Energy Economics 55 (2016) 234–246

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneeco

Efficiency and environmental factors in the US electricity transmission industry

Manuel Llorca [a,*], Luis Orea [b], Michael G. Pollitt [c]

[a] Oviedo Efficiency Group and Durham University Business School, United Kingdom
[b] Oviedo Efficiency Group, Department of Economics, University of Oviedo, Spain
[c] Energy Policy Research Group and Judge Business School, University of Cambridge, United Kingdom

ARTICLE INFO

Article history:
Received 25 June 2014
Received in revised form 10 February 2016
Accepted 16 February 2016
Available online 27 February 2016

JEL classification:
D22
L51
L94

Keywords:
US electricity transmission
Heteroscedastic stochastic frontier models
Inefficiency determinants
Weather conditions

ABSTRACT

The electricity industry in most developed countries has been restructured over recent decades with the aim of improving both service quality and firm performance. Regulated segments (e.g. transmission) still provide the infrastructure for the competitive segments and represent a significant share of the total price paid by final customers. However there is a lack of empirical studies that analyse firms' performance in the electricity transmission sector. In this paper an empirical analysis of US electricity transmission companies is conducted for the period 2001–2009. We use alternative stochastic frontier models that allow us to identify the determinants of firms' inefficiency. These models also permit us to control for weather conditions, potentially one of the most decisive uncontrollable factors in electricity transmission. Our results suggest that weather conditions clearly have an influence on transmission costs and that there is room for improvement in the management of US electricity transmission systems. Regulators should also be aware that more adverse conditions generate higher levels of inefficiency, and that achieving long-term efficiency improvements tends to worsen firms' short-term relative performance.

1. Introduction

The electricity industry in most developed countries has been restructured over recent decades with the aim of reducing costs, improving service quality and encouraging electric utilities to perform efficiently. As a result, former state-owned utilities have been privatised and there has been vertical separation of the generation, transmission, distribution and retailing segments, particularly in Europe (see Jamasb and Pollitt, 2005). Some of these segments, such as generation and retailing, have been opened to competition, while other segments such as transmission and distribution are still regulated. However, incentive-based regulation schemes have been implemented in several countries (e.g. UK, Norway) in order to encourage both transmission and distribution utilities to perform efficiently.

Much of the research in the electricity industry has focused on competitive wholesale markets, although the regulated segments provide the infrastructure for the competitive segments and constitute a significant share of the final price paid by electricity consumers (Joskow, 2014).[1] Even though electricity transmission is necessary for distribution and retailing, there is a lack of empirical studies that analyse both the economic characteristics of the technology and firms' performance in that segment.

Statistical benchmarking methods have been largely used in the electricity industry to determine the relative efficiency of individual firms' costs compared to their peers (see Haney and Pollitt, 2009, 2013). Obtaining reliable (and fair) measures of firms' inefficiency requires controlling for the different environmental conditions under which each firm operates. This is especially acute in benchmarking because of the financial implications that this analysis can have on the firms. One of the most interesting issues with environmental conditions is the question of whether firms are using them as an excuse for poor performance. In line with this, Nillesen and Pollitt (2010) find that firms which operate in unfavourable conditions can be best-practice for the case of US electricity distribution.

One of the most decisive uncontrollable factors in electricity transportation (i.e. transmission and distribution) is the weather conditions of the area in which the companies operate. Billinton and Wenyuan (1991) and Billinton and Acharya (2005) tried to explain changes in the probability of failure rate in the system using engineering models. Generally speaking, they pointed out that most technical interruptions occur when weather is adverse and, in particular, extremely adverse. They also showed that assessing likely failure rates while ignoring weather tends to give erroneous predictions which are too optimistic.

Regarding electricity transmission, Billinton and Wu (2001) pointed out that overhead transmission lines are exposed to a wide range of weather conditions. Moreover, both failure rates and the probability of

* Corresponding author at: Durham University Business School, Mill Hill Lane, Durham DH1 3LB, UK. Tel.: +44 191 33 45741.
E-mail address: manuel.llorca@durham.ac.uk (M. Llorca).

[1] Typically distribution and transmission charges combined compose around 25% of the residential bill (excluding taxes and environmental charges).

http://dx.doi.org/10.1016/j.eneco.2016.02.004
0140-9883/

overlapping failures tend to increase sharply during periods of extremely adverse weather conditions. Rothstein and Halbig (2010) find that many atmospheric and hydrological parameters not only affect electricity generation and consumption, but also electricity transportation. Indeed, overhead lines are affected by several atmospheric influences, such as lightning, wind, additional weight (e.g. ice or snow), low temperatures, humidity and moisture.

Despite the potential role of weather conditions in electricity transportation, only a few papers have analysed firms' performance in the electricity distribution sector controlling for environmental factors. In particular, Yu et al. (2009) showed using nine weather variables that severe weather conditions tend to increase service interruptions, and this in turn increases costs associated with replacing the damage equipment and restoring power. Jamasb et al. (2010, 2012) also concluded that the lack of inclusion of variables related to weather conditions might downward bias the estimated coefficients of other relevant variables, and, in particular, those associated with the marginal cost of quality improvements. Using weather and geographic composites, Growitsch et al. (2012) predicted up to 30% lower costs than average, for utilities that operate in areas with extremely good environmental conditions, and up to 39% higher costs than average, for utilities that operate in areas with extremely bad environmental conditions. On average, they predicted higher costs of about 5% as a result of hostile weather conditions.[2] More recently, Orea et al. (2015) advocate the use of supervised dimension reduction methods such as sliced inverse regression (SIR) in efficiency analyses of electricity distribution firms. The use of this type of approach avoids dimensionality problems when the number of weather variables to be incorporated in the empirical models is large.

