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Investment risks in power generation: A comparison of fossil fuel and renewable energy dominated markets

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ABSTRACT

Due to their high capital intensity, weather dependent renewable energies (RES) such as solar and wind face considerable investment risks in power markets. In addition, their uncertain production volumes also affect the investment risks of other plant types through the impact on power prices and residual demand. Increasing RES shares thus potentially increase overall investment risks in power markets, which many analysts consider to be a potential problem. Against this background, this paper compares investment risks of different technologies in markets with increasing shares of variable RES. It further analyses how generation mixes are affected by these investment risks if the risks are evaluated on a stand-alone basis or in a plant portfolio context of a private firm. For this purpose, a stylized investment and dispatch model is used to conduct Monte Carlo simulations from which risk measures are derived. The results show that capital intensive RES face the highest stand-alone risks, since their profits are most affected by the power price risk. However, the results further indicate that the stand-alone risks of variable RES decrease with their share in the market because of a negative correlation of output and price risk. In addition, RES have a risk benefit in firm plant portfolios in terms of constituting a hedge against losses of fossil fuel plants. This positive portfolio effect, however, rapidly decreases and becomes negative with increasing RES shares in the market.

1. Introduction

Many countries are aiming for high renewable energy (RES) shares, especially in the electricity sector. Rising RES shares will, however, lead to changes in the structure of electricity supply, which might require adjustments in market design. A significant change is that power markets are moving “from an OPEX to a CAPEX world” (Auverlot et al., 2014: 91), since RES such as wind and solar have high capital expenditures (CAPEX) and low operational expenditures (OPEX). An important implication of this could be an increase in investment risks for electricity producers, who are typically assumed to be risk averse and thus evaluate risks negatively. Many analysts consider these high investment risks to be a potential problem, since they could discourage investors or lead to very high capital costs due to risk premiums (e.g. Auverlot et al., 2014; Finon, 2013; IEA, 2014; Newbery, 2012).

Investment risks for power plants mainly arise because future cash flows to cover the capital expenditures (mostly investment costs) depend to a large extent on risky electricity prices (revenue risk) and risky fuel and carbon prices (variable cost risk). Since these differ by technology, each plant type has its own risk profile that is also strongly affected by the overall capacity mix of the market and the correlation between the plants' variable costs and the electricity price. Plants that often set the electricity price, typically plants with relative low fixed and high variable costs, can pass variable cost fluctuations through to the consumer by raising the electricity price. As a consequence, they have a “natural hedge” due to a positive correlation of costs and revenues. Very capital intensive technologies such as RES or nuclear, in contrast, do not exhibit such a correlation between costs and revenues. The recovering of the high investment costs based on short-term power prices thus tends to be more risky for these plant types (Finon, 2013; Gross et al., 2010; Roques et al., 2008).

Up until now, however, RES have only been exposed to market risks to a limited extent in many countries because they are not fully integrated into the market and are at least partly financed by risk reducing support schemes. In the case of feed-in tariffs, for example, producers receive regulated tariffs, which stabilize the revenues and reduce the investment risks (Klessmann et al., 2008; Mitchell et al., 2006). In order to accomplish integration, which from an economic point of view is all the more important as RES shares increase, RES dispatch and investment should be coordinated by electricity prices to enhance efficiency (Hiroux and Saguan, 2010; Steggals et al., 2011).

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Such market integration implies that the potentially high investment risks are borne by investors, and negative evaluation of risks may lead to reduced investment activities and high capital costs (see above). A strategy to mitigate the risk is to hedge electricity prices with long-term contracts for the sake of a more stable revenue flow. Finding counterparties for such hedging contracts that cover a substantial period of the plant's lifetime is, however, a difficult task for plant operators and thus not often observed in liberalized markets to date (Roques et al., 2008; Rodilla and Batlle, 2012). Moreover, a further concern is that the revenues of fossil fuel plants might also be affected by increasing RES shares. The intermittency and inter-annual production volatility of wind and solar influence the power price and the residual demand for fossil fuel plants such that their revenue volatility might increase (Steggals et al., 2011).

Against this background, this paper pursues the questions of how investment risks play out in markets with increasing RES shares, and how these risks affect the generation mix. More specifically, it first quantifies and compares investment risks of typical fossil fuel technologies (coal, CCGT, OCGT) and RES (wind, PV) in stylized electricity markets with different CO_2 prices which imply different RES shares. For this purpose, an investment and dispatch model and Monte Carlo simulations are applied, where inter-annual weather uncertainty (RES availability risks) and fuel and carbon prices (variable cost risks) are stochastic inputs. In the second step, the quantified investment risks are entered into the model to analyse the effect on the investment decisions of each plant type compared to a risk free base case. For this analysis, investment risks are evaluated on a stand-alone basis (resembling project finance) and alternatively in a firm portfolio context (resembling corporate finance). The latter case allows the study of diversification opportunities, since firm risk can be lowered by investments in plants whose cash flows are not perfectly positively correlated, which is especially important if hedging via long-term markets does not allow a substantial reduction of investment risks (Gross et al., 2010; Roques et al., 2008). The results have important implications for electricity market and support scheme design, which we discuss towards the end of the paper.

