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Electricity portfolio management: Optimal peak/off-peak allocations

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ABSTRACT

Electricity purchasers manage a portfolio of contracts in order to purchase the expected future electricity consumption profile of a company or a pool of clients. This paper proposes a mean-variance framework to address the concept of structuring the portfolio and focuses on how to optimally allocate positions in peak and off-peak forward contracts. It is shown that the optimal allocations are based on the difference in risk premiums per unit of day-ahead risk as a measure of relative costs of hedging risk in the day-ahead markets. The outcomes of the model are then applied to show (i) that it is typically not optimal to hedge a baseload consumption profile with a baseload forward contract and (ii) that, under reasonable assumptions, risk taking by the purchaser is rewarded by lower expected costs.

1. Introduction

In many countries electricity markets are liberalized. As a result large electricity purchasers, e.g. large industrial consumers and electricity retail distribution companies, need to contract the future expected electricity consumption (load) for their own company or for a pool of clients. In liberalized electricity markets, they can do so by managing a hedging portfolio of contracts that involve delivery of electricity in future time periods and/or financially settle the difference between a fixed and a variable price. Examples of such contracts are day-ahead contracts, derivatives such as forwards, futures, swaps, variable volume or swing options and direct or indirect investments in energy production facilities.[1] Proper management of the load hedging portfolio involves a continuous assessment of (a) the types of instruments (contracts) to buy or sell and (b) at what moment the portfolio needs to be rebalanced according to the risks the electricity purchaser prefers to take. An obvious objective of the purchaser is to incur the lowest expected costs for the expected electricity load, given a specific risk target.

Since the beginning of the liberalization of energy markets, researchers have primarily focused on the price characteristics of different energy commodities and the valuation of derivative contracts. Traditionally the academic literature has dealt with proposing optimal hedging strategies using commodity futures.[2] The issue of constructing efficient portfolios for electricity purchasers has received much less attention in the academic literature. Given the sometimes extreme price fluctuations in energy commodities, we feel that this issue is grossly undervalued. Poorly constructed portfolios exhibit either too high expected costs at a given risk level or, alternatively, too much risk for the current level of expected costs. This paper focuses on optimal instrument selection for a rational electricity purchaser that cares about the mean and variance of the future sourcing costs. It specifically tackles the question how electricity purchasers should choose between peak and off-peak forward contracts in order to structure their portfolios optimally. To do so, we construct a simple one-period framework and cast the allocation problem in a portfolio framework to find the optimal allocations to the forward contracts and the day-ahead market.

The paper is organized as follows. Section 2 discusses the literature on energy portfolio management. In Section 3 we present our model. Section 4 highlights some managerial implications of the model and provides answers to the questions how a company should purchase a baseload consumption profile and whether taking risk is rewarded by lower expected costs. Section 5 concludes.

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[1] Indirect investments in power plants often take the form of virtual power plants or tolling agreements, both being power purchasing agreements in which the owner purchases electricity from a power plant and pays according to a formula that relates the price to, among others, fuel prices.

[2] See for example Moschini and Myers (2002) and Alizadeh et al. (2008), and the references therein.

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2. Portfolio structuring in electricity markets

In order to facilitate trading of power contracts many countries have established over-the-counter (OTC) and centralized markets. The two most prevalent markets are the day-ahead and forward/futures markets. On the day-ahead market, traders can submit bids and offers for amounts of electricity to be delivered in the individual hours of the next day. This market is the closest equivalent to a spot market.[3] Electricity purchasers use day-ahead markets for buying (a part of) their electricity consumption, but the amount of price variation in these markets is substantial. As electricity cannot be stored in an efficient way, prices are very volatile, and seasonal and price spikes frequently occur.[4]

Instead of taking the risk of price variations in the day-ahead market, purchasers seek protection, depending on their risk appetite, and manage a portfolio of derivative contracts that involve delivery at future dates against fixed prices. Popular contracts are the so-called baseload and peakload forward and future contracts that can be traded on all OTC markets (forwards) and exchanges (futures).[5] On many electricity markets around the world electricity can be traded by using contracts that apply specifically to peak and off-peak hours.[6] Baseload contracts involve the delivery of 1 MW in all hours of the delivery period against a price fixated at the moment at which the transaction occurs. Peakload contracts are defined similarly, but involve delivery only in the peak hours of the delivery period. Delivery periods range from weeks, months, quarters to calendar years, sometimes up to six years ahead. By holding a portfolio of these contracts, the purchaser can already lock in the acquisition of (a part of) the expected future consumption long before the actual delivery and consumption period against fixed prices and can thereby manage the risks faced from price variations in the day-ahead market.

