Modeling Uncertainty in the EIA *Short-Term Energy Outlook*

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*This is a working document prepared by the Energy Information Administration (EIA) in order to solicit advice and comment on statistical matters from the American Statistical Association Committee on Energy Statistics. This topic will be discussed at EIA's spring 2009 meeting with the Committee to be held April 2, 2009.

Our Objectives

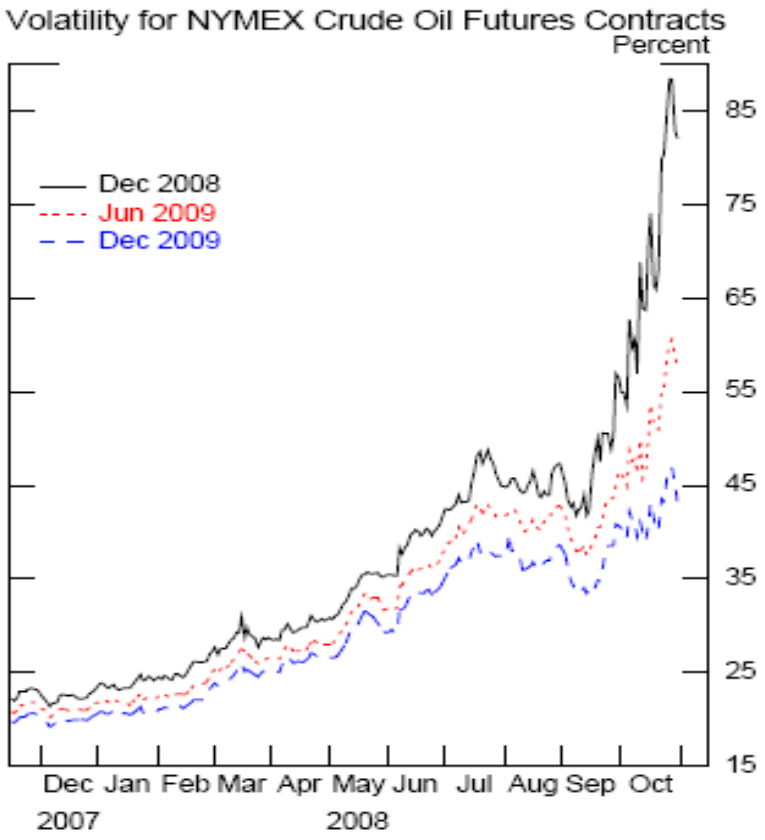
- Characterize the uncertainty surrounding short-term price forecasts
- One widely-cited measure of uncertainty is implied volatility of NYMEX options contracts
- What is the best way to apply this volatility measure to the STEO forecast?

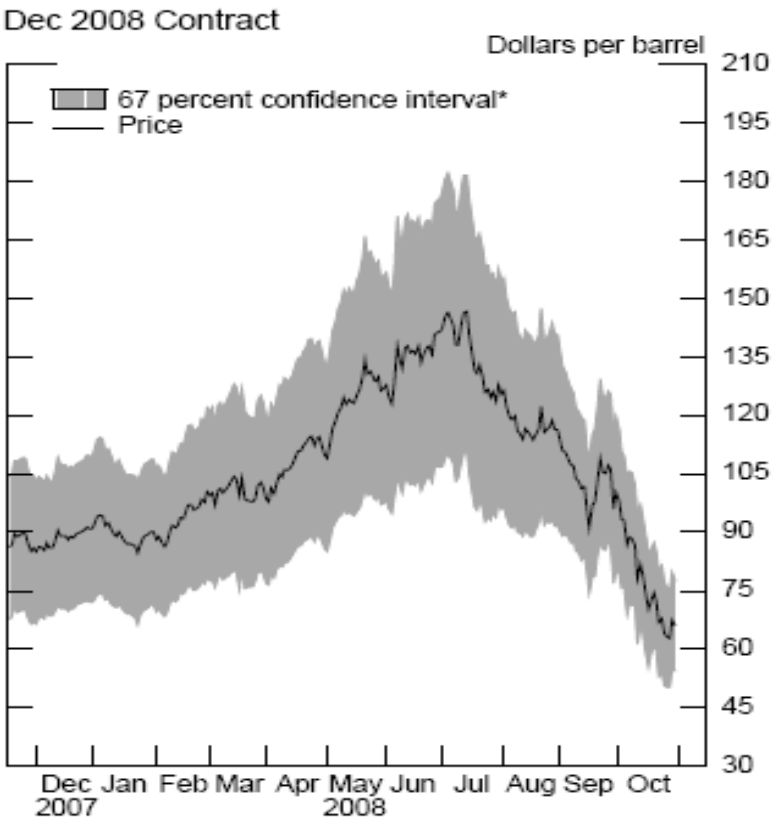
What is Implied Volatility?

