# The impact of local content requirements on domestic innovation in the solar auctions: The case of India

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## Overview

Solar technology diffuses across the globe as countries try to embark on a sustainable development path. Over time solar auctions have emerged as the dominant policy tool for expanding solar energy globally. The popularity of auctions originates mainly in the low bidding prices governments realized in auctions. Despite being a very popular policy tool for governments in developing economies, there are very few empirical studies of the impact of auctions on the local economy. Existing work focuses on comparing auctions to feed-in-tariffs and concentrates mostly on project realization rates (Dobrotkova et al. 2018, Bayer et al. 2018). However, other aspects such as a lack of incentives to invest in local production and R&D due to the strong price pressures exerted by open auctions, have not been examined. Furthermore, while several authors state that auction designs differ by country and that auctions' effectiveness depend on their design (Hochberg & Poudineh 2018, Del Rio & Linares 2014), there are no econometric studies that investigate the effect of auction design on economic policy objectives such as domestic innovation or technological upgrading. Existing empirical studies focus on more direct objectives of auctions, such as project realization rates (Matthäus 2021) and bidding price (Probst et al 2020).

In this paper we address these gaps by assessing the impact of 41 solar auctions in India, held between 2013 and 2019, on innovation in the 113 participating firms. More specifically, we analyze whether the participation in auctions that prescribed local content requirements (LCR) affected domestic patent applications. The main aim of LCR is to promote local, domestic manufacturing of the components used to build the solar PV plants that are auctioned but LCR may differ in their design and stringency. For example, LCR may require local manufacturing of single components, e.g. solar PV modules or cells, require a minimum share of locally sourced inputs measured in value or weight or require employing local staff. In terms of economic theory, the impact of LCRs on innovation is ambiguous. On the one hand, LCR may incentivize firms to invest in R&D given higher prices provide sufficient rents. On the other hand, lower and exclusively national competition in LCR-auctions may reduce firms' propensity to innovate.

## Methods

The central identification strategy of the study explores the fact that the Indian government, between 2013 and 2016, ran simultaneously auctions with and without local content requirements (LCR), as also done in Probst et al. (2020). In contrast to Probst et al. (2020), we focus on the firm rather than the bid-level to identify whether participation in LCR auctions has led firms to innovate and file solar PV patents. A simple comparison of the innovation activity between firms that participated in auctions with vs. without LCR may suffer from selection bias. While there might be some overlap between the firms that participated in either type of auction, both groups may have structurally different characteristics. To overcome this problem, we use propensity score matching combined with difference-in-difference to estimate a credible counterfactual and compare innovation outcomes before and after the introduction of LCR auctions between the treatment and control firms. Our main outcome variable is the total number of solar energy patents filed by the firms at the Indian Patent Office until 2020.

Our dataset is a cross-sectional dataset of 113 firms that participated in 41 solar energy auctions between 2013 and 2019, which compromises the second and third phase of India's national solar mission. The auction data, relating to the firms' participation and their request and awarded capacities, was retrieved from tender documents issued by the Solar Energy Corporation of India (SECI), which is a public company under the Ministry of New and Renewable Energy, established to facilitate the implementation of the National Solar Mission. The data about firm characteristics (e.g. location, origin, sector) stems from Mergent Intellect. Finally, the patent data was obtained from National Patent Office of India. Solar-specific patent were identified and classified based on the classification by Shubak (2019), who identifies 283 IPC codes related to solar photovoltaic (PV) technology.

In a first step, we determine the matching variables for the propensity score estimation. The exact covariates used in the propensity score estimation are informed by economic theory and we select the variables based on their significance adding one variable at a time and keeping the significant covariates in the model. Our final prediction variables for the propensity estimation are a dummy whether the firm is Indian or not, the number of non-solar patents filed prior to the treatment (converted to inverse hyperbolic sine, due to non-normality and large amount of zero),

whether the firm is a manufacturer and whether the firm participated in the first phase of the National Solar Mission. We are using the following logit model to estimate the propensity scores:

$$LCR_i = \beta_0 + \beta_1 ihs(patents\_pre)_i + \beta_2 SOE\_India_i + \beta_3 Indian_i + \beta_4 manufact_i + \beta_5 phase1_i + \varepsilon_i \quad (1)$$

