

Independent Price Verification

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Markets

- Options on Forwards contracts
 - Option Expiration up to 5 years out
 - Forwards are for Gas/Electrical delivery
 - Uniform delivery throughout the month
 - AECO, NYMEX (Henry Hub delivery), and ERCOT (peak)
- Whereas Forward prices for these markets are available, option prices on the forwards are not and are traded over the counter

Data

- Data from Bloomberg *Daily*
 - USD/CAD forward curve
 - USD interest rate
 - CAD interest rate
 - NYMEX (Henry Hub) Forward curve
 - AECO Forward curve
- Options Data from Traders *Daily*
 - AECO, NYMEX, ERCOT Put and Call prices
- TOTEM *Monthly*
 - Consensus based pricing
 - <http://www.markit.com/en/products/valuations/markit-totem/totem.page>

Totem

- Started in 1997
- Equities, Interest Rates, Currency, Commodity, Structured Credit, Bonds and other Indices
- Consensus Based
 - AECO - 20 participants
 - Henry Hub - 23 participants
 - PJM Peak - 4 participants

Totem

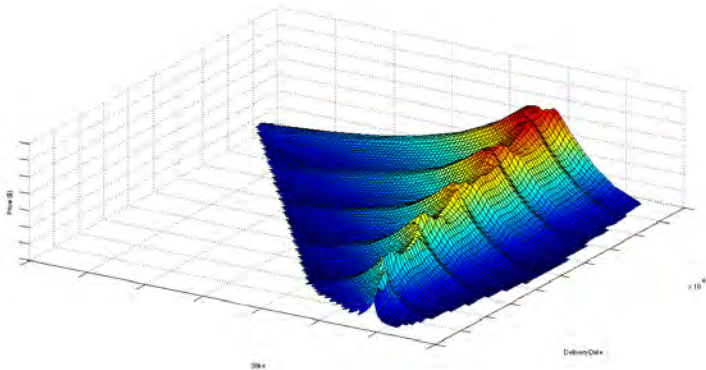


Figure: Price Surface

Price Data

$$AECO_{Outright}(t) = \frac{(NYMEX(t) + AECO_{Basis}(t))}{1.055056} \cdot USD/CAD(t)$$

Different Spaces

- TOTEM
 - Data is outright price at a strike and expiration date.
- Direct Energy
 - Volatilities per relative strike and expiration date

Blacks Model

Blacks

$$\begin{aligned} \text{Call} &= e^{-rT} [F \cdot N(d_1) \\ &\quad - K \cdot N(d_2)] \\ d_1 &= \frac{\ln(F/K) + (\sigma^2/2) \cdot T}{\sigma\sqrt{T}} \\ d_2 &= d_1 - \sigma\sqrt{T} \end{aligned}$$

Black-Scholes

$$\begin{aligned} \text{Call} &= S_t \cdot N(d_1) \\ &\quad - K \cdot e^{-r(T-t)} \cdot N(d_2) \\ d_1 &= \frac{\ln(S/K) + (r + \sigma^2/2) \cdot (T - t)}{\sigma\sqrt{T - t}} \\ d_2 &= d_1 - \sigma\sqrt{T - t} \end{aligned}$$

Delaunay Triangulation

- Developed in 1934 by Boris Delaunay
- “Circumcircles of all triangles have empty interiors.”
- Advantages
 - Maximizes the minimum angle of the triangles
 - Minimizes the maximum angle of the triangles
 - Triangles tend to be have more equiangularity

Delaunay Triangulation

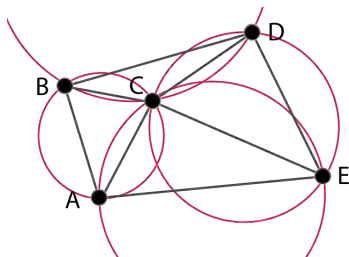


Figure: Delaunay
Triangulation

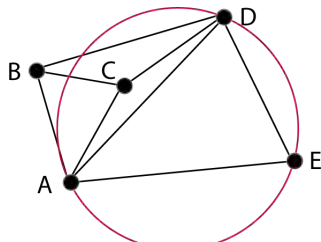
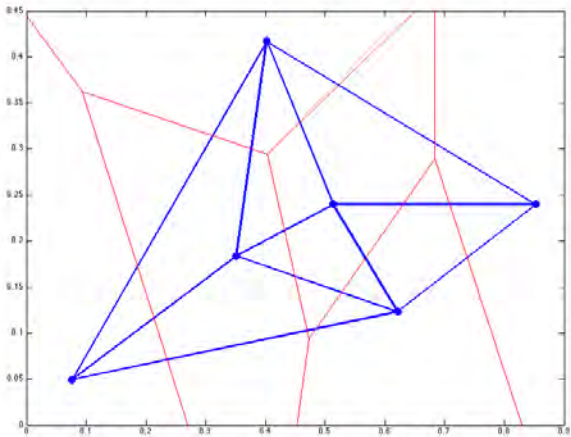