- Volatility can easily be measured using past prices of the asset
- Implied volatility of an option contract is the volatility implied by the option's market premium based on an option pricing model
- This forward-looking estimate of volatility derived from pooling expectations of those who are trading in the market

Implied Volatility Reports – Federal Reserve

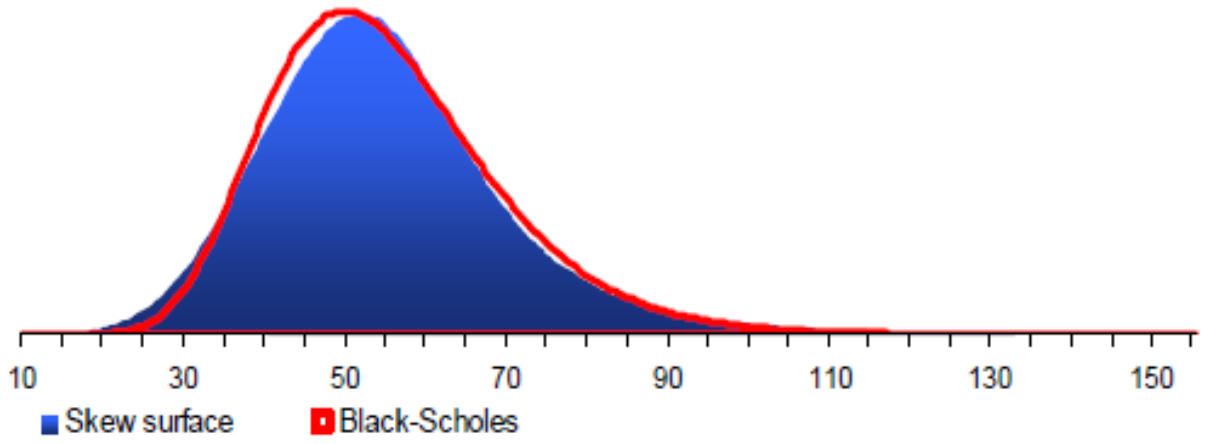
Oil Price Implied Volatility





Implied Volatility Reports – Deutsche Bank

Figure 1: Probability density function of the Jun'09 WTI contract



Source: Deutsche Bank

Implied Volatility Reports – Deutsche Bank

Figure 2: Probabilities of the Jun '09 WTI contract expiring above/below different price levels

WTI crude oil price (USD/bbl)	Probability	
	Below	Above
30	3%	97%
40	15%	85%
50	41%	59%
60	69%	31%
80	94%	6%
100	98%	2%
125	100%	0%
150	100%	0%
200	100%	0%

Source: Deutsche Bank

Some Basic Options Terms

- Call option – gives holder the right to buy an asset in the future – is a bet that the asset's spot price will rise
- Put option – gives holder the right to sell an asset in the future – is a bet that the asset's spot price will fall
- Expiration date – the last day than option can be exercised (or date that settlement takes place)
- Strike price - the fixed price at which the owner of an option can purchase, in the case of a call, or sell, in the case of a put, the underlying security or commodity
- Option Premium – the cost of purchasing the option contract

Black-Scholes Model of Pricing Options Premiums

$$p_t = S_t\, N(d_1) - K\, e^{-rT} N(d_2)$$

where $N(\ \ ) =$ normal cumulative distribution function

$$d_1 = \frac{\ln(S_t / K) + (r + \sigma^2 / 2)T}{\sigma\sqrt{T}}$$

$$d_2 = \frac{\ln(S_t / K) + (r - \sigma^2 / 2)T}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T}$$

