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Determinants of investment under incentive regulation: The case of the Norwegian electricity distribution networks☆

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ABSTRACT

Investment in electricity networks, as regulated natural monopolies, is among the highest regulatory and energy policy priorities. The electricity sector regulators adopt different incentive mechanisms to ensure that the firms undertake sufficient investment to maintain and modernise the grid. Thus, an effective regulatory treatment of investment requires understanding the response of companies to the regulatory incentives. This study analyses the determinants of investment in electricity distribution networks using a panel dataset of 129 Norwegian companies observed from 2004 to 2010. A Bayesian Model Averaging approach is used to provide a robust statistical inference by taking into account the uncertainties around model selection and estimation. The results show that three factors drive nearly all network investments: investment rate in previous period, socio-economic costs of energy not supplied and finally useful life of assets. The results indicate that Norwegian companies have, to some degree, responded to the investment incentives provided by the regulatory framework. However, some of the incentives do not appear to be effective in driving the investments.

1. Introduction

Electricity networks are capital intensive and exhibit natural monopoly characteristics and are, therefore, subject to economic regulation. In recent years, the need for network expansion, integration of renewable energy resources, enabling demand side participation, and adoption of new technologies such as deployment of smart metres and smart grids has necessitated significant amount of investments in the grid. This has placed the issue of network investment at the core of recent energy policies and regulations in the power sector. The objective is to ensure sufficient investment in maintaining and modernising the grid and at the same time avoiding inefficiency in capital expenditures in order to protect the end-users against high electricity prices. This is because nearly one-third of final electricity prices are related to distribution and transmission network charges (Pollitt and Bialek, 2008) and investments lead to higher consumer bills.

The investment behaviour of firms in a competitive market is among the most studied areas of economics (Jorgenson, 1967). However, the insights from competitive market may not be directly applicable to regulated industries such as network utilities. This is because investments in electricity networks, as regulated natural monopolies, are not driven by market signals where decisions are based upon the expected returns being higher than the incurred cost of capital. Instead, investments in networks companies respond to the regulatory framework and institutional constraints (Crew and Kleindorfer, 1996; Vogelsang, 2002). Therefore, regulators adopt various incentive mechanisms to ensure that there is no systematic underinvestment which jeopardises the reliability of the grid.

The challenge of regulation is to provide effective incentives for delivery of right quality of services while reassuring investors of the profitability of economically justified investments (Newbery, 2004). The advantages of an effective regulatory framework include lower network costs, quality of service improvement, support of competitive wholesale and retail electricity markets and encouraging investments to address the changes in supply and demand for electricity services (Joskow, 2008). As a consequence, identifying the main drivers of investments can help regulators to understand the responsiveness of firms to regulatory incentives and hence, more effectively address the issue of investments under incentive regulation.

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Despite the importance of investments in regulated industries, the empirical literature on the issue is rather limited. The current studies, except the work by Kinnunen (2006) which investigated the investment drivers in Finish electricity networks, do not analyse investment response to regulatory incentives. Instead the empirical research mainly aims to model the effect of certain regulatory features on investment. For example, some studies have attempted to explore the effect of public versus private ownership or unbundling of network utilities on investment (see, e.g., Gugler et al., 2013; Nardi, 2012). Another strand of literature has attempted to conduct cross country analysis in order to explore the effect of different regulatory regimes on investment (see, e.g., Cambini and Rondi, 2010; Gugler et al., 2013). Also, some studies analyse investment indirectly as the cost of quality of supply improvement (see, e.g., Coelli et al., 2013; Jamasb et al., 2012).

Therefore, little effort has been made to identify and analyse the determinants of investments in electricity networks under incentive regulation. This study investigates the key factors that drive the amount and direction of the investments in electricity distribution networks using a case study of the Norwegian network utilities. The next section discusses network investments and associated incentives under regulation and briefly reviews the Norwegian regulatory framework. Section 3 presents our methodology which is based on the Bayesian Model Averaging technique. Section 4 discusses the data used. The results and discussion of major findings are presented in Section 5. Section 6 is conclusions.

2. Investment in electricity distribution networks

Electricity distribution companies are responsible to deliver energy to the end users and hence, they are required to have a reliable and available network at all times. These obligations are usually stated in the countries' regulation and standard of practice for the power sector. In the UK, for example, under the Electricity Act of 1989 which was later modified by Utilities Act in 2000, distribution companies are obliged to support and facilitate a market-oriented electricity sector through developing and maintaining an economically and technically efficient distribution system (Shaw et al., 2010). The companies are also required to comply with additional standards such as those related to the environment, security of supply, safety and customer service. These challenges necessitate an investment plan that helps network companies to achieve their performance targets and at the same time ensure that all statutory and legal responsibilities are met.

