Revisiting Electricity Liberalization and Security of Supply: Empirical Evidence

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Abstract

What effect does firm structure have on the product service quality on offer? We answer this question by empirically assessing the impacts of complete vertical separation, such as ownership unbundling, on the quality of service delivered by a liberalized network industry. Electricity distribution utilities in New Zealand are considered for this purpose. The results show robust evidence that ownership unbundling contributed to a fall in the duration and frequency of supply interruptions in electricity distribution. However, the results also show that unbundling has no effect in reducing distribution network losses. Overall the results highlight the non-simple impacts of unbundling on quality of electricity distribution. We conclude that quality of service may improve when largely accounted in incentive regulation frameworks than completely relying on specific reform measures such as ownership unbundling.

Keywords: unbundling, ownership, quality, regulation

JEL classification: L94

1. Introduction

The relationships between firm structure and product service quality are important and extensively discussed in the industrial economics literature (Temin 1988; Economides, 1999). We contribute to this discussion by studying the impacts of vertical separation and electricity supply security in the context of a liberalized network industry. A reliable and affordable supply of electricity is a key factor in the economic prosperity and quality of life observed in modern developed economies. However, liberalized electricity markets which have experienced market oriented reforms since the early 1990s are experiencing energy security problems such as generation capacity shortages, lack of adequate network investments, increasing electricity prices and power outages. This contradicts the theoretical motivation for, and intended benefits of liberalization and creating competitive electricity markets (Joskow, 2007; Arriaga, 2007; Volk, 2013). Hence it is interesting to revisit and empirically test whether liberalized electricity markets are delivering the required level of security of electricity supply.

We study the case of New Zealand where liberalization and restructuring of the electricity sector in 1998 involved a forced vertical separation of the electricity supply industry (ESI) with respect to ownership (ownership unbundling). Ownership unbundling is a form of complete vertical separation, which involves a separation of previously vertically integrated entities. After the separation, the natural monopoly segments of the ESI (the electricity networks) operate under different ownership from the competitive segments (such as the generation and retail). All- encompassing holding and shared operational activities across different segments of the ESI are prohibited under an ownership unbundling scheme (Kunneke and Fens, 2007).

The primary motive of ownership unbundling is to prevent any discriminatory behavior of network owners and facilitate market entry and competition. Theoretically, the benefits of ownership unbundling of electricity distribution generally outweigh the costs, though econometric evidence in favor of this hypothesis is weak due to a lack of studies (Pollitt, 2008). New Zealand offers a unique case, as it was the first country in the world to introduce mandatory ownership unbundling of electricity distribution from other segments of the ESI. The complete vertical separation of electricity distribution from other competitive segments is in itself unique, most of the existing literature on vertical separation in the ESI focuses on ownership unbundling of transmission (Michaels, 2006).

The contribution of this study is to provide robust evidence on the impacts of adopting liberalized electricity reforms such as unbundling on security of electricity supply. We focus on the quality of electricity supply and not on traditional measures of energy security such as generation and fuel adequacy (as a disaggregated measure of supply security) because security of supply is a broad and multidimensional issue (Baumann, 2008). To measure quality of electricity supply we use power supply reliability indicators such as the System Average Interruption Frequency Index (SAIFI), the System Average Interruption Duration Index (SAIDI) and distribution system network losses. The findings of this study are particularly relevant for European countries like Austria, Germany, Finland, Norway, and Sweden where ownership unbundling of electricity distribution from the rest of the ESI is still in a discussion phase[1]. More broadly, ownership unbundling remains a topic for open discussion in the European Union since the Electricity Directive and the Gas Directive of the Third Energy Package introduced a structural separation between competitive and monopoly segments in the ESI (European Commission, 2013). Because ownership unbundling can be argued to be a prerequisite for the privatization of different segments of the ESI, our results on the impacts of unbundling on quality of supply are particularly interesting for countries like Australia whose electricity markets consist of both state-owned and private entities, and where discussions are ongoing over the need to privatize state-based electricity assets (Hilmer, 2014).

Quality of electricity supply has also received renewed attention in the Australian context given the anticipated improvements in electricity supply quality with increasing electricity prices[2]. The National Electricity Market (NEM) was created in 1998 in the Eastern jurisdictions with the objective of developing and operating electricity supply infrastructure to facilitate low-cost, safe, reliable and efficient electricity supply (AEMO, 2014).