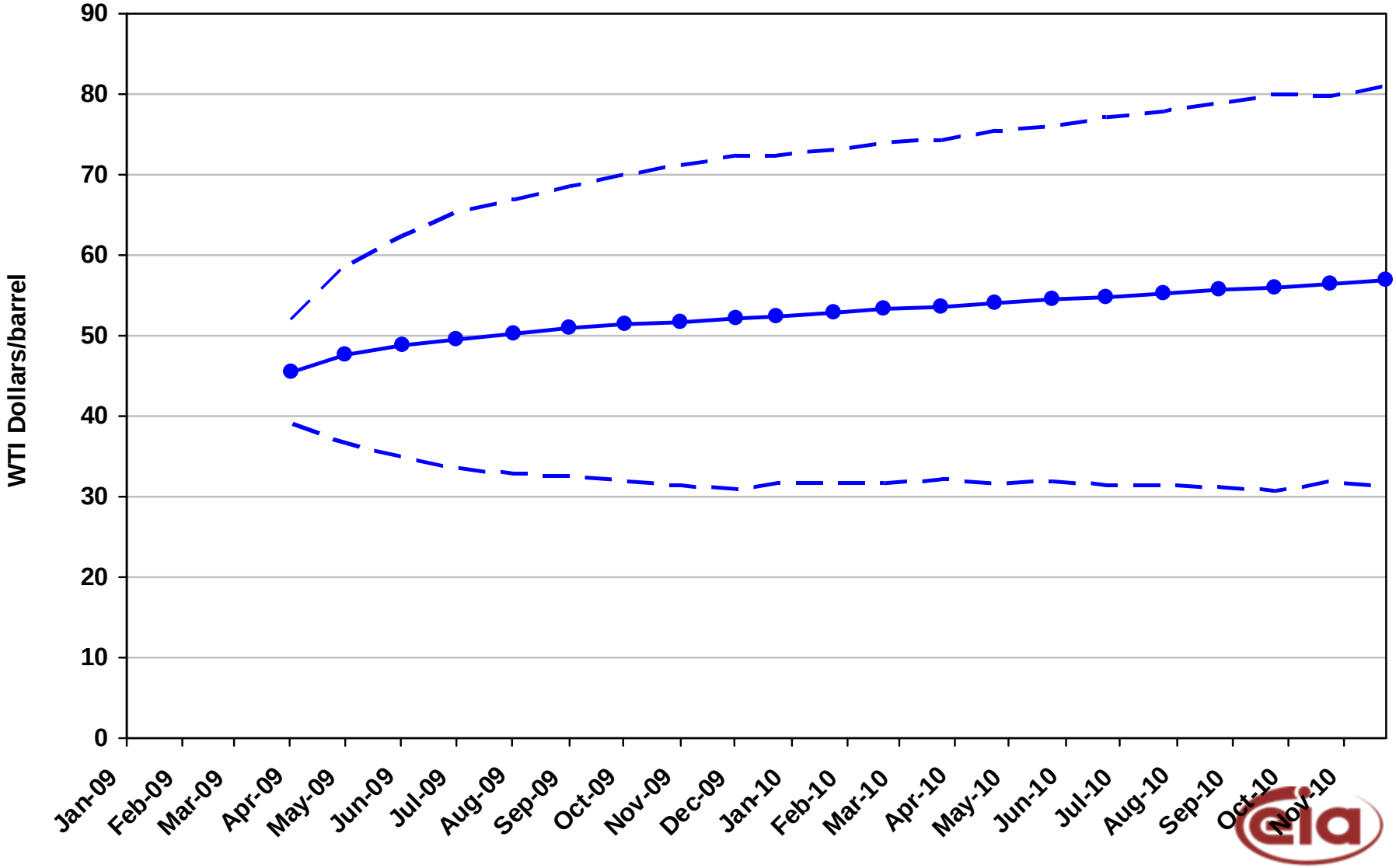
- p_t = option premium
- S_t = current price of underlying asset
- K = strike price of the option
- T = time to expiration of the option
- r = risk-free interest rate
- **σ = volatility of the option**

Source: Adapted from John C. Hull, "Options, Futures, and Other Derivatives", 7th ed. (2008)

