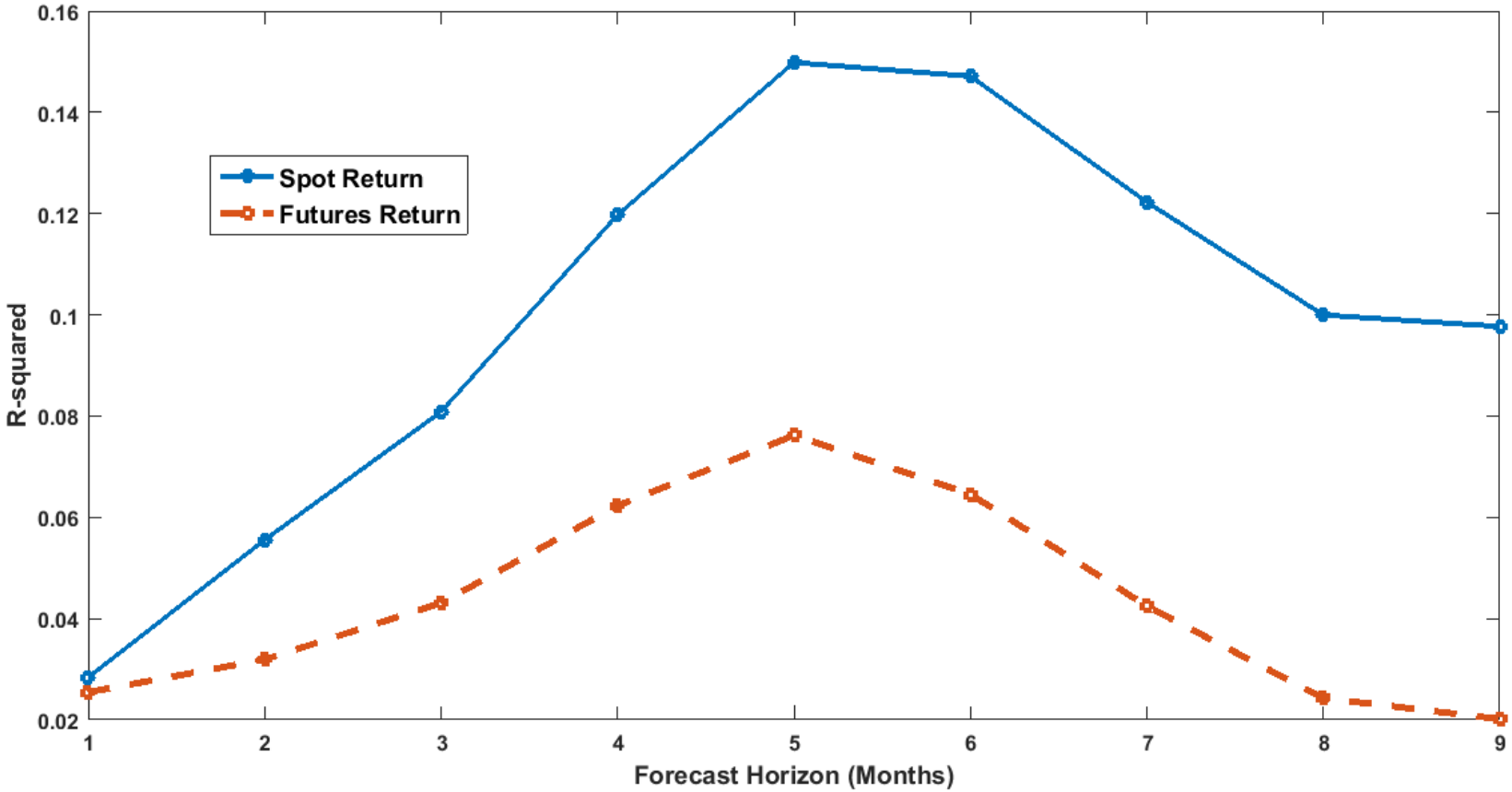
Newey-West standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Forecasting results for $i = 3$ and $i = 6$ months,