The prices of baseload and peakload forward contracts exhibit different characteristics than day-ahead prices. According to the expectation theory,[7] forward prices for non-storable commodities reflect the expectation of market participants on the (average) spot price in the delivery period and a risk premium that compensates producers for bearing the uncertainty of committing to sell against fixed prices. In electricity markets, risk premiums can be positive and negative. For instance, Bessembinder and Lemmon (2002) and Karakatsani and Bunn (2005) find negative risk premiums in low-demand off-peak hours due to power producers who are willing to pay a premium for not having to cut down production from plants with long ramp-up and ramp-down times in order to be able to produce more in the high-demand and more expensive peak hours.

For the portfolio manager forward contracts make it possible to fix delivery prices, thereby reducing the exposure to the price fluctuations in the day-ahead market. Purchasing power with forward contracts boils down to hedging the risk faced from the day-ahead market with the expected hedging costs being equal to the risk premium embedded in the forward price.

Given a set of forward and future contracts that can be traded every day, the task of the portfolio manager is to determine the optimal selection of forward contracts to hold for various delivery periods. The optimal selection depends on a risk assessment of the day-ahead market, an expectation regarding the expected price in the day-ahead market in the delivery period, the amount of risk premium she needs to pay and her personal (or the company's) appetite for taking risk. The goal of the portfolio manager is to maintain such a portfolio that yields lowest expected costs for electricity consumption while respecting her risk appetite.

This paper builds on the original ideas from Markowitz (1952), who proposes a methodology to construct efficient investment portfolios based on investors' goal to maximize expected future returns on their investments given a certain level of risk. The idea to use portfolio theory to construct energy hedging portfolios is not new. Several researchers have followed the Markowitz methodology to address the hedging decision process, particularly Näsäkkälä and Keppo (2005) and Woo et al. (2004). Both studies focus on the interaction between stochastic consumption volumes and electricity prices (day-ahead and forward contracts) and propose a Markowitz-style mean-variance framework to determine optimal hedging strategies. Näsäkkälä and Keppo (2005) apply static forward hedging strategies in a representative agent setting. The main result from this paper is that agents who are confronted with high load uncertainties will postpone their hedging strategies in the expectation of load uncertainties resolving over time. Their results crucially depend on the assumption on the correlation between forward prices and load estimates. In our view these correlation assumptions are difficult to maintain, especially as we feel no direct causal relation between these variables exists. In general, the relation between volumes, like load or demand, and prices is weak in electricity markets. See for example the evidence in Mount et al. (2006) and Kanamura and Ohashi (2007), who show that only in very extreme cases, where demand is extraordinarily high, that prices react substantially. In normal circumstances the impact of load on day-ahead electricity prices is statistically significant, but the economic significance of this result is limited.

Vehviläinen and Keppo (2004) take the viewpoint of a generating company and solve for hedging strategies using Value at Risk (VaR) as a risk measure instead of standard deviation. Their analysis based on both stochastic consumption and prices is meaningful, yet complex. Even after a number of simplifying assumptions (Vehviläinen and Keppo, 2004) need simulation techniques to solve for the optimal hedging strategies. Again, it is questionable if electricity prices are elastic with respect to consumption patterns. Furthermore, even if prices would be elastic consumption patterns are highly persistent, and therefore less informative for price explaining price behavior.

The paper that is closest to ours is Woo et al. (2004). These authors provide a general strategy of hedging shorter-dated price exposures with forward contracts. They also focus on finding the efficient frontier for trading off expected costs and risks. Our approach is different in the sense that we extend the set of hedging instruments by differentiating between peak and off-peak hours during the day. We find that this feature of the electricity market cannot be ignored. As a result we expect that efficiency of the expected cost-risk trade-off can be enhanced.

With respect to the studies mentioned above this paper focuses on providing analytical insight in the optimal hedging amounts for an electricity purchaser in a setting that allows for different types of forward contracts, day-ahead prices and risk attitudes. Special attention is given to the relative impact on the optimal hedging decisions of forward risk premia.

3. The purchase decision in a one-period framework

At time t, consider an electricity purchaser who has to decide on how to purchase the consumption for future delivery of electricity at day T. We have that $t<T-1$, i.e. the hedging decision needs to be made

[3] Many countries also run imbalance markets in which power changes hand in real-time. The liquidity of these markets is rather limited and prices are in some cases set by the imbalance operator at their discretion. Karakatsani and Bunn (2005) show that there may be an effect of the imbalance market on the day-ahead market, although they do not provide a clear economic rationale. In this paper we refrain from this relation and leave the balancing markets out of the analysis.

[4] We refer to Bunn and Karakatsani (2003), Huisman et al. (2007), among others, for an overview on (hourly specific) day-ahead price characteristics.

[5] In this paper, we do not differentiate between forwards and futures and only mention forward contracts, although in reality small price differences might occur due to differences in settlement procedures and margining schemes.

[6] See for example the overview in Eydeland and Wolyniec (2003) regarding North-American electricity markets. For Europe, see Brand et al. (2002).

[7] We refer to Fama and French (1987) for an overview of forward premiums in commodity markets.