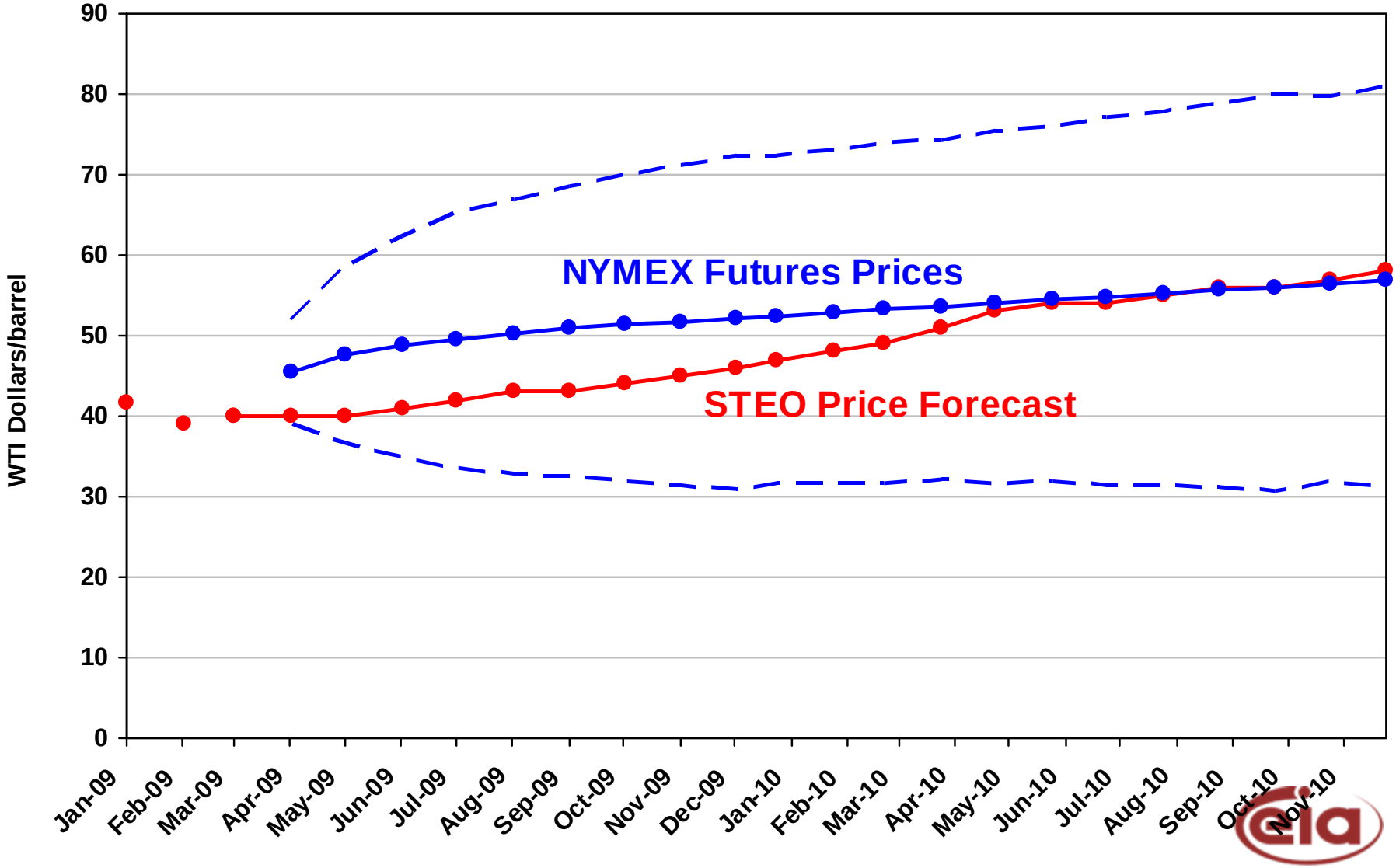
Possible Methods for Using BSM Implied Volatility to Illustrate Uncertainty

- Confidence interval for futures price in month m
  - $\exp\left(\ln(S_t)-\frac{1}{2}\left(\sigma_t^2 T\right)-k\left(\sigma_t\sqrt{T}\right)\right) < E(S_m) < \exp\left(\ln(S_t)-\frac{1}{2}\left(\sigma_t^2 T\right)+k\left(\sigma_t\sqrt{T}\right)\right)$
  - Current price of underlying asset (S_t)
  - Implied volatility of option (σ_t)
  - Time to option expiration ($T=\Delta t$)
  - Level of confidence (k)
- Futures price probability distribution function (PDF)
  - Show where STEO forecast falls on PDF
  - Compare PDF from previous STEO

