DYNAMIC (MIS)ALLOCATION OF INVESTMENTS IN SOLAR ENERGY

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Overview

Increasing the share of solar energy in electricity supply is one of the cornerstones of current climate policies. Over the past decade, annual global investments in solar energy have exceeded $100 billion (IRENA and CPI, 2020). Improving the cost-efficiency of these investments, that is how much renewable electricity is produced per dollar invested in solar facilities, could thus increase significantly the pace of the transition towards renewable energies.

A large body of research suggests that realized investments in solar energy are unlikely to have been cost-efficient (Callaway et al., 2018; Lamp and Samano, 2022; Sexton et al. 2021). More precisely, these studies find that a social planner would most likely have sitted solar facilities differently than what is observed in practice. For example, Lamp and Samano (2022) argue that reallocating solar facilities across space in Germany could increase their social value by about 5% relative to their current social value. These studies typically focus on misallocations arising because of the heterogenous social *value* of the electricity generated by solar facilities. Indeed, depending on *where* a solar facility is located, 1 kWh of solar energy will displace generation from power plants with heterogenous fuel costs and environmental externalities. In addition, existing studies typically focus on static misallocation, in the sense that they assess to which extent solar facilities could be reallocated optimally across space with some constraints on the maximum capacity that may be installed in each spatial unit. In contrast, we study inefficiencies regarding *when* different types of solar facilities have been commissioned.

We focus on a situation where the social value of 1 kWh of electricity generated by a solar facility is roughly uniform across space. This assumption is indeed more realistic in relatively small countries whose transmission grid experiences little congestion, such as France. Solar facilities are however very heterogenous in levelized-cost terms. Indeed, utility-scale units benefit from economies of scale relative to their distributed generation counterparts. Even within a given type of installations, say for example 90kW rooftop facilities, levelized costs remain very heterogeneous because they depend on solar resource availability, the orientation of the roof, how difficult it is to install the panels, etc. Such “supply-side” sources of heterogeneity may actually prove larger than the “demand-side” sources of heterogeneity studied in the existing literature.

We consider the dynamic optimization problem faced by a social planner who must choose, over a period of several years, the commissioning dates of a set of solar facilities. His optimization is constrained by a target trajectory of total yearly solar electricity generated, corresponding to the total solar output actually generated each year. Misallocation may then arise in a dynamic sense: the present value of the total investment costs of the realized deployment of solar installations may be higher than the present value of the cost of an optimized trajectory.

We formalize this dynamic misallocation of investments in solar energy and quantify its magnitude empirically for the case of France over the period 2005-2021. We argue that our approach provides a credible lower bound to the cost of misallocation of investments in solar energy. Indeed, in contrast to the existing literature, we assume that solar facilities can only be installed in locations where a facility actually exist today, avoiding measurement errors that could be induced by optimistic assessments of the maximum solar capacity that may be developed in each geographical unit. In addition, our optimized trajectory reproduces the realized total yearly solar generation, keeping constant the social value of the electricity generated (given our assumption of a uniform social value). This modelling choice thus abstracts from the possibility to have, in aggregate, over/under-invested in solar energy in any specific year.

Methods

We first develop a theoretical framework to clearly define our concept of dynamic misallocation. In particular, we show that the socially optimal trajectory of investments in the different solar facilities may be characterized as the solution of a linear program.

We then implement numerically our method to the set of 50,000+ solar installations that where commissioned in France between 2005 and 2021 (small rooftop installations are aggegrated at the neighbourhood level as a single unit).

Finally we compare the computed optimal trajectory to realized investment. We use the present value over the considered period of investments costs in solar facilities as our main evaluation metric.

Results

Preliminary results suggest that the optimal trajectory of solar investments over the period 2005--2021 would have been 30% cheaper (in present value terms) than the realized trajectory. In other words, the present value of deploying the existing solar generation fleet could have been 30% lower without changing the amount of solar electricity generated each year, which corresponds to a reduction in the levelized cost of solar energy of about 32 Euros per MWh. This result primarily arises from a very suboptimal timing of investments, both across technologies and across space. The optimal trajectory leverages economies-of-scale by commissioning the larger solar projects much earlier than they actually were. The optimization also exploits the heterogeneity of capacity factors across locations by postponing the commissioning of projects located in Nothern parts of the territory.

We implement several counterfactuals to investigate the drivers of the observed misallocation. Past public support mechanisms for solar energy seem to have played a significant role in the misallocation of solar invesments. Smallest installations (under 0.036 MW) are associated with almost 80% of the total misallocation despite representing only 21% of total installed capacity. This is consistent with the high level of the early feed-in-tariffs rates for small installations. Besides, the largest contributions to the misallocation occurred in 2009-2011, at a time were we observe the largest discrepancies between feed-in-tarrifs and levelized costs of solar energy. The introduction of solar energy auctions after 2016 appeared to have significantly reduced the misallocation of invesmtents.

Conclusions

Solar facilities installed in different locations are very heterogenous in terms of their levelized-cost, probably more than they are in terms of the social value of the electricity they produce. Although the existing literature has devoted significant attention to the latter source of heterogeneity, the former has been somewhat overlooked.

We propose a clearly-defined methodology to quantity the dynamic misallocation that can arise from the heterogeneity in levelized cost across installations. This approach is fairly conservative as it shuts down other sources of inefficiencies such as (i) the failure to install solar units in locations that would have been suitable ; or (ii) under/over aggregate investments in solar generation (relative to a social optimum) in any specific year.

We apply our methodology to the case of France for the period 2005-2021. Despite the conservative nature of our definition of misallocation, our results suggest that the present value of the investments in solar energy could have been 30% lower and still produce the same amount of solar electricity each year.

Our results suggest that most of the misallocation costs are due to the very large initial investment in smallest solar units. However, this may be justified by other policy objectives beyond efficiency. For example, small installations may generate economic benefits that are more spread out over space (jobs, revenue, taxes, etc.) and reduce conflicts regarding land uses. In addition, part of the misallocation may correspond to a somewhat necessary "trial and error" process when investing in a non-mature technology.

References

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