Research on the Economics of Renewable Energy Policies

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Decreasing investment costs and more ambitious environmental regulations have rapidly increased electricity production from renewable energy (RE) technologies worldwide. Installed renewable capacity has more than doubled during the last ten years, and it is expected to increase further during the coming years. The increasing presence of RE technologies in electricity markets raises important questions on the optimal policy to incentivize RE investment, and deployment and on the future performance of electricity markets where these types of technologies will dominate. Our team's research has contributed to shedding light on these questions.

In three recent publications from our team that are forthcoming in The Economic Journal, the American Economic Journal: Economic Policy, and the Journal of the Association of Environmental and Resource Economists, we highlight some critical trade-offs in this context. The first paper highlights the role of private information regarding available RE capacities, while the second paper focuses on the differences across support schemes for renewables. The third paper identifies and quantifies inefficiencies in allocating solar PV plants because of uniform subsidies across geographic regions.

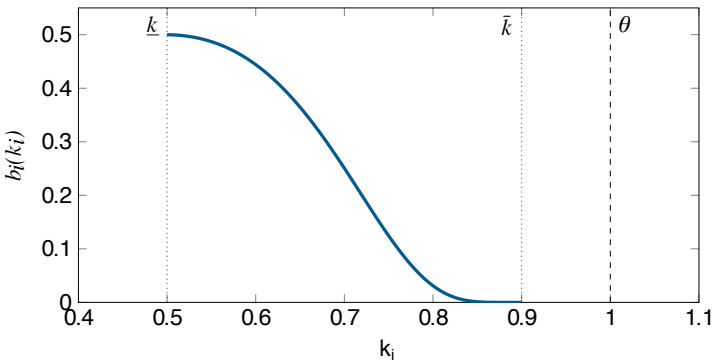
Auctions with Privately Known Capacities

An increasing share of RE production might impact firms' bidding behavior and market outcomes in electricity markets. From a competition point of view, there are two main differences between markets dominated by RE technologies and traditional electricity markets, which mainly depend on conventional technologies. First, the marginal cost of conventional power plants depends on their efficiency rate as well as on the volatile price at which they buy fossil fuels. In contrast, the marginal cost of renewable generation is constant (and essentially zero), as plants produce electricity from freely available natural resources, such as wind or sunshine. Second, the availability of energy from renewable power plants depends on weather conditions that are difficult to predict, unlike conventional power plants. These factors can fundamentally change the type of information available to bidders and, therefore the competitiveness of the market.

To account for these differences, in this paper, Natalia Fabra and Gerard Llobet develop a model of competition in electricity markets in which available capacities are treated as firms' private information. The authors characterize bidding behavior under different auction designs: a uniform-price auction (or pay-as-clear), which pays the winning producers at the market-clearing price, and a discriminatory auction (or pay-as-bid), which pays each producer at their bid. Moreover, the paper studies how private information changes the nature of market equilibria.

The paper finds that under the uniform-auction format firms have incentives to exercise market power by offering all their capacity at a price above marginal cost or by withholding capacity, as shown in Figure 1. Bidding behavior under the discriminatory auction is similar. Yet, firms do not gain from withholding output as this does not affect the price they receive, and they tend to offer higher prices relative to the uniform-price auction. However, since they receive their bid rather than the highest accepted one, consumers end up paying lower prices under the discriminatory format compared to the uniform-price format. Finally, to understand how private information changes the nature of the equilibrium, the paper also characterizes competition when all information is either publicly known or unknown. The authors find that more information (on costs or capacities) strengthens firms' market power.