67% Confidence Intervals for the NYMEX WTI Futures Price Curve, March 6, 2009



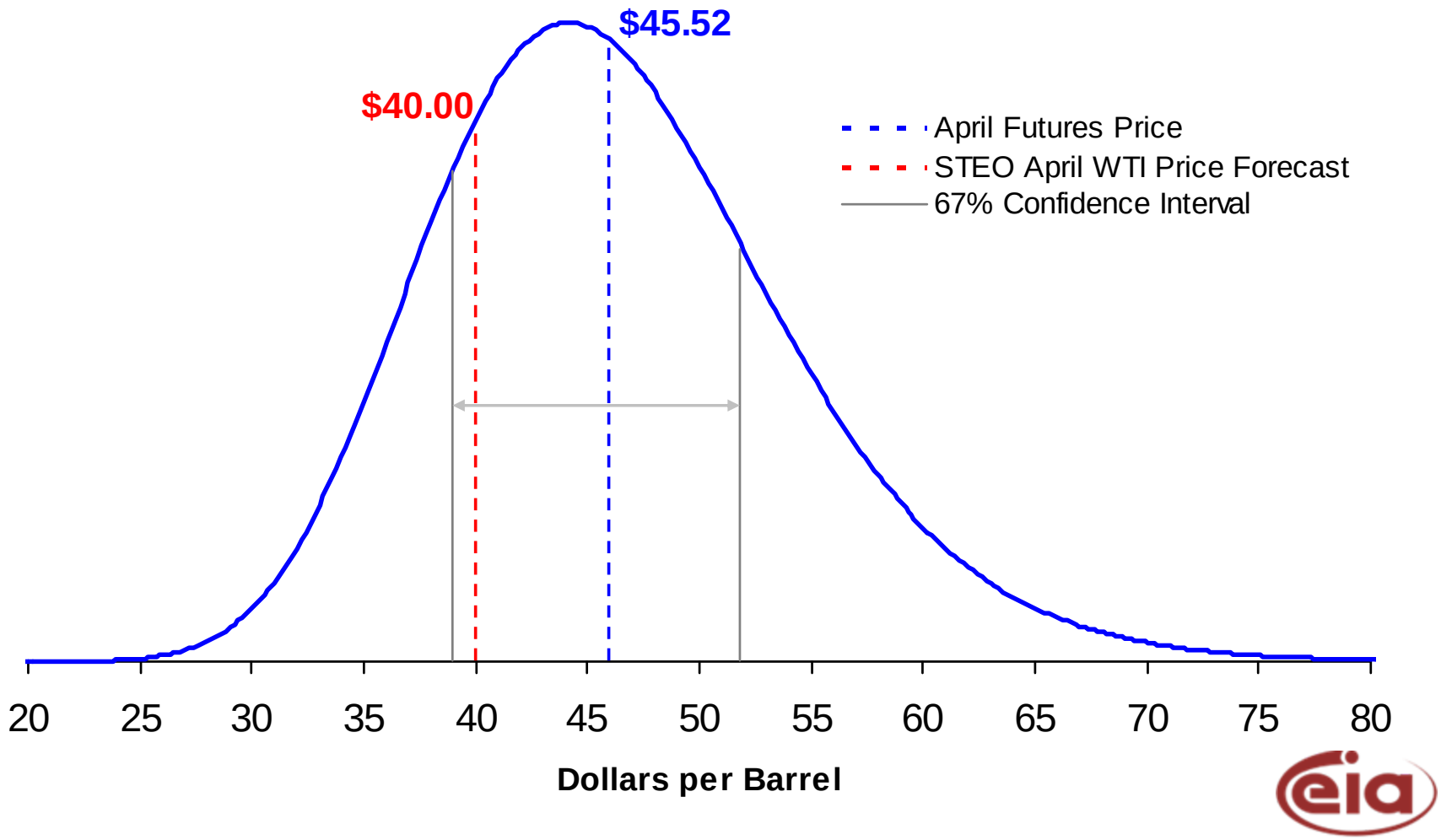
How March STEO Monthly Price Forecasts Fit in NYMEX Confidence Interval



