The Power Sector Model

David Soronow, Mike Pierce and King Wang, of Financial Engineering Associates, Inc. introduce the firm's Power Sector Model as the next step in derivatives pricing

The deregulation of the energy markets has seen derivatives valuation techniques come to the forefront of the power market practitioner's repertoire of analysis tools. Although most of the derivatives modelling techniques were originally developed for financial markets, over the years researchers have adapted and modified these models to account for the unique nature of energy price behaviour. In this article, we present the next step in this evolution by extending the pure stochastic financial models to account for the underlying physical drivers of power prices.

Regardless of the model chosen, the general approach to solving the derivatives valuation problem is always the same: we start by writing down the stochastic process for each variable that underlies the derivative in question, and these variables are related to one another by imposing a correlation relationship between the random variates of each stochastic process.

Unfortunately, the traditional stochastic approach to derivatives valuation has had limited success in cases where a truly integrated model of load, power prices, fuel prices, and weather is required. Such a model is a crucial ingredient into any earnings, profit, cashflow or value-at-risk calculation. In addition, an integrated model is useful for pricing contingent claims that result in some combination of price, weather and/or volumetric risk such as full requirements contracts, or weather and price contingent structured products. The simplification of the relationship between variable pairs into a single correlation coefficient, although convenient for maintaining analytic tractability, fails to account for the key drivers of power prices and the fundamental physical and economic nature of their interdependencies.

In this article, we introduce an integrated model for the joint evolution of power prices, fuel prices, weather, and load across multiple regions; aptly named: the Power Sector Model.

Model context

The formulation of an integrated model can be approached from many different perspectives. For example, taking a fundamental perspective our approach would be to focus the modelling efforts on the fundamental cost drivers of each power generation unit in the region, the characteristics of relevant transmission lines, and other relevant characteristics defining the nature of the generation stack. The downside of this approach is the onerous data and input parameter requirements, as well as the overly burdensome computational costs. In addition, fundamental models ignore non-physical market influences such as the operational strategies of each generator, and the current observed forward price curve.

An alternative approach would be to focus on improving upon the traditional stochastic models used in derivatives valuation by identifying and modelling the most salient factors driving the joint evolution of load and power prices. This is the approach discussed in this article and represents a significant extension to the traditional stochastic derivatives valuation models in order to account for the intricate interdependencies between the factors driving power prices and load.

Model overview

The first step is to identify the most salient state variables driving the evolution of power prices. In the case of the Power Sector Model, we have identified weather and marginal fuel prices as independent variables driving load levels and power prices. This is grounded in the understanding that, to a large extent, weather dictates load conditions, which, together with the marginal fuel price, then determine the power price.

The second step is to conduct a detailed empirical study of the nature and relationships among the various components under analysis (weather, load levels, fuel prices and power prices). The goal of the study is twofold: to understand the relationship between the variables, as well as to determine the seasonal aspects inherent in each component. For example, the relationship of load to weather is different on business days versus non-business days. The data used in this study is historical daily temperatures, historical hourly loads, historical hourly power prices, and historical daily fuel prices.

The next step is to establish and calibrate models for each of these components, while also allowing for alternative model specifications. The reader should note that the modularity of this approach naturally allows for a choice of simulation models for weather, fuel prices, and load.

Once the models are calibrated, we use model-based Monte-Carlo simulations to value power contracts, generation assets, or to conduct any other type of risk analysis that depends on the joint evolution of load, power prices, fuel prices or weather.

Sample model choices

As stated earlier, the approach outlined above is modular and adaptable in the sense that almost any reasonable stochastic process can be chosen for weather, load and fuel prices. The key to the Power Sector model is the functional form of the variable interdependencies. Some model examples are as follows:

Weather: A cross-regionally correlated multi-factor, mean-reverting model for temperature.

Load: The daily load shape (ie, the load for each of the 24 hours in a day) follows a multivariate normal distribution with distributional parameters (mean and variance) conditional on simulated daily temperature and business day/non-business day categorisation.

Fuel: A lognormal mean-reverting model fitted to the current forward price curve.

Power: A historically fit function of load and marginal fuel price, with load-dependent volatility and jump parameters.

Figure 1 illustrates the simulated Power Sector Model results for price and load, as well as the historical results from New England.

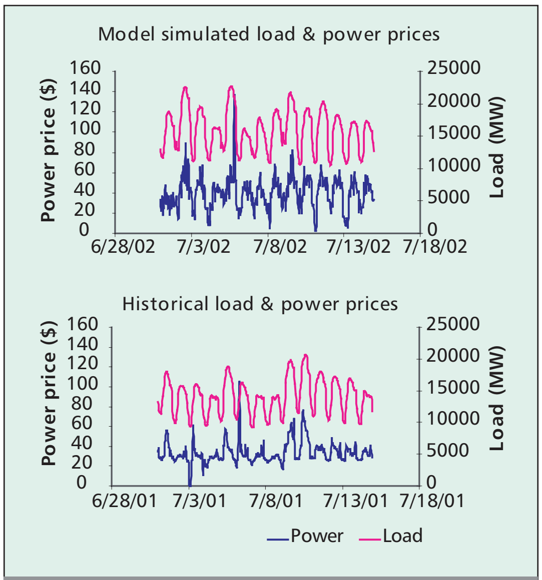

Figure 1: Power Sector Model results for load & prices

Advantages

The Power Sector Model approach has several advantages:

- The approach focuses on the use of relevant, publicly available historical data thus eliminating the onerous data requirements often characteristic of full-scale fundamental models.
- The approach is capable of capturing the essential power price characteristics such as seasonality in price and volatility, mean-reversion, price spikes, volatility clustering, and regional correlations.
- By adopting a modular approach, each component of the model can be extended or improved upon gradually over time and with experience.
- The model is self-contained, and when fully calibrated, Monte Carlo simulation provides the basis for valuing power contracts and generation assets directly.
- The approach lends itself to model validation/back-testing. For example, by isolating one component at a time then substituting the relevant historical data for the model-based simulated data, one can easily compare the results to check for modelling accuracies as well as for their impact on valuations.

Conclusion

This article introduced FEA's Power Sector Model. This approach represents a significant extension to traditional stochastic derivatives pricing models and provides for a truly integrated model of the joint evolution of weather, load, fuel prices, and power prices. **NF**

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