Figure 1: Equilibrium price offers as a function of realized capacity



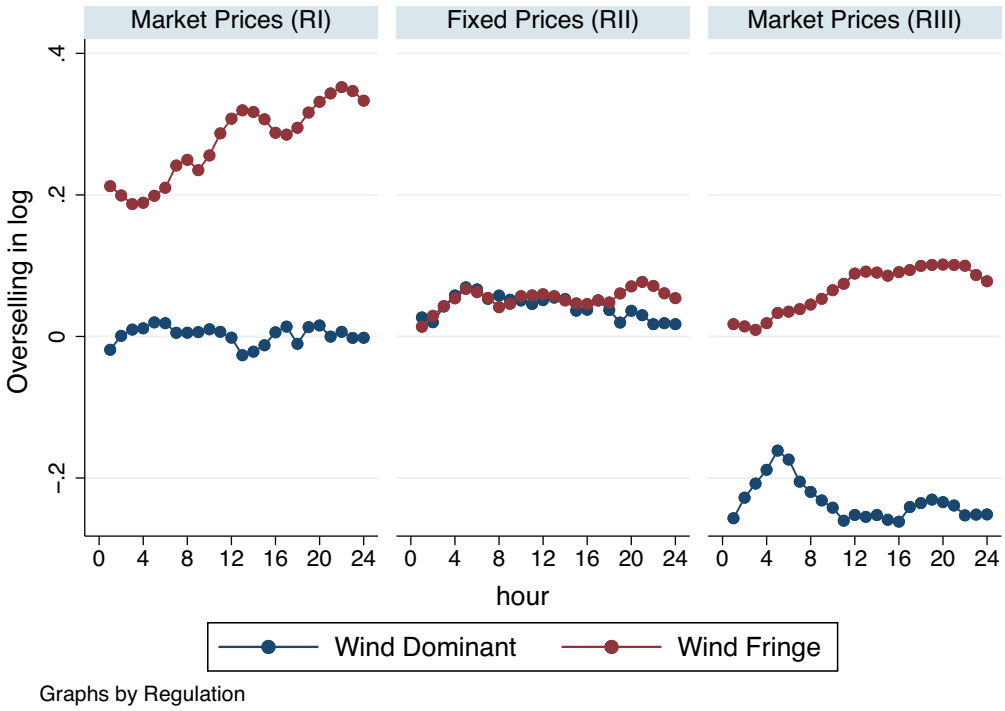
The findings clearly show that market prices will go down as more renewable energy capacity becomes available. Still, they will not converge to marginal costs unless sufficient excess capacity exists. Another insight from the study is that when marginal costs are pretty similar (as is the case for renewables), market transparency might exacerbate market power without delivering efficiency benefits.

Market Power and Price Exposure: Learning from Changes in Renewables Regulation

As market power might offset (some of) the price-depressing effect of renewables in wholesale electricity markets, it is crucial to understand how renewable energies affect firms' pricing incentives and how this impact depends on regulation. In this paper Natalia Fabra and Imelda study how RE technologies impact wholesale electricity prices and how this effect depends on the regulatory environment. In particular, the article focuses on two types of commonly used regulations for renewables: whether they are paid a fixed price or exposed to fluctuations in wholesale electricity prices.

The paper first develops a theoretical model to show that fixed market prices, such as feed-in tariffs, are relatively more effective at curbing the market power of dominant firms that own large shares of renewable capacity. In a second step, the

Figure 2: Wind sales across markets (day-ahead – final allocation)



authors estimate the causal effect of these pricing schemes on firms' behavior (for example, the decision to withhold output in the day-ahead market to push prices up), leveraging a quasi-experiment in the Spanish electricity market. In particular, the regulator first decided to expose existing wind producers to wholesale market prices, moved them to fixed prices, and ultimately switched them back to market-based prices.

These changes in the pricing scheme strongly impacted the strategic producers' behavior, as can be seen clearly in Figure 2. In particular, the strategic producers withheld more wind output when exposed to market prices as a way to exercise market power. Motivated by this variation in bidding behaviour, the authors empirically test for the main theoretical predictions using structural and reduced form estimates. They confirm that switching from full-price exposure to fixed prices caused a 2-4% reduction in the average price-cost markup.

This paper contributes to the ongoing policy debate on how to pay for renewables. Since compliance with environmental targets requires massive investments in renewables, it is paramount to understand how alternative renewable pricing schemes impact market prices and efficiency. A key message of the paper is that for this kind of analysis, it is essential to consider the interaction between conventional and renewable generation technologies, and not just renewables alone. The interplay between the two very much depends on the ownership structure, which drives the paper's market outcomes and efficiency results.

(Mis)allocation of Renewable Energy Sources

The type of policy support may also impact the efficiency of RE investment. Most policies, such as feed-in tariffs, offer little flexibility to adapt to heterogeneous benefits across geographic locations. This paper provides a framework to empirically quantify the extent of misallocation of solar PV plants, potentially driven by the lack of location-specific incentives in uniform feed-in-tariff policies.

