POWER PLANT INVESTMENTS UNDER UNCERTAINTY - A LINEAR MEAN RISK MODEL FOR SELECTING EFFICIENT POWER PLANT PORTFOLIOS

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Overview

Long-term investments in thermal power plants are capital-intensive, usually irreversible and subject to several risks and uncertainties. Investors are exposed to, inter alia, price risks (uncertain development of prices of primary energy carriers, emission certificates and electricity), volume risks, e.g. resulting from the fluctuating supply from renewable energies and regulatory uncertainties due to political decisions. Applying the theory of portfolio selection (Markowitz, H.M. 1952) to investment decisions in the power industry provides a possible way to minimize the overall risk of falling short of profit targets. The model presented within this paper allows to determine the efficient frontier comprising all efficient power plant portfolios, over a specific period. Out of all selectable power plant portfolios the efficient set offers the lowest risk for any given level of expected profit. The downside risk of missing the target (expected) profit is measured by the Conditional Value at Risk (CVaR), also known as the Tail Value at Risk (VaR) or Expected Shortfall, which has to be minimized in the objective function of the portfolio model. Based on loss distributions, the CVaR quantifies the expected loss beyond the VaR, which in turn is a certain α-percentile of the loss distribution. More precisely, the VaR is the threshold value such that the probability that losses exceed or equal to this value is lower than or equal to the confidence level α.

Method

In order to assess the risk from unknown future prices of primary energy carriers and emission certificates projections were made by using a regression model and different basic stochastic processes. Whereas the prices of energy carriers and emission certificates substantially determine the generating costs, future electricity prices are crucial for the expected revenues of the generating units. The assumed future electricity prices are outcomes of a fundamental electricity market model in which the overall costs of the electricity generation system over a chosen planning period are minimized. Electricity prices based on the short-term marginal costs in this model are comparable to electricity wholesale prices on an energy-only market. This electricity market model is applied to the German market repeatedly with all combinations of price scenarios for primary energy carriers and CO2 allowances discussed before. In this way, a distribution describing the risks of electricity prices can be generated. In addition to price risks the steadily increasing power supply from renewable energy carriers as a result of several promoting schemes of the government's policy impose a volume risk for conventional generating units. Since the current promoting scheme for renewable energies guarantees the priority feed-in, the revenues of conventional units become more vulnerable to the amount of renewable power generation in the electricity system. Unlike the generation from hydro-electric power plants the feed-in from wind turbines or PV systems is more intermittent and less predictable. In this paper, stochastic wind profiles derived from the historical data are used to demonstrate the impact of intermittent wind generation on the electricity prices und furthermore on the revenues of conventional generating units. Subsequently, the price projections for primary energy carriers, CO2 allowances and electricity are used to calculate profit distributions for a set of thermal power plant technologies available for investment. According to the interpretation in this paper the investor suffers losses when the annual scenario specific portfolio profits fall below the annual expected portfolio profit. Based on the distribution of the cumulative losses in the planning period, the VaR and the CVaR are calculated following the approach in (Rockafellar, R.T. and Uryasev, S. 2000). The identification of the efficient frontier comprising the efficient power plant portfolios requires several optimization steps with the described portfolio model. In the first step at least the smallest expected portfolio profit in the planning period must be earned. The portfolio model provides the technology shares that meet this constraint and minimize the CVaR simultaneously. In the following steps, the profit requirement is increased incrementally to its maximum. In the last optimization step, power plant portfolios with the highest expected profit are identified.

Hereafter, the portfolio model is applied for an exemplary power plant operator in Germany in the modeling period from 2015 to 2030. The future development of the power generation from renewables is set according to national targets. It is assumed that the operator has no existing power plants in his portfolio at the beginning what makes investments necessary to fulfil the target profits. However, his investments during the modeling period are limited to a total budget of 20 billion Euro. Power plant technologies available for investment are coal steam turbines

(COALST), lignite steam turbines (LIGNST), combined cycle gas turbines (CCGT) and open cycle gas turbines (GASGT). The price of lignite is considered to remain constant. The confidence level is set to 0.05.

Results

A profit analysis is firstly carried out for each investment option based on the electricity prices resulting from the electricity market model. As the findings show only lignite plants can cover their total costs in an energy-only market. Consequently, efficient portfolios consist exclusively of LIGNST which means an efficient frontier is not determinable. Currently, diverse mechanisms are discussed to solve this "missing-money" problem. Such a mechanism should provide incentives for investments in conventional units which are inevitable for a secured power supply in the future. Since the electricity market model has not yet been extended to capture the price effects of such mechanisms the electricity prices resulting from the electricity market model are exemplarily increased by 15 %. In that case, investment incentives also exist for the other technologies except for GASGT which is still unviable. As demonstrated in Figure 1, the risk minimal portfolio is a mix of COALST, LIGNST and basically GASCC. In fact, the minimum target profit is obtained exactly by a pure GASCC portfolio. However, a pure GASCC portfolio would not be efficient or rather be located far below the efficient frontier. In volume terms, a pure GASCC portfolio generating the same expected profit over the modeling period (5.12 bn. €) is exposed to a nearly eightfold higher risk (CVaR = 9.49 bn. €). By increasing the target profit incrementally the share of GASCC is declining continuously being replaced by more profitable coal and lignite power plants.

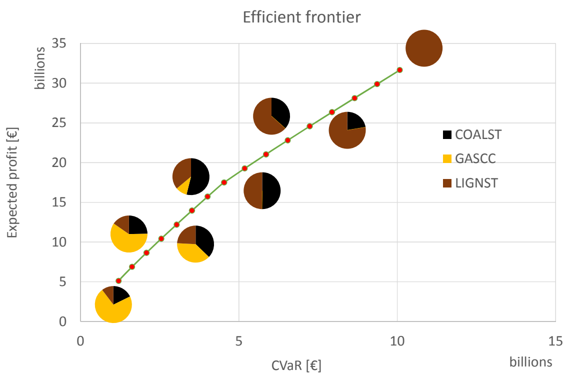

Figure 1: Efficient power plant portfolios in a scenario with 15 % higher electricity prices

As the figure shows, the share of COALST grows disproportionately. While the expected profit of lignite plants is greater than the profit of coal plants, the former are exposed to a higher risk of falling off target profit. This means that despite the absence of fuel price risks the higher exposure to the CO2 price risk leads to higher potential losses of lignite plants. In the upper third of the efficient frontier, coal plants are substituted by lignite plants as target profits are raised toward the maximum. The highest target profit can only be satisfied by a pure lignite portfolio. However, this technology constitutes the highest risk of falling short of the expected profit.

Conclusion

As the analysis shows price and volume risks can have substantial impacts on the profitability of power plants. Applying the theory of portfolio selection originally suggested by MARKOWITZ to investment decisions in the power industry provides a possible way to minimize the overall risk of falling short of profit targets by operating efficient power plant portfolios. Based on the assumptions made for the future development of prices for primary energy carriers and emission certificates only lignite power plants are able to generate a positive expected contribution margin in the present political framework with a high share of renewable energies. Higher electricity prices or additional income e.g. out of a capacity market could provide incentives for investments in coal and gas fired power plants, too. In such circumstances, a high share of gas fired power plants provides risk minimal portfolios. Postulating higher expected target profits the share of gas gives way to coal and finally lignite power plants. The latter can satisfy the highest expected return, however at the expense of the highest risk of failing.

References

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