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[1] Please see the Technical Annex of EU Energy Benchmarking Reports (2010).
[2] Retail electricity prices have gone up about 50 percent over the last four years in Australia.

The remainder of the paper is structured as follows. Section two provides an overview on the electricity reform process in New Zealand. In Section three we review the literature on the theoretical and conceptual relationships between ownership unbundling and quality of electricity supply. We also review existing empirical evidence on the impacts of electricity liberalization reforms on supply quality. Section 4 discusses the econometric model and the data. Section 5 presents the results and concludes section 6 concludes with some policy recommendations.

2. Electricity Reforms in New Zealand

The unfolding of electricity reforms in the context of New Zealand is well discussed in earlier studies by Evans and Meade (2005), Bertram (2006) and Nillesen and Pollitt (2011). The overall conclusion is that that the history of the New Zealand electricity reforms is extremely complex issue (Bertram, 2013). New Zealand's approach to electricity reform differs from most other countries in the world that have attempted radical restructuring of their ESI's due to its non-interventionist style of regulation (Gunn and Sharp, 1999).

Reforms were initiated during 1986 as a result of neoliberal policy changes advocated by the fourth Labor Government, in office between 1984 to 2000. In this period, the State-Owned Enterprises Act (SOE Act) and the Commerce Act were introduced. This changed the management and ownership structure of the electricity industry, in addition to instituting major changes in regulatory principles.

The electricity sector underwent major liberalization and deregulation in 1992. Prior to this, the electricity supply industry (generation and transmission) remained publicly owned (New Zealand Electricity Department (NZED)) and served by vertically integrated electricity distributors, combined with local electric supply authorities (known as the Electricity Supply Authorities (ESAs)). NZED was corporatized in 1987 and morphed into the Electricity Corporation of New Zealand (ECNZ) before being split into separate generation and grid companies in 1994. Electric power transmission remained in the hands of the state-owned enterprise, Transpower, which was formed as a wholly owned subsidiary of the ECNZ in 1987. Electricity transmission was separated from ECNZ and became a state-owned corporation in 1994. During 1993-1994, the ESAs and Municipal Electricity departments also underwent commercialization, in accordance with the Energy Companies Act of 1992. As a result, the objective of the electricity industry switched from providing a social service to profit-maximization. The Act fundamentally changed the operating environment of the ESAs. Some of the changes involved deregulation and self-regulation as they lost their local monopoly franchises and were required to ring-fence their network businesses, themselves made subject to 'light-handed regulation' concerning information disclosure requirements (Bertram, 2013).

The creation of Contact Energy out of the ECNZ in 1996 split the generation market between two competing generators. Contact Energy was eventually privatized in 1999 at the same time as the remaining generation assets of the ECNZ were broken up into three new SOEs and a small group of independent private companies. Between 1992 and 1998 the New Zealand ESI experienced a number of problems[3]. The major concerns included:] low retail competition (non-decreasing price levels and low switching rates following liberalization); a highly concentrated generation segment (consisting only of the publicly owned ECNZ and the privately owned Contact Energy); cross-subsidies across the vertically integrated segments of the ESI; threats of discriminatory network access; rent seeking and cost padding in electricity distribution and untapped economies of scale in electricity distribution. The Electricity Industry Reform Act (EIR) was introduced in 1998 in an effort to stimulate more competition in the sector (Parliamentary Counsel Office, 2014). One of the prominent features of the Act was that the forced ownership unbundling of energy generation and retailing by the Electricity Supply Authorities.

The timeline of changes in the EIR included the corporate separation of networks and energy businesses (to be achieved by 1 April 1999) and complete ownership separation (to be achieved no later than 31 December 2003). The EIR prohibited the same party from being involved in both the monopoly segments (network business) and the competitive segments (generation and retail) of the ESI. The 1994 electricity regulation was replaced by Electricity Regulations 1999, which was 'heavy-handed' in terms of the prices and profitability controls it imposed. The ECNZ was further segregated into three new generators, which led to six (three privately owned and

[3] As outlined in Nillesen and Pollitt (2011)

three state-owned) large vertically integrated electricity generators and retailers by 2000. The current arrangements of the electricity generation and retailing in the ESI represent a highly concentrated market with the cartelization (or consolidation) of five large players controlling above more than 90 percent of electricity generation and retail and a few independent players on the fringe.