On the other hand, as far as we are aware there are only five published papers that separately study the performance of transmission firms. None of them includes inefficiency determinants and only the most recent of them has controlled for environmental conditions. Using a sample of US firms, Pollitt (1995) analysed differences in efficiency between state-owned and private electricity transmission companies. He did not find significant differences between both types of firms using parametric and nonparametric specifications of the frontier model. Using also US data, Huettner and Landon (1978) and Dismukes et al. (1998) have examined the existence of returns to scale in the provision of electric transmission services. Huettner and Landon (1978) do not find increasing returns to scale, except for one category of sales expenses. By contrast, Dismukes et al. (1998) find significant economies of scale for all the NERC (North American Electric Reliability Corporation) reliability regions using data for the period 1986–1991. von Geymueller (2009) carried out a comparison of static and dynamic DEA (data envelopment analysis) models in electricity transmission using data of 50 US utilities for the period 2000–2006. The author finds that static models tend to overestimate firms' inefficiency because they do not take into account the existence of quasi-fixed inputs. Recently, Llorca et al. (2014) propose using a latent class model (LCM) approach to control for technological (or environmental) differences when DEA is applied in a regulatory context of electricity networks. In addition to a simulation exercise, the proposed procedure is illustrated with an application to the US electricity transmission industry.

Our paper contributes to the literature analysing firms' performance in the electricity transmission industry with an empirical analysis of US electricity transmission systems for the period 2001–2009. The analysis of the economic characteristics of the technology and the inefficiency of each utility relies on the estimation of several specifications of heteroscedastic models taken from the recent stochastic frontier analysis (SFA) literature. Unlike previous papers, our SFA models allow us to identify the determinants of firms' inefficiency in this industry, and discuss whether the environmental factors should be treated as determinants of firms' performance or as part of the technology.[3] This is not simply a semantic point within an incentive regulation framework because the indirect effect (through firms' inefficiency) is likely less difficult to mitigate than a direct effect (through the cost frontier) that is independent from firms' relative performance given the nature of the technology. To examine this issue we have applied a modified version of the 'zero inefficiency stochastic frontier model' recently introduced by Kumbhakar et al. (2013). To the best of our knowledge, this is the first time this model has been used to capture differences in technology instead of differences in performance.

The estimated coefficients provide useful information about the firms' performance with both policy and managerial implications. We find using more recent data and larger firms than in previous papers that, given network infrastructure, most electricity transmission networks exhibit natural monopoly characteristics. Our results also indicate that more adverse conditions generate higher costs, mainly through higher levels of inefficiency. Furthermore, we find that investing in capital is an effective strategy to deal with adverse weather conditions. On the other hand, we find that, as expected, firms' performance improves when demand tends to be steady as firms cannot adjust their inputs without cost over time. The average efficiency at the beginning of the period is larger than in previous studies. But, using our preferred estimated model, the results indicate that efficiency has declined and diverged over time. This suggests that there is room for improvement in the performance of the US electricity transmission system. It should be mentioned that the use of US data to benchmark European and Australasian utilities is often suggested and has been undertaken by some regulators including the British energy regulator, Ofgem. Hence although the results obtained here relate to US transmission network, they are important for non-US regulators.

This paper is organised as follows. Section 2 provides a brief review of the transmission and distribution literature and the most commonly used approaches to benchmark firm performance in incentive regulation schemes. Section 3 describes the theoretical cost function that we estimate as well as the empirical specifications of the estimated models. Section 4 presents the data and variables used in the empirical analysis. Section 5 reports the parameter estimates and the results obtained from those estimates. Section 6 presents the main conclusions.

2. Benchmarking in electricity transmission

The electricity sector is an industry with different and interrelated activities, which are affected by production and consumption decisions across the whole system. The US electricity system traditionally has been composed of large vertically integrated utilities. Nevertheless, in the last two decades several reforms have been implemented with the aim of disaggregating most utilities into differentiated segments. These reforms have led to different treatments of the separated activities: generation and retail are regarded as potentially competitive markets, while transmission and distribution networks are treated as natural monopolies that have to be regulated (see Joskow, 2014). As Jamasb and Pollitt (2007) point out, from an economic perspective, the aim of electricity unbundling is to provide utilities with incentives to improve their operating and investment efficiency and to ensure that consumers benefit from the efficiency gains. The main methods used to achieve these objectives are incentive regulation mechanisms, which include financial rewards and penalties for the firms linked with their performance.

Joskow (2014) notes that much of the research in the electricity sector has focused on the competitive segments of the system. However,

[2] By contrast, Nillesen and Pollitt (2010) find that the best performing US electricity distribution companies do not correlate with unfavourable conditions.

[3] An additional contribution of the present paper is that we control for weather characteristics by including a set of weather variables as determinants of firms' inefficiency. The data was gathered specifically for the present application. In addition, as our sample period is more recent than those analysed in previous papers we can see whether there has been an improvement in average efficiency in the US electricity transmission industry.