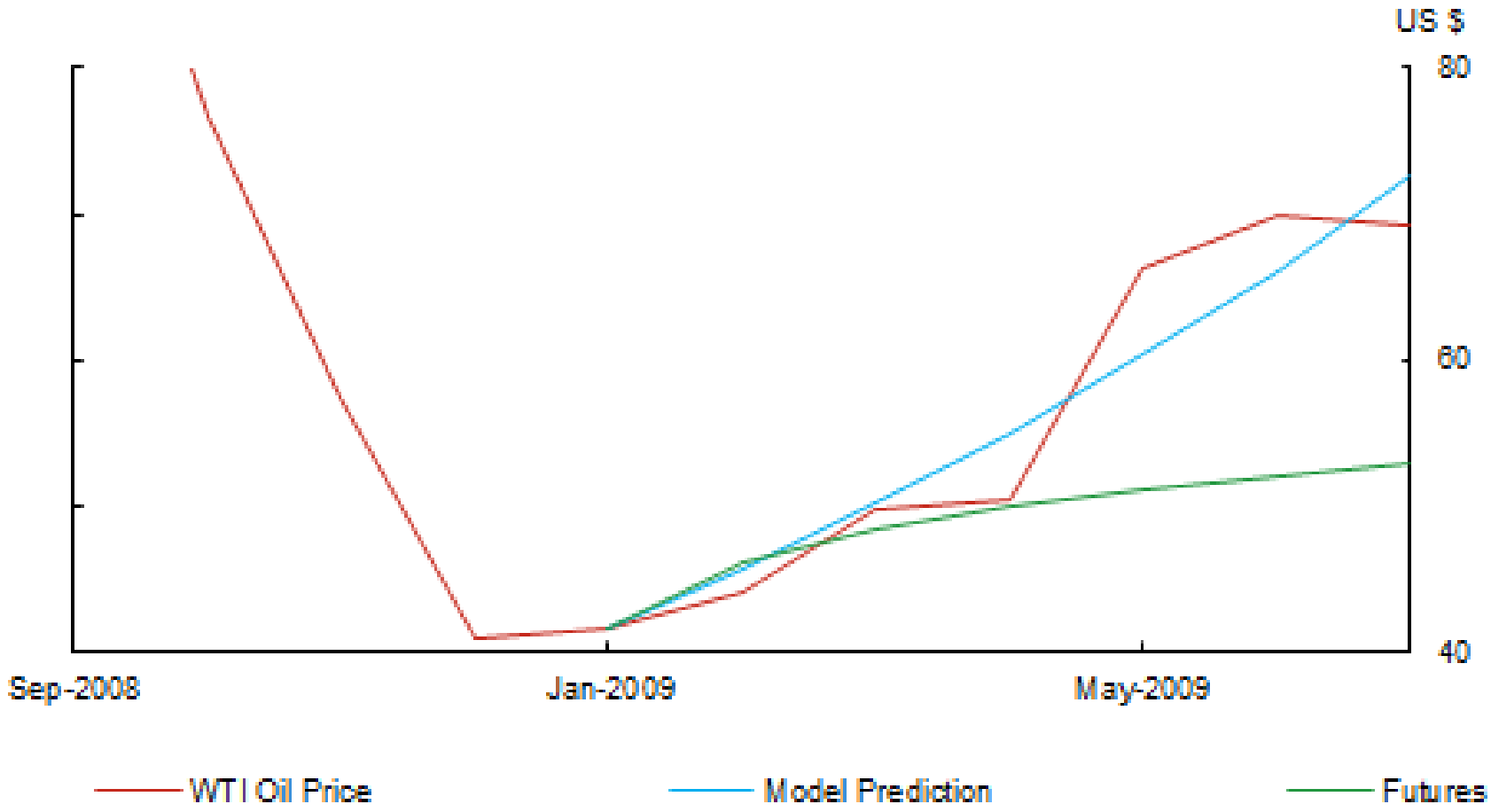
$r_{S,...}$ spot return, $r_{F,...}$ futures return

Robustness

Return Predictability: Different Forecast Horizons



Tail Risk in 2008/2009



Forecasting Regression Results: Robustness

- Controls:
  - Oil market specific: OILVIX2, VRP, RV, Δ Stocks, Slope of Term Structure, Open Interest Growth
  - Macro-financial: D.A. Business Conditions, Real Activity Indicator, VIX, TBill Yield, Bond Spread

- Out-of-sample: Cross-Validation
- Similar results when augmenting Kilian & Murphy (JAE, 2014) VAR with FI_t

VAR results

Aggregate Fear / Uncertainty I

- Bollerslev, Todorov & Xu (JFE, 2015), for equity index options:

- $FI_{spx,t}$ captures Investors sentiment
- $VRP_{spx,t} - FI_{spx,t}$ captures macroeconomic uncertainty

- high correlation, but little predictability from $FI_{spx,t}$, $VRP_{spx,t}$ for oil (futures) prices

Forecasting Regressions

Aggregate Fear / Uncertainty II

- Stock Market returns:
  ($r_{Mkt,t+3}$ 3 months market excess return, S&P 500)

Variables	(1) $r_{Mkt,t+3}$	(2) $r_{Mkt,t+3}$	(3) $r_{Mkt,t+3}$
$FI_{oil,t}$	-0.09		1.05**
	(0.34)		(0.52)
$FI_{spx,t}$		-0.01	0.01
		(0.02)	(0.02)
$VRP_{spx,t}$		0.01***	0.02***
		(0.00)	(0.01)
Adj. R^2	0.00	0.04	0.07
Observations	212	212	212

Newey-West standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Conclusion

Oil market disaster fear has explanatory power for oil prices:

- Large and time varying tail risk premia for crude oil spot, futures
- Consistent with changes in risk attitude
- Non-arbitrage conditions: Futures and spot prices overshoot

$\rightarrow$ important driver of oil price and futures dynamics

Tail risk premia for individual assets informative about risk premia