Evaluating Electricity Capacity with Option Pricing

John Birge
Northwestern University
Joint work with Steve Kou
Columbia University

Outline

- Derivatives
- Real options and electricity markets
- Asset evaluation
- Model and solution
- Challenges and extensions
- Conclusions

Energy and Weather Derivatives

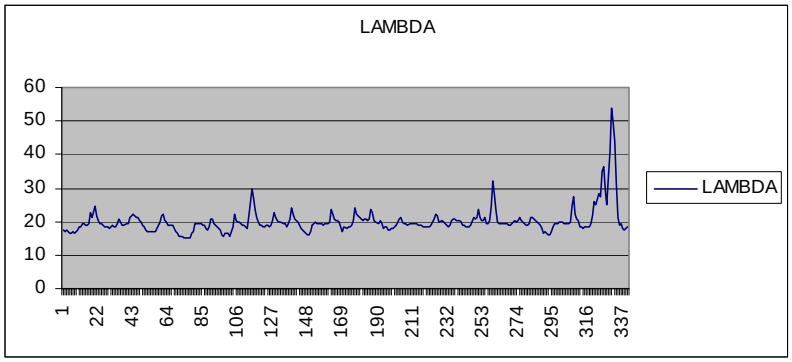
- Exchange-traded options: CBOT and NYMEX
- Over-the-counter: Many weather applications
- Uses:
  - Reducing risks
  - Finding value of plant (difference in prices)

Interest in Energy Derivatives

- High Volatility
  - 10 to 100 times that of common stock
  - Prices from 0 to $10,000 per MWhr
- Difficulty in storage
  - Electricity close to un-storable
    - Difficulty substitution (liquidity)

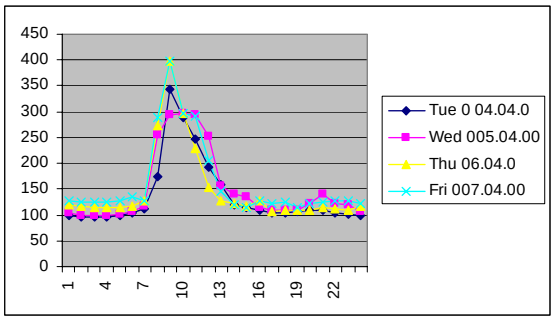
Electricity Price Example: USA

- California Power Exchange



Electricity Price Example: Norway

- NOK Prices

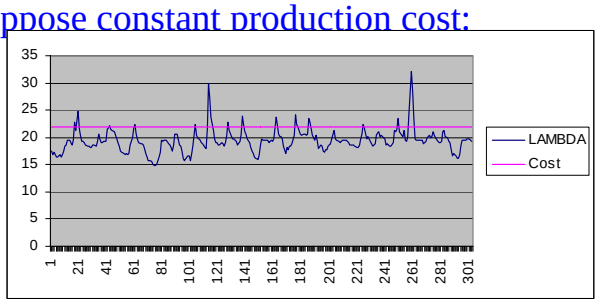


Observations on Data

- Price follows:
  - Mean reversion
  - Seasonality
  - Jumps
- Need:
  - Model to capture
  - Possible evaluation

Use of Valuation Formula

- Now, can value options
- What to use for?
  - Plant is worth something when price above cost to produce
  - Suppose constant production cost:



Constant Production Cost

- Value is like call on production cost at all times
- What if costs vary?
  - Other commodity
  - Example: Oil or natural gas
- Can value as difference between prices
- Some traded varieties

Modeling the Cost

- Suppose 2 futures prices $F_1(t,T^*)$ is the future price at T^* for unit of electricity at time t; $F_2(t,T^*)$ is the same for fuel
- K is the conversion factor from fuel to electricity
- So, plant has value if $F_1(t,T^*)-F_2(t,T^*)>0$
- For $S_i(T)=F_i(T,T)$, the plant is worth

$$A' \left(\int_0^T E^*[P[0,t]\,(S_1(t)-KS_2(t))^+]dt\right)$$

where A' relates to plant capacity, P[0,t] is present value of zero-coupon bond maturing at t, E^* is expectation under a risk neutral measure.

The Generation Option (Spark Spread)

Under mean-reverting processes with same rates β of mean reversion with $S(t)=J(t)K(t)$ where J is a jump process with Poisson rates $\lambda\zeta_i$ and lognormal jump sizes with log-mean γ_i, st.dev. δ_ι, correlation ρ, K is O-U process with mean rate α_i, and covariance Σ

$$E^*(P(0,T)\{S_1(T)-S_2(T)\}^+)$$
$$= P(0,T)\sum_{n=1}^{\infty} e^{-\lambda T}[((\lambda T)^n/n!)*$$
$$\psi(F^{(1,n)}(0,T^*),F^{(2,n)}(0,T^*),T,(\sigma^2(T,T^*)+n\delta^2)/T)$$

where…..

Parameter Definitions

$\psi(x_1,x_2,T,a^2) = x_1\Phi((\log(x_1/x_2)+(a^2/2)T)/(aT^{0.5}))$

$- x_2\Phi((\log(x_1/x_2) - (a^2/2)T)/(aT^{0.5}))$,

$F^{(i,n)}(0,T) = c_i(T)e^{-\lambda(1+\zeta_i)T}(1+\zeta_i)^n$,

$c_i(T) = \exp\{e^{-\beta t}\{\log(S_i(0))+\alpha_i\int_0^t e^{\beta u}du\}\}*$
$\exp\{(1/2)e^{-2\beta t}\sigma_i^2\int_0^t e^{2\beta u}du\}$

$\delta^2 = \delta_1^2+\delta_2^2-2\rho_x\delta_1\delta_2$,

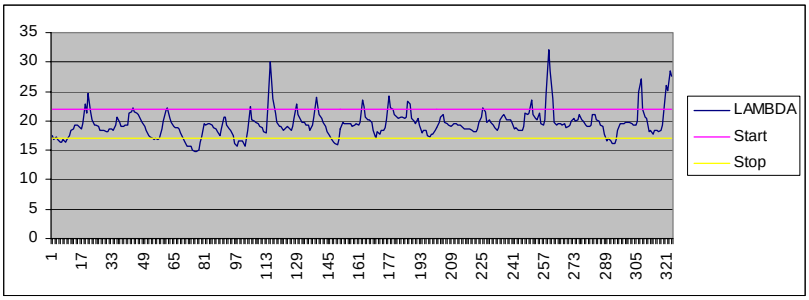
$\sigma^2(t,T) = \sigma^2\int_0^t e^{-2\beta(T-u)}dt$,

$\sigma^2 = \sigma_1^2+\sigma_2^2-2\rho_b\sigma_1\sigma_2$.

Additional Complications

- Real costs:
  - Cost to start operating
  - Cost to stop operating
- Need:
  - Policy for operating the plant
  - Price to start and price to stop

Example



Valuation

- Must value integral over transition time from start to stop point
- Count the number of cycles in a period
- Evaluate average cycle value
- Include correction for end effects

Conclusions

- Electricity and other real options large part of market
- Important for valuation of assets
- Treat as Brownian motion and jumps
- Can price by traditional techniques
- Difficulties with fixed costs and imperfect markets – uses of utilities and equilibria