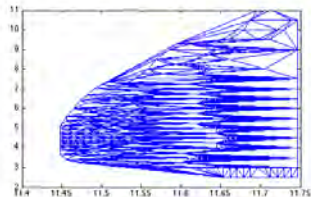
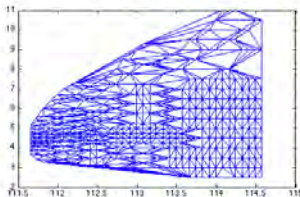
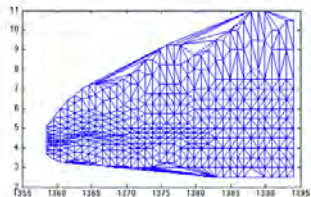
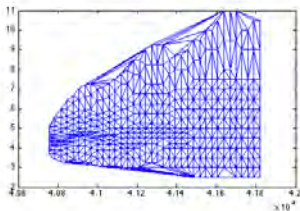
Figure: Non-Delaunay
Triangulation

Delaunay Triangulation

Exploit Duality with Voronoi Graph



Delaunay Triangulation



Delaunay Triangulation

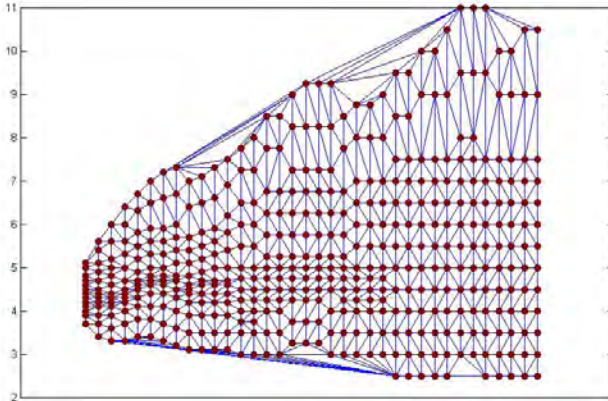


Figure: Delaunay Triangulation of Strike / Delivery

Surface Sizes

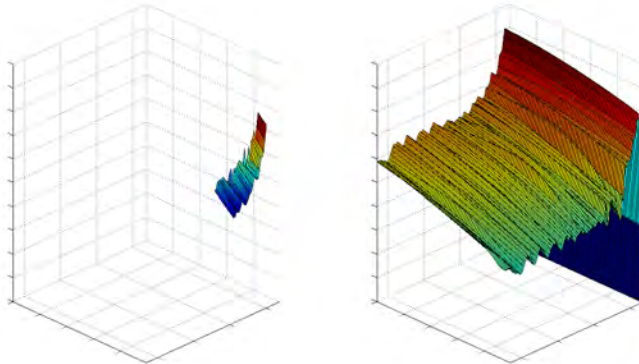


Figure: Comparison of Surface Sizes



Price Standard Deviation expressed as Volatility

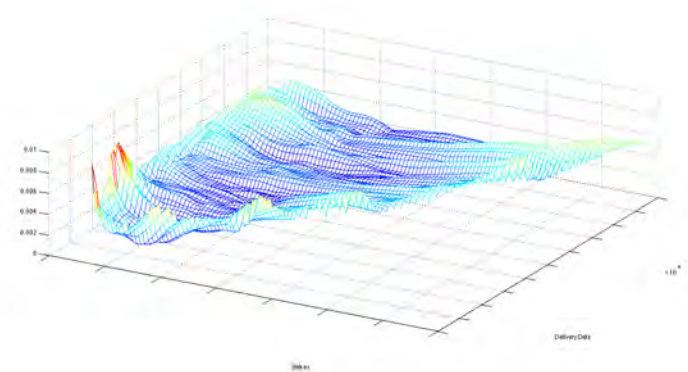


Figure: 1-Standard Deviation Price Error Translated to Volatility



Interp Error versus +1 Standard Deviation

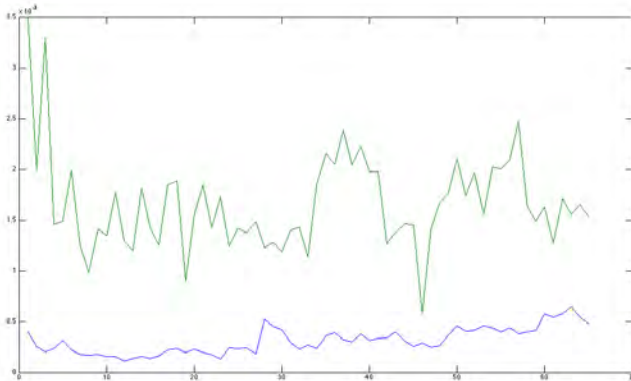


Figure: Maximum Interp Error Estimate versus Minimum Standard Deviation Error by Date

Questions?