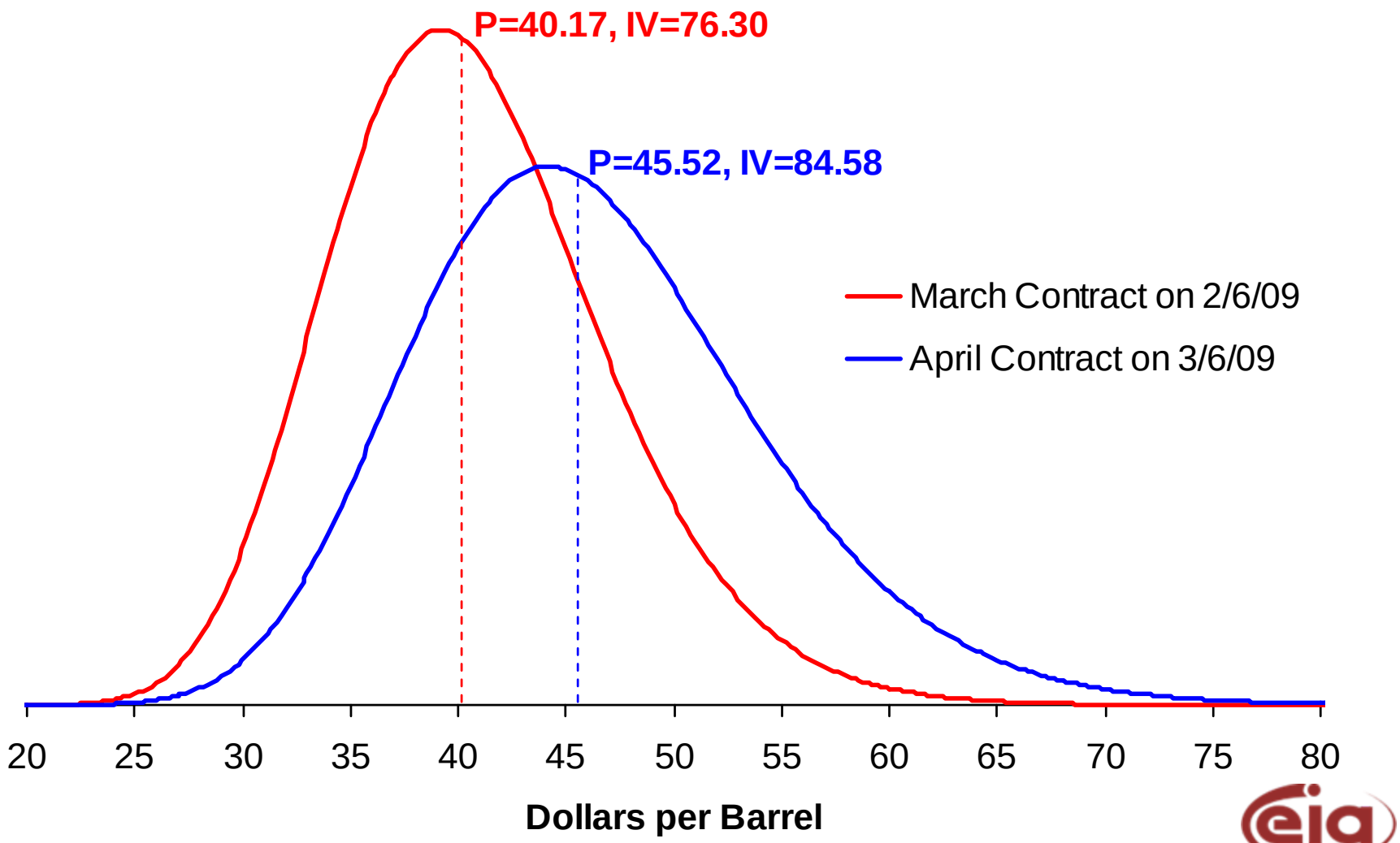
2009 WTI Prices: 67% Confidence Interval Table

2009	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
STEO	***41.68***	***39.09***	40.00	40.00	40.00	41.00	42.00	43.00	43.00	44.00	45.00	46.00
NYMEX				45.52	47.72	48.77	49.58	50.23	50.88	51.34	51.73	52.12
high				51.90	58.60	62.31	65.13	67.00	68.54	69.99	71.31	72.34
low				39.07	36.64	34.89	33.56	32.90	32.59	31.96	31.32	30.99
Interval				12.84	21.95	27.43	31.57	34.10	35.95	38.03	39.99	41.35
STEO-NYMEX				-5.52	-7.72	-7.77	-7.58	-7.23	-7.88	-7.34	-6.73	-6.12

April 2009 WTI Futures Price Probability Distribution (Implied in Call Option Premiums & Volatility on 3/6/09)



One-Month-Ahead WTI Futures Price PDF (Implied in Call Option Premiums & Volatility)



Probabilities of April 2009 WTI Spot Price Expiring Below/Above Different Levels

	Probability			
WTI Price ($/bbl)	Below	Above	STEO Forecast	Futures Price
$30.00	1%			
$35.00	5%			
$40.00	20%		$40.00	
$45.00	44%			$45.52
$50.00		32%		
$55.00		16%		
$60.00		7%		
$65.00		2%		
$70.00		1%		

Questions for the Committee

- Is it appropriate to compare EIA's STEO forecast with uncertainty in NYMEX futures options markets?
  - Caveats/disclaimers?
- Do confidence intervals and/or PDF charts adequately illustrate uncertainty?
- Best way to portray uncertainty information
  - Graphically?
  - Tables?