Challenges and Pitfalls of Commodity Modeling

Alexander Eydeland
Morgan Stanley
Vienna, July 2011
Evolution of Models

Black-Scholes:

constant volatility

option value reflects the cost of delta hedging (only)

But we do vega hedging, thus, contradicting the assumption of constant volatility

Moreover, what is the cost of vega hedging and why is it not reflected in the option value?
Evolution of Models

Stochastic Volatility Models (SV)

Take care of non-constant volatility and vega hedging

But we now face a new set of problems:

We have introduced a number of additional model parameters (e.g., vol-of-vol, correlation between price and volatility processes, strength of volatility mean reversion, etc.)

Calibrating these parameters is a difficult but mostly manageable task. The problem is that these parameters change from day to day, sometimes, significantly. Hence, they require hedging. Again, we run into contradiction since, while calculating option values, we have assumed that these
Evolution of Models

Chasing the “hedging” tail

Similar problems exist for other modeling approaches (jump-diffusion, regime switching, stochastic time change models, etc.)

We choose these methods to model observed market behavior – fat tails, volatility smile, jumps, spikes, etc.

However, each model brings with it a number of model parameters presumed constant in option valuation. These parameters need to be calibrated on market prices.

Needless to say, these parameters change from day to day (thus, contradicting the assumptions) and, hence, need to be hedged.

Perpetual question: what is the cost of this hedging and do we need a model
Evolution of Models

More serious problem

In commodity markets we find ourselves in the situation of “incompleteness” even for models with relatively few parameters to hedge, i.e., there are no market instruments to hedge all we want to hedge

In this case the usage of risk-neutral methodology is questionable. We may need to use physical measure

The non-hedgeable model parameters calibrated on market data may be substantially different from the realized values

For example, if in a SV model (e.g., Heston) the vol-of-vol parameter calibrated on the implied option volatility smile is significantly different from the realized vol-of-vol, we risk to seriously overestimate the structures that are convex in volatility
Vol-of-Vol: realized vs implied
Evolution of Models

Modeling challenges:

Issue of parameter non-uniqueness

In many commonly used models (SV, jump) the shapes of generated volatility smiles diverge from typically observed shapes in the OTM region
Model vs Market

Market Volatility vs Model Volatility (SV, Jump Process)
Evolution of Models

Local Volatility Model (LV)

Pros: very economical as parameters are concerned

“Cons”: Volatility evolution is induced by the current implied volatility structure

What is correct volatility dynamics in commodity markets (sticky strike, sticky delta, etc.)

Empirical evidence or even a hint – none

Moreover, LV is designed for spot processes. In many commodity markets spot evolution is meaningless (no liquid spot prices). Futures prices have very few early exercise option prices available.
Do commodity vols exhibit in a stable way such properties as “reverse leverage”, i.e., negative correlation between price and vol movs? Probably, no.
Stable Empirical Properties

Samuelson effect

Example: #2 Heating Oil and #6 Fuel Oil At-the-Money Implied Volatility Curves on 21/10/2003
Samuelson effect

The historical graphs of the implied volatility ratios

\[ \frac{\sigma_{\text{impl}}(T; t_1)}{\sigma_{\text{impl}}(T; t_0)} \]

depend on the time to expiry \( T-t_1 \).
Stable Empirical Properties

Correlation structure

Correlation between returns of Jan ’05 NYMEX heating oil (HO) futures contract and

![Graph showing the correlation coefficient over time]
Criteria for Choosing and Validating a Model

Ability to match the market data

Frequently the model value is known for extreme values of these parameters; this property results in a natural test of the model

Another version of this test – checking inherent monotonicity, continuity, belonging to a certain interval, etc.

Compare to a benchmark, or alternative model

The best test: Historical or simulated hedge performance

Example: SV vs log-normal with re-calibrated implied vol. In our
Commodity Derivatives: Financial Products

Payout is well defined, financially settled

Examples:

Listed and OTC options: APOs (average price options), CSOs (calendar spread options), swaptions

Baskets, Indices, Options on baskets (related to component performance: best-of, Himalayan)

Modeling is not much different from other markets
Commodity Derivatives: Real Options
Commodity Derivatives: Physical Products

Payout at expiration is not well defined; a result of complex process involving optimization, logistics, transportation, dispatch, procurement, etc.

The majority of energy derivatives are spread options

Spread Options

Power plant -- spark spread option (option on the spread between power prices and fuel(s)+emission price

Storage -- calendar spread option

Transmission -- geographical spread option

Refinery -- crack spread option
Modeling Real Options: New Challenges

Non-market/non-price parameters

Examples:
- Load growth
- Changes in the market structure
- ISO activity

Regulatory actions

Examples:
- New emission markets
Example: CERs

Certified emissions reductions (CERs) are created through emissions reducing projects in developing countries, and can be used by European emitters to meet their EU emission obligations.

The principal difference between traditional EU emission credits (EUAs) and CERs is due to the fact that CERs are not delivered until the project achieves emission reduction and those emission reductions are certified.
Forward contracts on CERs, as well as swaps, carry additional uncertainty related to the delivery of the CERs at settlements. Several major stages in the life of a CER can be identified: UN registration, project implementation, ongoing delivery. A successful passage of each of these stages increases the probability of successful CER delivery, and hence, of success in entering a forward contract or a forward starting swap. Alternatively, the failure to complete any of these stages will result in canceling of the forward or swap.
Risk Management Challenges

The deal depends on unhedgeable parameter

One risk management approach is to use tradable instruments to minimize the variance of the deal value conditional on the distribution of this parameter

Diversification
What to do?

Scenario analysis to determine sensitivities to non-price parameters

If sensitivities are significant (sometimes, they are dominant as the option value is concerned) we should look for other approaches to manage this risk different from standard delta hedging:

Insurance

Contractual clauses

Diversification

Hedging with other real options
Other modeling approaches

Growing interest in replication and model free bounds

Useful tool as hedging is concerned
Hybrid Power Price Model
Power is a function of principal drivers

1. Demand
Hybrid Power Price Model

\[ P_T = \alpha_1 s^{gen}(D_T; T, U_T, \Omega_T(\alpha_2 \lambda), E_T, VOM_T, \alpha_3 C_T) \]

Model uses fundamental and market data

\( sgen \) - function determined by technical characteristics of all power plants (efficiency, operational constraints, etc.)

\( D \) - demand

\( U \) - fuel(s) used

\( \Omega \) - outages
Hybrid Model generates realistic paths
Disclosures

Respective participants are referred. No representation or warranty can be given with respect to the accuracy or completeness of the information herein, or that any future offer of securities, instruments or transactions will conform as well as the legal, tax, regulatory and accounting characteristics and consequences, of the transaction.

Certain assumptions may have been made for modeling purposes only to simplify the presentation and/or calculation of any projections or estimates, and Morgan Stanley does not represent that any such assumptions will restrict their purchase, holding, sale, exercise of rights or performance of obligations under any transaction. Morgan Stanley does not undertake or have any responsibility to notify you of any changes to the attached information.