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The effects of renewables in space and time: A regime switching model of the Italian power price

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HIGHLIGHTS

- A regime switching model of the effects of renewables on network congestion.
- Focus on the highly congested link between Sicily and the Italian mainland.
- Renewables produced in Sicily reduce the congestion frequency.
- Wind power from Sicily acts as a substitute for transport capacity.
- The merit order effect is confirmed.

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ABSTRACT

Renewable energy production can exercise a downward pressure on electricity prices by partly crowding out conventional units characterized by higher marginal costs (*merit order effect*). Yet, congestion induced by renewables would partly offset the merit order effect in the congested zone, unless renewables reduce the need for imports and allow the emergence of prosumers. These *congestion effects* of renewables are hereby jointly tested with the merit order effect by means of an endogenous regime-switching model wherein a regime corresponds to the observable status (congested/non-congested) of the grid. The model is taken to data from the Italian power exchange, observed in 2012 and 2013, with a focus on the line connecting Sicily with the South zone, a frequent bottleneck in the Italian transmission grid. The results confirm the merit order effect previously detected in the literature and highlight a negative congestion effect, i.e. renewables relieve congestion from Sicily, a systematic importer, but not from the Italian peninsula (the exporting region). This effect is mainly driven by the wind power in-feed.

1. Introduction

Integrating renewable energy (RE) sources within transmission grids conceived under the centralized power generation paradigm is a major challenge in current energy policy. Cross-border limits induced by intermittent RE production slow down the integration of electricity markets, as it is the case in the European Union (Zachmann, 2011) and in the Mediterranean basin (Cambini and Rubino, 2014); their mitigation is among the priorities of the 2030 Climate–Energy Package approved by the European Council in October 2014. The constraints that are binding within countries, though, deserve at least the same share of attention, as their removal adds value to long range interconnections.

Congestion driven by renewables, empirically documented by Førsund et al. (2008) and Kunz (2013), among others, can increase the overall power system costs, since the opportunity cost of using a line is higher when transmission constraints are binding. The transmission cost is a relevant component in the overall cost of running RE plants, especially for sources, such as wind, that tend to be located far away from load centers. It has also been argued that RE-driven congestion is a negative externality causing individual investors to choose larger plants than in the social optimum (Hitaj, 2012) and to exploit market power opportunities in geographically constrained market zones. The effects of congestion can be exacerbated by pricing rules that do not give enough

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incentives to optimize the location of new RE plants (Neuhoff, 2011; Kunz, 2013). RE-driven congestion is a highly relevant policy question, since large amounts of public funds, dispensed in the form of subsidies to RE, may turn into congestion rents received e.g. by companies producing from fossil-fueled units.

New RE capacity may nonetheless relieve congestion. Photovoltaic panels and micro-wind turbines represent major examples of distributed generation, a substitute for transmission capacity because it allows the emergence of prosumers who self-generate power for their own needs. RE supply can moreover avoid congestion in regions of the grid that, being characterized by a sizable imbalance between demand and conventional supply, are systematic importers of energy.

Such *congestion effects* of renewables are relatively neglected in a literature that has mainly focused on the energy expenditure savings and profit redistribution related to the so-called *merit order effect*: renewables are found to reduce the amount of highly priced fossil-fueled electricity that is needed to clear the market, yielding a downward pressure on the market-clearing price (see e.g. Saenz de Miera et al., 2008; Twomey and Neuhoff, 2010). Congestion induced by renewables would enhance the market power attempts of pivotal generators running fossil-fueled units, threatening to offset, at least in part, the energy expenditure savings descending from the merit order effect.

This paper seeks to jointly estimate the merit order effect (renewables crowding out conventional units) and the congestion effect (whether renewables relieve congestion or aggravate it). The merit order and congestion effects of renewables are assessed through an endogenous regime-switching model. In the econometric model proposed here, the electricity price in a spatially constrained market zone is regressed on electricity demand, intermittent RE production, and a market power indicator. The marginal effect of RE production in the price equation is the merit order effect. As a novel feature of this model, the parameter tuning the merit order effect is allowed to vary across regimes identified by the observable status (congested/not congested) of the transmission line linking two market zones. Unlike in Haldrup and Nielsen (2006a,b), who also assumed observable regimes, the regime probabilities are endogenous with respect to the amounts of RE produced and electricity demanded at both sides of the possibly congested line. The marginal effect of the RE in-feed on congestion is hereby called the congestion effect. Its sign is positive if RE production causes congestion, negative if renewables reduce the frequency of bottlenecks. The merit order and congestion effects are, respectively, direct and indirect effects of RE production on electricity prices, that can be separately estimated through the regime switching model.

