Induced innovation from standardization in grid modernization technologies

Myriam Grégoire-Zawilski (Syracuse University) and David Popp (Syracuse University)

Models of directed technical change explain innovation in environmental technology as a function of tax-inclusive prices, market size, and knowledge stocks (Acemoglu et al., 2012; Popp, 2002). These models have been powerful for explaining why firms chose to innovate in clean versus dirty technologies in areas such as the automotive industry (Aghion et al., 2016) and the electricity sector (Noailly and Smeets, 2015). With technological advances making renewable energy cost competitive with conventional fuels, the next big challenge towards decarbonizing energy systems will be ensuring that the electrical grid can accommodate a growing volume of distributed intermittent energy sources and fleet of electric vehicles. A distinctive feature of grid modernization technologies is that they must function within complex decentralized grid networks. Compatibility between devices operated by different grid vendors may help unlock network externalities, enabling more flexible load management and improving grid quality. Despite these potential collective benefits, investment in the development and deployment of grid modernization technologies has been scant. Given the interoperability challenge, this paper asks whether - in addition to prices, market size and knowledge stocks - standardization helps explain patterns of technological change in this area.

In the past decade, some OECD governments and industry have worked together through standard-setting organization, to develop voluntary interoperability standards for the smart grid. In the absence of ambitious policies for modernizing the grid, interoperability standards appear to be a key channel through which governments have taken action to induce technological change. To the best of our knowledge, no study has yet combined standard data with patent data to investigate the effect of standardization on inventive activity in smart grids.

This paper posits that the effect of voluntary standards on innovation could be positive or negative. Standards provide inventors with information about which protocols and technical specifications other inventors in this market are likely to adhere to. This may in turn reduce the uncertainty faced by inventors, if their ability to commercialize their invention depends on whether it will be compatible with other devices on the market. If standards provide credible information about this, they might encourage investments in R&D. However, if standards are adopted early on in the innovation process, they may instead prematurely stifle experimentation, and lock-in sub-par technology. Because little is known about the nature and extent of inventive activity in the grid modernization sector, this paper will start by presenting descriptive statistics about the scope of innovation and the firms active in this area. In our regression analysis we will then explore both average and heterogeneous effects of standardization on patenting, including in deregulated versus vertically integrated markets, between newcomer ICT firms (new to the electricity sector) and incumbent electrical equipment firms, and between start-ups and established firms.

Data

The International Electrotechnical Commission, the National Institute of Standards and Technology (United States) and the European Committee for Electrotechnical Standardization have compiled lists of standards relevant to the smart grid. Using these publicly available lists, we

leverage a new dataset on *Technology Standards, Industry Consortia, and Innovation* available through the Searle Centre on Law, Business and Economics to identify when those standards were accredited by national-level standard-setting organizations (Baron and Spulber, 2018). To proxy for innovation, we use data on granted patents, available through the European Patent Office's PATSTAT database. We use the CPC Y class to identify patents relevant to grid modernization. To measure companies' knowledge stocks, we then collect information on firms' overall portfolio of patents in the pre-sample period. To account for other policies affecting smart grid innovation, we include variables on government RD&D budgets in relevant areas, household electricity prices, renewable energy penetration, and market regulation. These data are from the OECD/IEA. Our sample includes priority patents filed in 23 OECD countries over the 1996-2016 period.

Empirical strategy

Several demand-pull and technology-push forces may affect innovation in the area of grid modernization: interoperability standards, knowledge stocks and spillovers, electricity prices, renewable energy penetration, electricity market regulation, government R&D grants and other R&D incentives. We will use Poisson regression to estimate the effect of these factors on smart grid patenting activity at the firm-level. Following Aghion et al. (2016), Noailly and Smeets (2015), and Lazkano et al. (2017), we will generate unique country weights for each firm in our sample, capturing the national markets in which the firm filed patents during the pre-sample period. New firms for which pre-sample knowledge stocks are inexistant will be identified with a dummy variable, following the approach in Noailly and Smeets (2015, p.27). Using these weights, we will compute a yearly count of standards that is exogenous and based on the unique combination of national markets each individual firm is exposed to. Where appropriate, we will also weight the other independent variables listed above. Finally, to account for path-dependency and knowledge spillovers, we will control for a firms' own knowledge stocks, and for the knowledge stocks of other firms in the markets where it operates.

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