We are then testing different matching algorithms to select the control observations. To avoid matching firms that are too different from one another, we decide to employ caliper radius matching, restricting our control sample to observations that are within a 0.1 or 0.05 caliper of the propensity score of a treated observation. Following the approach from Munch & Schaur (2018) the average treatment effect on the treated is estimated as the average difference between the increase in patents y for firms i in the treatment group (T) minus the weighted average of increase in patents for the selected control firms i in the control group (C). The weight w is equally distributed the control firms are within the 0.1 or 0.05 caliper of the propensity score of the matched treated firm.

$$\delta_{ATT} = \frac{1}{N} + \Sigma_{i=1}^{N} (\Delta y_i^T - \Delta w * y_i^C) \quad (2)$$

## Results

Figure 1 shows the results of our difference in difference analysis combined with matching. We do not find evidence that participation in LCR auctions leads to a significant increase of a firm's patenting activity. The result is robust to the exclusion of two outlier firms, Bosch and Sunedison, who own many patents but only participated in one auction respectively. The effect does also not change significantly when restricting our sample to firms that actually won an LCR auction, as winning could be regarded as a more direct effect of the demand stimulus created by LCR than mere participation. As can be observed by the (non-significant) negative coefficients, patent application for firms that did not participate in LCR auctions actually increased more than for LCR participants. Figure 2 shows that while firms with LCR participation actually patent more over the whole period, they have done also prior to the introduction of the LCR policy (pre-2011). Therefore, the net increase (+8) is smaller for the treatment group than for the controls (+15).

Difference-in-difference combined with matching

| | All firms | | Winner firms | | All w/o outliers | |
|---|---|---|---|---|---|---|
| | (1) caliper = 0.1 | (2) caliper = 0.05 | (3) caliper = 0.1 | (4) caliper = 0.05 | (5) caliper = 0.1 | (6) caliper = 0.05 |
| participated in LCR | -0.27 | -0.18 | -0.48 | -0.01 | -0.31 | -0.37 |
| | (0.67) | (0.64) | (0.55) | (0.19) | (0.30) | (0.31) |
| Constant | 1.09*** | 1.00*** | 0.98** | 0.14 | 0.44* | 0.50* |
| | (0.41) | (0.37) | (0.45) | (0.13) | (0.27) | (0.29) |
| Observations | 113 | 113 | 69 | 56 | 101 | 98 |

Standard errors in parentheses
DiD based on solar patents 2011-2020 minus 2001-2010.
Common support imposed in all specifications.
Robust standard errors in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

*Figure 1*

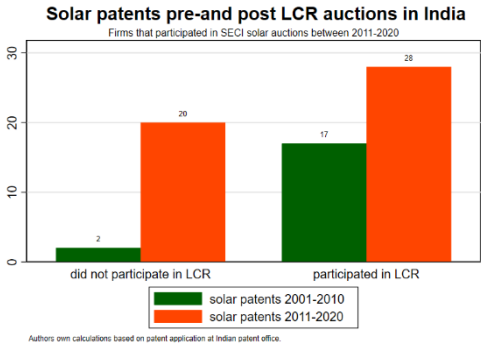


*Figure 1*

## Conclusions

Our results suggest that the LCR auction schemes that were held in parallel to open auctions between 2013 and 2016 did not have a significant impact on domestic innovation. We derive two potential explanations why the LCR auction scheme did not have a significant impact. The first explanation is that the demand stimulus provided by the LCR auction was insufficient and too short. Ex-ante power calculations for our sample reveal that we would need to observe a minimum increase of 1.38 patents per firm to measure a statistically significant difference. Estimates from other studies from the EU and the US suggest that 1 million USD R&D spending is associated with a return between 0.5 to 1.3 patent per firm (Santoleri et al. 2020, Howell 2017). In the case of the Indian solar auction the additional demand for PV modules created by the LCR was much smaller. Furthermore, 4 years may have also been too short for LCR to promote significant innovation impacts, as India stopped LCR in 2016 after a complaint was filed by the US at the WTO. A second explanation is that the requirements set by the Indian government were not ambitious enough to promote innovation, relating back to Rodrik's (2008) argument that industrial policies need to include carrots as well as sticks. The fact that LCR auctions in India mandated less quality standards (Münch & Mariam 2022) and had lower levels of competition, in terms of the number of bidders, support this idea. As this was, to our knowledge, only the second quasi-experimental and firm-level study of LCR in auctions, future research should analyse LCR in other country contexts and assess more intermediate outcomes, such as sales or R&D spending which we were unable to assess to data availability constraints.