The model is estimated on daily-frequency data from the Italian power exchange, observed between January 2012 and September 2013, with a focus on the line connecting Sicily with the Italian mainland, a frequent bottleneck in the Italian transmission grid: the island was separated in about 86% of the hourly market sessions in the sample period. Italy is an interesting test-bed for the relationship between renewables and network congestion. Italian wholesale electricity prices have historically been higher than the European average, causing the returns from adequate investment policies to be high. Generous RE promotion policies co-exist with inefficiently decentralized authorization procedures. Sicily and, similarly, Sardinia have for long time been nearly *electricity islands*, due to the limited capacity of their links with the Italian mainland, and the paucity of their hydropower resources implies limitations in flexibility and storage.

Together with a merit order effect, the results throw light on a location dependent and negative congestion effect, whereby congestion is relieved by non-dispatchable renewables produced in Sicily (the importing zone), but not by those produced in the South (the exporting zone). Estimates of a model separately including intermittent renewables show that the congestion effect is mainly due to Sicilian wind power. The results are confirmed after including hydropower among renewables, controlling for the volatility of intermittent renewables, and accounting for the endogeneity of the market power indicator. Since the diffusion of distributed generation in Sicily is relatively low, the capacity shortage affecting the Sicilian power system seems the most likely explanation for the negative congestion effect.

The paper is structured as follows. Section 2 motivates the regime switching method, derives the specifications estimated in this paper from a simple structural model, and describes the sample. The results are illustrated in Section 3, along with robustness exercises. Section 4 offers a discussion of the results, whereas Section 5 outlines the main policy implications before concluding.

2. Methods

2.1. Literature review

2.1.1. The merit order effect and grid congestion

Along the path toward grid parity, public support to RE sources seemingly proves beneficial not just for the environment, but also for consumer budgets. Evidence from Germany (Sensfuss et al., 2008; Cludius et al., 2014) and Spain (Saenz de Miera et al., 2008) shows that the electricity price savings achieved through higher renewable penetration exceed the volume of the net subsidy payments, or partly reduce the burden of feed-in tariffs (McConnell et al., 2013 on Australia, Tveten et al., 2013 on Germany). Such positive net returns to RE support hinge upon the so-called merit order effect. Power generated from conventional plants is partly crowded out by RE that is produced at basically null marginal costs. As a result, renewables exercise a downward pressure on the market-clearing price, mirrored in lower retail prices.

A wealth of econometric studies provides empirical support to the merit order effect. In Ketterer (2014), the German power price is modeled through a mean-reverting process with conditionally heteroskedastic disturbances, including the predicted wind power feed-in in both the mean and the variance equation. A 10% increase in wind power production leads to a decline in the power price by nearly 1%. Paraschiv et al. (2014) estimate a state-space model of the German power price with time-varying coefficients and find that the coefficients associated to wind power ad photovoltaics are negative, although the wind power coefficients are more volatile than for photovoltaics. Including information about renewable energy production improves the explanatory power of the model. In Veraart (2015), focused on EEX Phelix baseload prices, a larger predicted wind energy production yields a downward pressure on price in a regime-switching model with generalized hyperbolic disturbances, albeit at the cost of higher volatility, skewness, and tail fatness.

The merit order is more neatly linked to market structure and conduct in simulation studies based on various theoretical models. The simulations of an oligopolistic model in Twomey and Neuhoff (2010) showed that the average difference between energy prices received by wind and thermal power plants can be larger than 20 GBP/MW h in some scenarios. Sioshansi (2011) used data from the Electric Reliability Council of Texas (ERCOT) market to show that an additional 10 GW of wind capacity would lead to divergence between the average value of overall electricity sales and the average value of wind energy sales. In the power auction simulated by Banal-Estañol and Ruperez-Micola (2011), a low-cost, intermittent plant (e.g. wind) brings prices down, but prices remain well above marginal cost because generating companies