The privatization process has been rather slow in the sector. However, legislation passed in 2012 allowed part-privatization of the three state-owned generators by selling up to 49 percent of shares to the private investors. This process is expected to be completed by 2014.

3. A Review of Relevant Literature

The energy economics literature on the costs and benefits of electricity sector unbundling (or vertical separation) is considerable. Vertical separation can involve four different models: *accounting unbundling, functional unbundling, legal unbundling* and *ownership unbundling*[4]. Accounting unbundling is the "lightest" form of unbundling while ownership unbundling is the complete or strongest form. The magnitude of costs and benefits can vary depending on the models of vertical relations prevalent within different segments of the ESI. The benefits of vertical integration include certain synergies pertaining to vertical economies of scope such as coordination economies (Joskow and Schmalensee, 1983), market risk economies (Williamson, 1979) including hold-up risks, and specialization economies (Meyer, 2012b). Pollitt (2008) encapsulates the benefits and costs of transmission ownership unbundling in terms its effect on competition, ease and effectiveness of regulation, facilitation of privatization, security of supply, transactions costs of unbundling amongst others. Hence the theoretical impacts of unbundling on security of supply are, unsurprisingly, ambiguous.

A limited number of econometric studies have examined the impacts of unbundling (and ownership unbundling in particular) in electricity sectors. With respect to electricity prices, a study by Copenhagen Economics (2005), based on factor and fixed-effect analysis, found that transmission ownership unbundling led to lower

[4] See Meyer (2012a) for an overview on the different types of unbundling in the electricity sector.

electricity prices in the EU. On the other hand, Steiner (2001) used factor analysis and fixed and random effects techniques, which suggested that unbundling of transmission from generation did not lead to lower prices but did lead to higher capacity utilization rates across 19 OECD countries. Surprisingly, Hattori and Tsutsui (2004), using fixed and random effects analysis for the same dataset, found that unbundling of transmission from generation seemed in fact to raise electricity prices. With respect to investment, Alesina et al. (2005), using Generalized Method of Moments (GMM), showed that investment in the electricity sector increases with the extent of transmission vertical separation. In a study with a broad focus, Sen and Jamasb (2012) - using a bias corrected fixed-effect analysis - did not find conclusive evidence of any relationship between unbundling of electricity networks and key economic variables in the Indian context. So, it can be seen that existing econometric evidence on the impacts of unbundling (and particularly ownership unbundling) on quality of electricity supply is scarce, and also that studies are mostly focused on transmission unbundling.

A recent study by Growitsch and Stronzik (2014) explicitly models the economic impacts of ownership unbundling of gas transmission networks across 18 EU countries using panel data techniques based on different dynamic estimators and the bias-corrected fixed effects estimator. However, the study focuses on the price impacts of reforms rather than the quality of supply. To the best of our knowledge, the study by Nillesen and Pollitt (2011) is the only one that focuses on the impacts of ownership unbundling on quality of supply in the context of New Zealand although Filippini and Wetzel (2014) analyze the impacts of ownership separation on the cost efficiency of distribution companies[5]. Our study differs and develops from Nillesen and Pollitt (2011) in a number of ways.

The authors note that difference-in-means-testing indicates the pre-unbundling mean for both SAIDI and SAIFI are higher than the post-unbundling mean. This does not imply causality. They do not delve into further inference, probably due to the fact that their modelling approach does not account for extreme climate related events. Extreme weather effects are not accounted for in the data and can generate biased

[5] The results indicate that ownership unbundling had a positive effect on the cost efficiency among the electricity distribution companies.

estimates, which may lead to incorrect inference on the effect of ownership unbundling. We attack this problem by including controls for yearly climate change (in both temperature and rainfall) and conduct additional robustness checks related to possible sample outliers caused by extreme weather. Our analysis focusses entirely on the issue of quality of service and also assesses the relationship between industrial structure and factors related to quality of service. We go beyond Nillesen and Pollitt's analysis of quality of service from an interruptions point of view to a broader analysis that includes transmission losses. Our modeling approach also maintains simplicity and allows for easy interpretation of coefficients.