There are several technical and non-technical factors that can potentially drive investment in distribution network companies. The number of connected consumers and distribution of load, in a specific region, can change and hence require network reinforcement (Blokhuis et al., 2011). In these cases, distribution companies identify development of new residential or commercial sites, within their network area, and forecast demand by taking into account the general macroeconomic and market conditions. Thus, a non-trivial part of investment of distribution companies is related to demand for new connections.

At the same time, the load profile of the existing customers can change and, over time, lead to lower or higher demand for electricity. For example, consumers may use more energy efficient equipment or appliances and therefore, cause the demand for electricity to decline. Similarly, consumers can use larger appliances and cause the demand for electricity to rise. Under the conditions that the load growth pushes the grid capacity to its limit, distribution companies need to carry out reinforcement to enhance network capacity (Poudineh and Jamasb, 2014).

The need for connection of supply side resources such as distributed generation is another investment driver of distribution companies. Distributed generations mainly comprise renewable resources and combined heat and power plants (CHP) which are connected to distribution network and can bring the network to its operational limit (Vovos and Bialek, 2007).

Network companies are also responsible for quality of service and reliability of electricity supply at distribution level (Giannakis et al., 2005). This means the companies need to reduce progressively the frequency and duration of electricity supply interruptions as well as the number of affected consumers. The networks often experience technical faults which, in the worst case, can lead to power cuts. Thus, appropriate investment measures need to be taken in order to rectify these faults which may damage consumers' appliances. In this respect, distribution companies need to carry out frequent inspection and maintenance of network assets to ensure that all devices work properly and provide a highly reliable service. This is specifically important with respect to those assets that are required to be switched off for maintenance. This is because due to asset specificity and the lack of redundancy their availability directly affects security of supply. Investment in remote control and power distribution automation systems is part of the solution to the network reliability (Liu et al., 2006). These systems send warning signals to replace non-functional and faulty equipment and hence, can minimise the disruption to the consumers.

External factors can also necessitate network investment because they affect the operation of grid. For example, extreme weather conditions or proximity of distribution lines to trees increase the likelihood of power disruption (e.g., falling tree in the storm). In these instances, investment is necessary to protect the overhead lines against the risk posed by extreme events. The network companies are also required to invest in order to improve safety of the grid. This, for example, includes horizontal and vertical clearance of overhead lines in accordance with the national and international electricity standards and also protection of the equipment from theft and vandalism. This is because the increase in price of metals, in recent years, has made the distribution substations attractive targets for metalwork larceny.

Another important driver of investment, in electricity distribution companies, is network energy losses. Around 5% of electrical energy is lost in the distribution system due to the conductors' natural resistance and/or technical problems (Shaw et al., 2010). Apart from the issue of energy inefficiency, these energy losses account for around 95% of operational CO_2 emissions of distribution network companies (Shaw et al., 2010). Thus, network energy losses need to be reduced to the minimum feasible level.

The investment drivers in distribution network companies are not confined to technical problems. Non-technical factors can also potentially lead to capital investment. For example, network companies may need to invest in costly underground cables in order to avoid disturbing natural beauty areas or to reduce public opposition with respect to infrastructure development at local communities' proximity (Steinbach, 2013). Additionally, environmental legislation compliances such as reducing noise or oil leakage in substation can drive investments. Furthermore, distribution companies undertake investment in R&D activities and facilities that support delivery of operational projects (e.g., buildings, computers, etc.).

2.1. Investment incentives under regulation

In order to enable distribution network companies to maintain their network, comply with regulation and standards and provide an acceptable quality of supply, the regulatory framework needs to incentivise "investment sufficiency". A "reasonable" rate of return on capital is a major incentive for network companies to undertake investment. The allowed rate of return, for efficient financing, is based upon the capital stock employed in production process and is at least equal to the estimated costs of capital of the notional company (Ofgem, 2013). The financing process is usually a combination of debt and equity and thus, a weighted average cost of capital (WACC) is calculated given different capitals have different costs of acquiring. Depending on the regulatory framework, the low risk and protected monopoly nature of the sector can cause the rate of return to be lower than unregulated companies (Kinnunen, 2006).