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Evaluation of different hedging strategies for commodity price risks of industrial cogeneration plants

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HIGHLIGHTS

- Evaluation of commodity price risk hedging strategies for industrial cogeneration.
- Value-at-risk analysis of eight different hedging strategies.
- Mean-variance portfolio analysis for determining the optimal hedging strategy mix.
- A mix of hedging strategies further improves profitability of heat-based CHP.

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ABSTRACT

In this paper, we design and evaluate eight different strategies for hedging commodity price risks of industrial cogeneration plants. Price developments are parameterized based on EEX data from 2008 to 2011. The probability distributions derived are used to determine the value-at-risk (VaR) of the individual strategies, which are in a final step combined in a mean-variance portfolio analysis for determining the most efficient hedging strategy. We find that the strategy adopted can have a marked influence on the remaining price risk. Quarter futures are found to be particularly well suited for reducing market price risk. In contrast, spot trading of CO_2 certificates is found to be preferable compared to forward market trading. Finally, portfolio optimization shows that a mix of various hedging strategies can further improve the profitability of a heat-based cogeneration plant.

1. Introduction

In light of the cold wave in Europe in February 2012, it became evident how important it is for an uninterrupted power supply that sufficient baseload power plants are in operation. The decommissioning of eight German nuclear power plants in 2011 incurred over the last couple of weeks of that year considerable challenges, particularly in Southern Germany (Flauger, 2012). In February 2012, here and there emergency reserves had to be called upon[1] , which for the power supply sector constitutes an important element to maintain the security of supply should bottlenecks arise in the electricity supply. In order to avoid such emergency situations in the future, and at the same time to account for climate change mitigation goals, targeted expansion of energy-efficient and environmentally benign baseload power plants has to be effected.

A highly energy-efficient and therefore environmentally sound technology for the constant supply of electrical energy is that of cogeneration (combined heat and power, CHP) based on the gas and steam combined cycle (CC) (Baehr, 2005). The advantages resulting from the use of this CC–CHP technology with regard to fuel consumption and CO_2 emissions led already in 2002 to the entering into force of a German federal law for the promotion of CHP plants (Kraft-Wärme-Kopplungsgesetz; KWKG, 2011). The aim of the CHP Act and related ordinances is to promote power production with this energy-efficient technology.

If heat demand is guaranteed, for example, by installing such a plant in an industrial enterprise which requires process heat throughout the year, then capacity factors of up to 90% can be realized. At the same time, the obligation to continuously provide

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[1] Emergency or so-called "cold reserve" plants are inoperative power plants that can go online in the case of electricity shortages, despite high operating costs.

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heat energy to an enterprise imposes risks that would not occur in the case of a normal gas-fired power plant.

The continuous operation and the resulting constant fuel demand and CO_2 certificate requirements in the case of industrial CHP plants lead to considerable market price risks when purchasing the commodities (Westner and Madlener, 2011a). Moreover, electricity is produced independently of the market prices at the electricity exchange, due to the heat-demand-driven operation of the plant[2]. Possibly unprofitable operating conditions can therefore not completely be avoided. The main reason for the occurrence of risks is the high volatility of the price developments at the energy exchange. Electricity in particular, due to its non-storability[3], is subject to marked price variations (Vehviläinen and Keppo, 2003). A reliable estimation of possible profits or losses is thus very difficult. In order to nevertheless deal with these risks, various approaches allow for the valuation and mitigation of risk.

In this paper, we first design eight hedging strategies that offer different possibilities for hedging the above-mentioned price risks. In a next step, the price developments of electricity, natural gas, and CO_2 certificates are analyzed and the strategies scrutinized *ex post* with regard to their profitability. In order to support the selection of future strategies on scientific grounds, price developments of the years 2008–2011 are parameterized on the basis of statistical testing, and suitable probability distributions are estimated. These distributions serve to feed a model with data, which in the framework of a Monte Carlo simulation allows the assessing of the *Value at Risk* (VaR) for the choice of an individual strategy. Finally, the strategies are combined, following Markowitz' portfolio theory, in order to determine the best strategy mixes based on the prevailing risk preference of the plant operator concerned.

The remainder of this paper is organized as follows. In Section 2, we review the related literature and introduce the method applied. In Section 3, the model is presented in detail and the assumptions made listed and justified. In Section 4.1, a brief historical analysis of the strategies is undertaken, while in Section 4.2 a Monte Carlo simulation and in Section 4.3 the portfolio analysis is performed. Finally, in Section 5, the results are summarized and an outlook on possible further research is provided.