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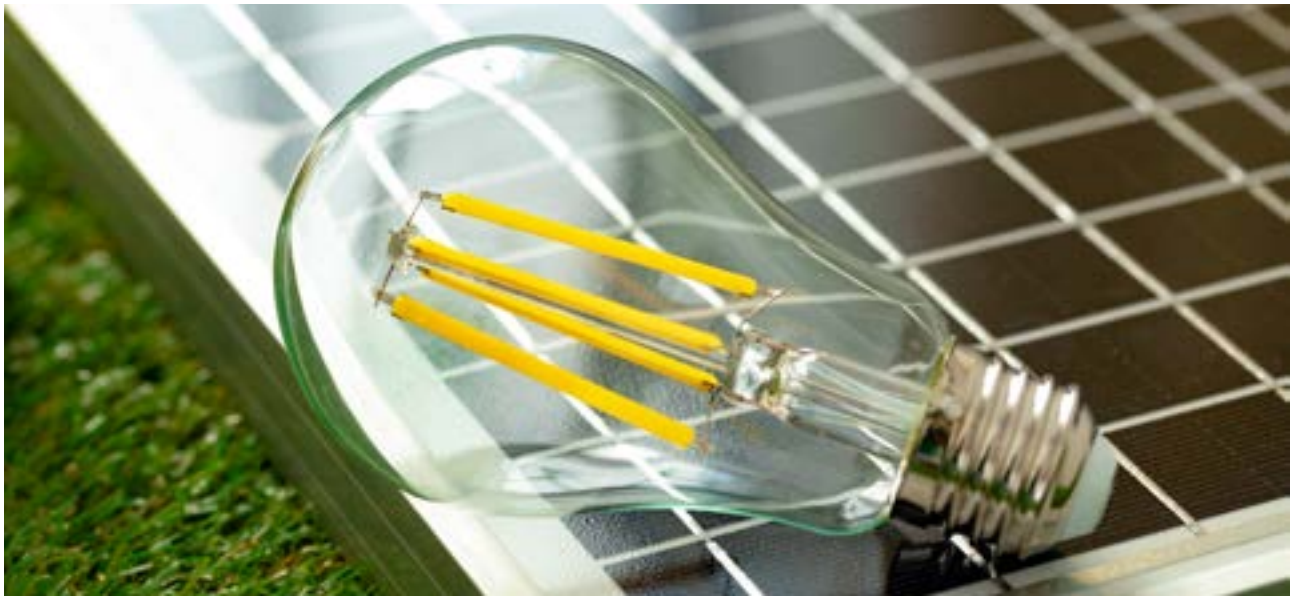
To do so, Stefan Lamp and Mario Samano use high-frequency data on production and demand for the German electricity market to measure the benefits of an additional unit of electricity output from solar due to the displacement of production from conventional sources.



These benefits include the private costs of production and grid reliability and the social costs of the displaced emissions. Equipped with these estimates, the authors construct a series of counterfactual scenarios in which solar capacity gets reallocated from regions with low marginal benefits into regions with higher marginal benefits to maximize surplus while keeping the total amount of solar capacity constant within the entire market. This allows the authors to simulate total output and calculate the gains across the different counterfactual scenarios.

The results show that the gains from reallocation range from approximately 16% to 30% at intermediate values of the maximum solar rate

The paper also recognizes the importance of electricity trade in reallocating output from solar and calculates the gains from an increase in transmission capacity between subregions. To do this, the authors compute the shadow cost of transmission and use it to back out the implied size of the transmission capacity. This allows them to reallocate solar capacity assuming that the transmission capacity is expanded within a pre-estimated range, and to compute the gains from reallocation for different levels of capacity expansion. The results show that the gains from reallocation range from approximately 16% to 30% at intermediate values of the maximum solar rate, defined as the ratio between the solar capacity allowed and the maximum feasible solar capacity.

Overall, this paper quantifies the inefficiencies of the allocation of solar PV and puts in perspective the costs of simple economic incentives for technology adoption. A key finding is that the optimal siting of solar, in line with the marginal benefits, would lead to substantial gains compared to the status quo, especially if transmission capacity between regions is taken into account •

Further reading

Fabra, Natalia, and Gerard Llobet (forthcoming) "Auctions with unknown capacities: Understanding competition among renewables.", *The Economic Journal*.

Fabra, Natalia and Imelda (forthcoming) "Market Power and Price Exposure: Learning from Changes in Renewable Energy Regulation." *American Economic Journal: Economic Policy*.

Lamp, Stefan, and Mario Samano (forthcoming). "(Mis) allocation of Renewable Energy Sources.", *Journal of the Association of Environmental and Resource Economists*.