3. Methodology

The aim of the paper is to examine the impact of firm structure on quality of service in a liberalized electricity industry. The focus of the analysis is on the effect of unbundling on quality of electricity supply, controlling for several company characteristics. It is expected that ownership unbundling improved security of supply in electricity distribution networks in New Zealand (Nillesen and Pollitt, 2008). We estimate the following model in order to achieve easy interpretation and correct inference:

$$\begin{aligned}\log(QS)_{it} = \quad & \log(LOAD)_{it} + \log(CAPACITY)_{it} + \log(C.DENSITY)_{it} \\ & + \log(ENERGY)_{it} + \log(CAPITAL)_{it} + \log(RAIN)_{it} \\ & + \log(TEMPERATURE)_{it} + UNBUNDLE_{it} \quad + t + t^2 + \mu_i + v_{it}\end{aligned}$$

The dependent variables are the quality of service (QS) indicators such as the SAIFI, SAIDI and percentage of distribution network losses[6]. The explanatory variables are carefully chosen as they could influence the quality of service in electricity distribution. The load factor (LOAD), which is the amount of electricity entering the system divided by the maximum demand multiplied by the total number of hours, can influence (QS) as higher load factors can hurt performance and cause network issues. Capacity utilization (CAPACITY) is expressed as maximum demand divided by transformer capacity (expressed in percentage). It is possible that very high capacity utilization leads to issues in dealing with peak demand and subsequent quality

[6] Reichl et al. (2008) also use SAIDI and SAIFI as quality of service indicators to assess the impact of grid tariffs on quality of service.

problems, even if higher levels of this ratio are desirable in terms of effectiveness of resource use across the network.

Another considered factor is customer density (C.DENSITY). Higher density implies the concentration of customers in a definable area, which can lead to an improvement in quality of service when compared to relatively isolated areas. The total energy delivered per capita (ENERGY) is also included as it is an important output of the network. We also include a per capita measure of capital of the network (CAPITAL). The components of total cost are variable cost (readily available) and capital cost (estimated as in Lawrence et al. (2009) and our explanatory variable of interest in this case) assuming a depreciation rate of 4.5 percent of the Optimized Deprival Value and an opportunity cost of 8 percent of the ODV and translation to capital as 12.5 percent of ODV. A dummy variable taking value of 1 if the network is unbundled in ownership terms and 0 if not (UNBUNDLE), is also added, and the sign of its coefficient is of central interest to our research question. Provided that it is statistically significant, if this coefficient is positive, unbundling has a positive effect on quality of service and vice versa if it is negative.

The effect of extreme events can bias the estimated coefficients, and controlling for these factors is crucial for the robustness of results since rain, wind and snow account for many interruptions and service issues. Therefore, a proxy for extreme climate events is included. Data on national rainfall is available, and the quadratic positive monthly deviations above a threshold of 10 centimeters (cm) per month (RAIN) are included in the regression as the effect of extreme rainfall is unlikely to be linear. Quadratic monthly deviations of temperature (national data as well) below the threshold of five degrees Celsius (TEMPERATURE) is also included to control for extremely cold conditions and its possible impact of quality of service. Finally, a quadratic time trend is considered to account for the possibility of exogenous technological change, while holding some level of flexibility on the functional form of this change. The variable μ_i represents a set of network-specific fixed or random effects.

4. Data and Descriptive Statistics

Our data spans from 1996 to 2009[7], across 29 electricity distribution networks, with a total of 391 observations in an almost completely balanced panel, with only one missing observation (Otago Power in 2003). All variables must be stationary in order to avoid the problem of spurious regression, a point to which we return to immediately below. All variables are also logarithmically transformed, implying that the coefficients can be interpreted as elasticities. However, in the case of the dummy variable for unbundling, this is not an exact interpretation. A more appropriate interpretation, as in Kennedy (1981), that is nearly unbiased when errors are normal, is that elasticity with respect to the dummy variable is 100[exp (b^*-0.5$v^*(b^*)$) -1], where $v^*(b^*)$ is the estimated variance of b^*. The unbundling coefficient can be interpreted as passing from 0 to 1, and in that case the simpler formula 100[exp (b^*) -1] appears considering that there is no way back from unbundling (no reversal).

The Im-Pesaran-Shin (2003) panel stationarity test is preferable given the sample size is not very large. The test is specified on the basis of fixed N and fixed T asymptotic. Additional flexibility of the test that stems from a different rho for each unit in the test. Cross-section means of variables are removed and the lag selection is done by the AIC. The null hypothesis is that all panels contain unit-roots and the alternative hypothesis is that (at least some) panels are stationary. Table 1 illustrates the results (test statistic and p-value respectively), which indicate that the problem of spurious regression was not be present in our estimation.

