Competition in Electricity Markets with Renewable Energy Sources: Non-technical summary

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With mounting concerns over climate change caused by fossil fuels, there has been growing reliance on renewable energy. Currently, 67 countries, including all EU countries, have renewable energy policy targets, mandating electricity companies to provide a minimal fraction of total electricity supply from renewables. In the United States, for example, this target is set to grow to 20% by 2020, while it is 33% in the UK and also 20% in the European Union. These targets have motivated many conventional (thermal) energy companies to seek a diversified energy portfolio and increase their investments in renewable supply. The European energy giant Alstom has thus concluded: "A diverse energy portfolio is the only sound business and policy strategy able to address any Energy & Climate scenario". Though the high setup costs of renewable plants are often subsidized by public funds, they are argued to benefit the economy not just by reducing fossil fuel emissions but also by delivering cheaper energy to consumers through the *merit order effect (MoE)*. The merit order effect arises because renewable energy has negligible marginal costs and reduces the spot equilibrium price. Figure 1 depicts the merit order effect in action in the German market and shows the strong negative correlation between the supply of (intermittent) renewable energy and the wholesale electricity price.

This paper argues that the objective of a diversified energy portfolio of conventional energy companies conflicts with the presumed benefits from increasing supply of renewables in terms of lower prices (via the merit order effect). We show that when the increase in the supply of renewable energy takes the form of diversified energy portfolios, the MoE is partially neutralized. In the extreme case where all of the supply of renewables comes in the form of such diversified energy portfolios (meaning that it is supplied by the same conventional energy companies), the MoE is fully neutralized, and greater renewable supplies, or more favorable realization of renewable supply outcomes, have no impact on equilibrium energy prices.

Our baseline and simplest model uses the standard Cournot oligopolistic competition setup to establish the partial or full neutralization of the MoE. The main economic force leading to this result is that diversified producers have an incentive to offset the price declines due to the MoE by reducing their conventional energy supplies. The greater is the supply of renewables, the stronger is this incentive. This force is related to the strategic substitutes property of Cournot competition, inducing suppliers to cut production when the supply of renewables is high. But crucially, this incentive is exacerbated because diversified energy companies take into account the loss of profits from their own renewable supplies that would result in the absence of such a cut.

We then enrich this baseline model to incorporate two important features of energy markets: forward contracts, and correlated imperfectly observed shocks to geographically proximate renewable energy suppliers. Forward contracts play a central role in many energy markets, both because of private parties' incentives to hedge pricing risk and because of regulations mandating forward contracts for generators. We analyze forward contracts by adapting the seminal work of Allaz and Villa (1993), who demonstrated that forward contracts lead to lower equilibrium prices in oligopolistic

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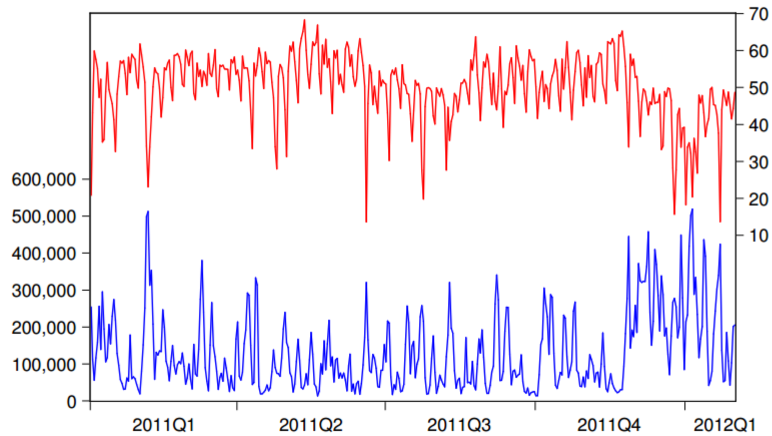
Figure 1: The relationship between prices ($ /MWh) and renewable energy output (MWh) in Germany (top: prices; bottom: renewable energy output). Source: European Energy Exchange (EEX).



markets. We show that our main results on the partial and full neutralization of the MoE applies in the presence of forward contracts in exactly the same fashion as in our baseline model.

Our full model incorporates both forward contracts and correlated, imperfectly observed shocks. We model this latter feature by assuming that renewable energy supplies in similar geographic areas are subject to locally correlated variability, and that each firm only observes its own realization of renewable supply, but is aware of the structure of local correlation. We are not aware of any other work in the literature developing a tractable model of incomplete information Cournot equilibrium with forward contracts and renewable energy. The incomplete information Cournot equilibrium in this case again shows the neutralization of the MoE. In addition, this version of the model enables us to study the implications of renewable supply on price volatility. Focusing on spatial configurations in which the correlation of renewable supply decays according to distance across plants, we show that the spot price volatility increases as the distance among renewable plants increases. This is because when renewable plants are far apart so that there is less correlation among renewable supply, they create more miscoordination in supplies, increasing price volatility. Using this intuition, we further show that among *all* geographic configurations with "regular" structures, the maximum price volatility occurs when renewable plants have a "ring" structure and the minimum price volatility arises in geographic configurations exhibiting a "complete" structure.

Finally, we study the profit and welfare implications of diversified renewable portfolios. Intuitively, diversified energy portfolios are beneficial for thermal producers, but detrimental for consumers. Most importantly, the negative effect on consumers resulting from higher markups dominates, and overall welfare declines with greater diversification.