The outline of this paper is as follows: in Section 2, the related literature and the contribution of this paper are presented in more detail. Thereafter, the investment and dispatch model (Section 3.1) and the considered scenarios (Section 3.2) are described. The results are presented in Section 4 and limitations of the approach are discussed in Section 5. Finally, the main findings and their implications are summarized and discussed in Section 6.

2. Literature overview and contribution

This research relates to three interlinked strands of literature, namely (1) the investment risks of capital intensive and variable RES, (2) the impact of these technologies on power prices and investment risks, and (3) portfolio optimization in electricity markets. We focus on the quantitative model based work in line with our approach.

The first strand investigates investment risks of RES under different support schemes. Kitzing (2014) and Kitzing and Weber (2015) analyse the investment attractiveness of offshore wind parks with a cash flow model and Monte Carlo simulations given power prices and wind availability risk. They find that feed-in tariffs (FIT) induce lower support costs than feed-in premiums (FIP) because the latter expose investors to electricity price risks such that they require higher returns to compensate for higher investment risks. This result is also often stressed in the literature that discusses market integration of support schemes (e.g. Klessmann et al., 2008; Mitchell et al., 2006). Less established, however, is the point made by Bunn and Yusupov (2015). They apply a simulation model to calculate financial risks of wind farms and show, somewhat in contrast to Kitzing (2014) and Kitzing and Weber (2015), that investment risk under a more market integrated support scheme (green certificate trading) can be lower compared to a FIT. The reason is a negative correlation between the output risk and the electricity price risk, i.e. a lower wind production leads to higher power prices and vice versa, such that revenue volatility is mitigated. This implicit hedge increases with the wind share, but is not effective under a FIT, since wind generators receive fixed tariffs instead of power prices (see also Nagl, 2013).

A second strand of literature relies on simulations that indicate increasing power price volatility for higher RES shares due to their variable output (Green and Vasilakos, 2010, 2011; Muñoz and Bunn, 2013; Pöyry, 2009; Redpoint, 2009). The crucial question, however, is whether higher price volatility also translates into higher investment risks for the plants in the market. Green and Vasilakos (2011) find a moderate increase in the volatility of fossil fuel plants' profits – as an indicator for investment risks – given year-to-year wind output variations for a wind capacity share of about 30% compared to a case with solely year-to-year demand variations. The Monte Carlo simulation by Muñoz and Bunn (2013), also incorporating other risk factors (e.g. fuel price risks), results in substantially higher financial risks for wind, nuclear and CCGT plants if wind capacities replace coal.

Finally, another relevant stream of the literature relates to portfolio optimization. The mean–variance portfolio theory (MVP), initially developed by Markowitz (1952) for financial securities, is used to optimize plant portfolios by considering plant risks and their correlations to reduce portfolio risk through diversification. Awerbuch develops and conducts MVP in various studies from a social planner perspective (e.g. Awerbuch, 2000; Awerbuch and Berger, 2003; Awerbuch and Spencer, 2007). The approach is refined in several papers, for example to capture RES availability as well, as in Arnesano et al. (2012) and Jansen et al. (2006), and to combine it with investment and dispatch models, as in Delarue et al. (2011) and Sunderkötter and Weber (2012).[1] A typical finding of these studies is that adding technologies with high fixed costs, such as RES, to a generation mix including high shares of conventional plants with volatile fuel costs lowers expected portfolio risks (or costs) for a given level of costs (or risks), even if the capital intensive technologies have higher costs on a stand-alone basis.

In this paper we pursue a similar approach, but instead of employing a social planner perspective we conduct a portfolio optimization from a private investor's perspective. That is, we take a market perspective, where plants interact via the power price, which constitutes an important risk factor for the plants. This in particular allows us to study diversification incentives for firms in liberalized markets.

Such a private investor perspective is also used by Roques et al. (2008), who calculate Net Present Value (NPV) distributions with Monte Carlo simulations serving as input for the portfolio optimization. They use a cash flow model and simply assume fixed production volumes and normally distributed fuel, CO_2 and electricity prices and correlations between these prices. Other studies pursue a similar approach but calculate endogenous production volumes and power prices with supply function models (Green, 2008) or use stochastic processes for fuel and power prices (Ziegler et al., 2012).[2] Lynch et al. (2013) conduct a least-cost unit commitment and dispatch model. Production volumes and electricity prices are thus determined endogenously. They calculate long-term investment risks with Monte Carlo simulations for inter-annual fuel and CO_2 price risks, but pursue a non-equilibrium approach, which means they do not account for scarcity prices such that all plants have negative expected returns. This also implies that the peaker plant

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[1] Other applications of MVP in the power sector in different models from a cost perspective include, for example, Bhattacharya and Kojima (2012), Doherty et al. (2006), Gotham et al. (2009), Huang and Wu (2008), Vithayasrichareon and McGill (2013) and Vithayasrichareon et al. (2015). Further explanations about MVP and several other applications can be found in Bazilian and Roques (2008).

[2] Fortin et al. (2008) generate the profit or cost distributions for their electricity generation portfolio optimization by employing a real options approach. Similar to the portfolio applications, real options theory also has its roots in finance and has often been used to dynamically optimize irreversible investment under uncertainty, see, for example, the overview in Kuik and Fuss (2011).