Table 1. IPS Panel Stationarity Tests

	Test Score	P-value
Log(SAIFI)	-6.13	0.0000
Log(SAIDI)	-8.09	0.0000
Log(LOSSES)	-4.67	0.0000
Log(LOAD)	-4.49	0.0000
Log(CAPACITY)	-1.99	0.0232
Log(C.DENSITY)	-4.49	0.0000
Log(CAPITAL)	-3.04	0.0012

[7] Data is in fiscal years finishing in the given year (i.e. 1996 ends in 31 March 1996).

Log(ENERGY)	-7.59	0.0000
Log(RAIN)	-8.98	0.0000
Log(TEMPERATURE)	-8.66	0.0000

- Rainfall and temperature measures are the same across networks, so no demeaning is necessary in this case to perform the test.

Table 2 reports the descriptive statistics of the raw data used in this study (prior to its logarithmic transformation). Capacity utilization shows large variability in the sample but never exceeds 63%. Similar variability can be seen in load factors, where the maximum is close to 85%. There are also very large differences in customer density across companies as they operate in more or less urban areas. It is also true that the number of customers across networks varies significantly. Networks are unbundled in approximately 75% of the observations in the sample, which is a natural consequence of the sampling choice, given the available data. There are also quite large differences across firms in per customer energy supplied, mostly due to fundamental differences in the kind of customer (more weight of industrial end-points, for example). The same variation occurs with capital per customer as well, with very large differences across networks. This could be due to large geographical differences in the areas of operation of the networks and the population characteristics within those areas.

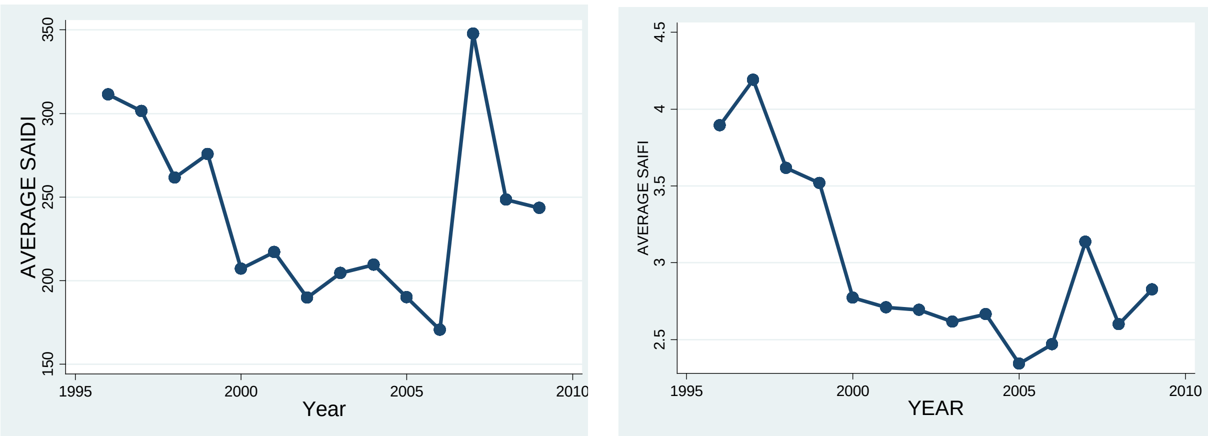
Table 2: Descriptive statistics

Variable	**Mean**	**Std. Dev.**	**Minimum**	**Maximum**
SAIDI	241.492	207.9732	15.4	1918
SAIFI	3.0046	2.152	0.184	15.8
LOSSES %	6.220026	1.917741	2	21.23141
CAPACITY	33.4309	6.6897	21.972	63
LOAD	62.6344	6.641	30.401	84.71
C. DENSITY	11.1533	7.5883	3.0075	38.556
UNBUNDLE	0.7135	0.4527	0	1
ENERGY	0.01527	0.0041	0.00429	0.0305
CAPITAL	465.6139	161.9044	120.3295	1097.916
RAIN	32.57465	34.51935	4.623671	104.6146
TEMPERATURE	1.884664	1.529123	0.000892	4.350464