2. Related literature and method adopted

In this study, we first evaluate the prices published by the European Energy Exchange (EEX) for the commodities electricity, natural gas and European Union Emission Allowances (EUAs) for a historical consideration of the years 2008–2011. Next, we introduce effective strategies that enable the hedging of the price risks occurring when operating a CC–CHP plant. These strategies comprise the purchase of natural gas and EUAs and the sale of electricity at the EEX at different delivery periods, i.e. for instance in the spot and futures markets. Based on this, we calculate the clean spark spread[4] summed up over the course of a year of the respective strategies, and value the latter relative to alternative strategies. Subsequent to this valuation based on historical values, the modeling of the price developments for electricity, gas, and EUAs follows, aimed at a risk valuation of the various strategies for a future year.

Energy price modeling has been a popular subject in numerous publications. Especially for the representation of price mechanisms on the power market, a rich body of literature exists. In the course of electricity market liberalization, there followed first approaches, in which attempts were made to model the electricity price developments at the exchange with well-known capital market models (see e.g. Felder, 1996; Vehviläinen and Keppo, 2003). However, it soon became apparent that the price formation of electricity due to non-storability[5] follows other rules. Weron et al. (2001) and Guthrie and Videbeck (2007) find that simple finance models are insufficient to model the high volatilities of the spot market prices of electricity.

Modified models have thus been applied to model the specific characteristics of the electricity price development at the energy exchanges, e.g. by Escribano et al. (2002). They take various factors into account for the analysis of the spot market prices such as seasonality and GARCH behavior (see also Duan, 1995) or time-dependent jumps, which were analyzed for their relevance on the basis of the data of different markets. Boubonnais et al. (2006) consider a *univariate time series approach* and Huisman et al. (2007) develop and apply a model for the representation of hourly electricity prices. Models for the price formation on the futures market were proposed and investigated, among others, by Deng (2000), Burger et al. (2004) and Bauwens et al. (2011).

For the price developments on the EUA market, albeit to a lesser extent, there also exist a number of publications and models. Benz and Trück (2009), for instance, investigate the usefulness of a *Markov-switching model* and an *AR-GARCH model* for representing the certificate price development on the European emissions trading system (EU-ETS). In contrast, El Hedi Arouri et al. (2012) investigated the relationship between the prices for CO_2 certificates on the spot and on the futures markets by means of a *vector autoregressive* (*VAR*) *model* and a *switching transition regression-exponential GARCH model* (*STR-GARCH*). Recent studies, e.g. by Chevallier (2011), deal with the instability of the volatility of EUA prices when using an *EGARCH model*.

Apart from these studies, which deal with the forecasting of EUA prices, other studies focusing on the price development of natural gas exist as well. Price volatility of gas products was already modeled, for example, by Herbert (1995). Further studies were conducted, e.g. by Pindyck (2003) or Geman and Ohana (2009). A detailed analysis of various models for the simultaneous modeling of gas and electricity spot market prices for a gas-fired power plant is provided by Heydari and Siddiqui (2010). They conclude that price volatility forecasts from non-linear stochastic models are the most accurate ones.

Based on these insights, in our study we also pursue the approach of representing the volatility by means of stochastic parameters and simulations.

In contrast to the models published so far, price developments of all commodities (electricity, natural gas, and EUAs) that are needed to compute a clean spark spread of a CC-CHP plant, are stochastically analyzed and evaluated by means of a *goodness-of-fit* test. The combined analysis of these commodities in the context of the special characteristics[6] of a heat-demand-operated CC-CHP plant is an original contribution. To our knowledge, only Rong and

[2] The type of power plant investigated in this study is mainly used for generating process heat for industrial applications. Hence the flexibility in operating the power plant is strongly restricted. For more details see Section 3.1.

[3] In general, electricity is considered to be non-storable in large quantities, in contrast to other commodities such as natural gas or grain. Physically, this is not quite correct, but the very high costs arising when "storing" electricity make this assumption justifiable.

[4] The clean spark spread is computed as the difference between the revenues gained from electricity sales and the expenditures that result from purchasing fuel and CO_2 certificates for the amount of electricity produced, cf. Eq. (1) (see also Alberola et al., 2008).

[5] This particularity of the commodity "electricity" leads to a situation where on the markets there may be short-term scarcity and overflows that cause the prices either to rise or fall markedly. In reality, both price rises of several hundred percent and negative prices could be observed up to now.

[6] Because the plant is operated based on heat demand, it cannot, for instance, be switched off arbitrarily when electricity prices are low.