Does geography matter?

A Study of Technological Learning in Solar PV Balance-of-Systems Innovation

[Xue Gao, LBJ School of Public Affairs, xuegao@utexas.edu]
[Varun Rai, LBJ School of Public Affairs, raivarun@utexas.edu]

Section 1: Research Questions

Recent literature starts to emphasize the importance of local markets, local policy, and local contexts in solar photovoltaic (PV) deployment, and the role of the local nature of PV balance-of-system (BOS) technologies, however, it is still unclear about which factors influence the degree of localized learning, and the extent to which and at which geographic level localized learning is important for PV BOS innovations. Meanwhile, most studies usually take no account of the international dimension and the interdependent of knowledge at different geographic scales. Innovation is the outcomes of interaction, it is valuable to explore the interaction between firms at different geographic scales.

To address this research gap, this paper empirically investigated firms' learning and innovation processes in relation to the geography. The aim is to answer the following three questions: 1) When conducting PV BOS innovation, what firm level or local area characteristics influence knowledge acquisition choices (local knowledge vs. non-local knowledge)?; 2) How do geographic distance and border influence the citation networks, and how does the localization effect evolve with time? and 3) How do local and non-local knowledge affect the value (or quality) of technology innovation?

Section 2: Data and Methodology

This paper addresses these research questions using a unique database of U.S. PV BOS patents issued between 2010 to 2015, cultivated using keyword search strings and then collecting detailed information of these focal patents, their backward citations, and their forward citations. Citations indicate that there are intellectual property claims the new patent yields to. Backward citations are patents that are cited by a patent, while forward citations are patents that cite the focal patent. Taking "patent A" as an example, backward citations of the patent A are patents cited by the patent A, and forward citations of patent A are patents that cite the patent A in the future. By exploring the knowledge flows from backward citations to the focal patent then to the forward citations (the whole knowledge spillover chain), we are able to meticulously study firms' technological learning and information acquisition behaviors. The link between a focal patent and each backward citation can also be understood as a type of network, and we can assess the effect of geographic distance on the citation networks (i.e., any pairs between PV BOS patents and backward citations). We used t-tests, gravity model and Negative binominal regression model to answer our three research questions, respectively.

Section 3: Research Results

This paper provides empirical evidence that knowledge acquisition is associated with technology characteristics. Technologies that are more related to local context use more local knowledge. In PV BOS innovation, technologies regarding mounting and site assessment absorb more knowledge from local areas, compared to technologies regarding inverters and monitoring. Knowledge acquisition is also associated with firm's location. In PV BOS innovation, patent with assignees located in California (the core region of solar PV industry) acquire more knowledge from local areas than firms that locate in other states. Firm location is a prioritized factor compared to firm age, which means, although our results show that startups use more non-local knowledge, startups locates at the core region (i.e., California) use significantly more local knowledge than startups located in peripheral regions.

The results of the gravity model help us answer that "how local is local" in the localized learning of U.S. PV BOS industry. We find that citation-related network has a strong localization effect at state level, however, the country border has no effect on citation-related networks. We also find that the number of citations-based network decreases with distance. This result provides a direct evidence that the technological learning of PV BOS is a local phenomenon, and the localized learning is at state level. The results of negative binomial regressions show that international knowledge significantly contributes to high-quality patents, which emphasize the value of knowledge diversity in

technological innovation and reject the notion that local knowledge in PV BOS innovation is of exclusive importance. The regression results also show that firm location in the core region of the PV industry (California) is not associated with high quality patents. This may be the result of overreliance on local knowledge by firms located in the core region, which reinforces the value of geographic diversity of knowledge. It also suggests that firms located in peripheral regions may compensate for lack of sufficient local knowledge by accessing more non-local knowledge. In other words, this result indicates that local and non-local knowledge are substitutable rather than complementary, to some extent.

Section 4: Implications

This paper provides new evidence about firms' technological learning processes (especially knowledge acquisition) and technological innovation activities in the field of PV BOS. The finding enables us to provide direct and effective policy suggestions to accelerate technological learning and reduce soft costs in solar PV deployment. We find that the current localization effect of technological learning of solar PV BOS is at state level, but we also find that international knowledge significantly contributes to the quality of patents, which suggests that state border might be a barrier of current knowledge spillover, and only focusing on local innovation networks is not sufficient for promoting PV BOS innovation. The knowledge spillover barriers should be more serious for startups firms and firms located in peripheral regions, as reaching non-local resources might be more challenging for these firms. Policymakers may want to pay attention to whether local firms face difficulties in accessing non-local knowledge, and help local firms bridge non-local networks with local networks. For example, local governments or industry associations can organize more formal or informal activities that facilitate communication (i.e., knowledge spillovers) among firms from different states and different countries. Moreover, building a prosperous local industry cluster is a long and difficult process. The value of non-local knowledge indicates an alternative way that local policymakers can start by helping local firms build networks with firms in other areas, which can partially compensate for insufficient local knowledge.