The correlation coefficient of SAIDI and SAIFI is 0.69, showing high correlation between the measures of frequency and duration of interruptions. It is clear also that there is a high degree of heterogeneity in SAIDI numbers, which vary a great deal across time and across networks. A noticeable spike in both SAIDI and SAIFI is present in 2007, which can be attributed partially to the snowstorms in June 2006. At the national level, the rainfall variable shows large spikes only in 1996 (which saw persistent rain but no major events), 1997 (which saw cyclones Drena and Fergus) and 2004 (Cyclone Ivy). Other considerable events associated with storms occurred in fiscal years of 1999 and 2002. Interestingly, the 2002 and 2004 events (post-unbundling) were not contemporaneous with visible spikes in SAIDI and SAIFI. It is very likely therefore that the problems in quality of supply in the first years of the sample were not significantly affected by storms.

Figure 3 plots the means of SAIDI and SAIFI across the sample.

Figure 3. Means of SAIDI and SAIFI across the sample , 1996-2009



5. Results

We estimate the Fixed (FE) and Random Effects (RE) models to account for the network-specific unobserved heterogeneity in the sample of electricity distribution networks, which is constant throughout time. Hansen tests were conducted to make the most appropriate model choice for individual cases of SAIDI and SAIFI since the latter requires the additional assumption that the regressors are not correlated with the Random Effects though it increased statistical efficiency. The results obtained from estimations using STATA are presented in table 2. The Wooldridge test for first-order autocorrelation in panel data (Wooldridge, 2002) points that the null is not rejected and therefore there is no issue of serial correlation in all cases. This method uses the residuals of the first-differenced model for the test and is applied using the "xtserial" command (Drukken, 2003).

Table 3: FE and RE estimations for SAIDI and SAIFI

	SAIDI	**SAIFI**
Chosen Model *(P-value of test of overidentifying restrictions)*	FE (0.0166)	FE (0.0000)
Load Factor	-0.151 (0.357)	-0.256 (0.403)
Capacity Util.	0.424 (0.206)**	0.269 (0.155)*
Cust. Density	-0.651 (0.471)	-0.234 (0.371)
Capital Per Cust.	-0.765 (0.266)***	-0.218 (0.197)
En. Supplied Per C.	0.181 (0.413)	0.235 (0.420)
Unbundling	-0.281 (0.096)***	-0.255 (0.072)***
Rainfall	0.015 (0.019)	0.014 (0.015)
Temperature	-0.002 (0.011)	-0.003 (0.007)
Time trend (linear and quadratic coef.)	-0.058 (0.042) 0.006 (0.003)**	-0.040 (0.026) 0.003 (0.002)*
Effect of unbundling on SAIDI/SAIFI (from point	-25.1%	-22.9%

estimate)		
***, ** and * denote significance at 1%, 5% and 10% levels respectively. Standard errors in parenthesis, except in Hansen test where p-value is presented. Constant and fixed effects coefficients are omitted in the results.		

It is important to consider that using the RE results for this regression would not induce significant changes in the analysis (there is no change in the magnitude and significance of the unbundling variable, for example), except for a strong significance of customer density, given that the test of FE versus RE in the case of SAIDI leads to a not very strong rejection (valid at 5% level but not at the 1% level). The linear coefficient of the time trend also becomes slightly significant, but no other clear changes occur. However, this result might be a consequence of the violation of the independence assumption of Random Effects. The case is clearer for SAIFI, where the RE model is clearly inadequate. Another possible issue is the breach of the strict exogeneity assumption necessary for the Fixed and Random Effects estimation.

While it may be easy to argue that most regressors are strictly exogenous, as SAIDI or SAIFI would not cause, for example, changes in rainfall or customer density, the same case cannot be made for capital. For example, very high or very low service quality might be the consequence, but also a cause, of different levels of capital in the electricity network. This is because overall costs (including investments) are correlated with quality (Spence, 1974). Hence, we implemented an alternative test proposed by Wooldridge (2010) by adding to the regression the lead of capital as an additional regressor and testing its significance. In both cases, the variable is not significant, so the strict exogeneity assumption does not appear to be problematic. The choice of a quadratic time trend for increased flexibility in capturing exogenous technological progress appears to be justified as it is significant in both cases and the linear trend is nearly significant at standard levels and with the expected sign. There is no evidence of serial correlation.

Results reveal interesting insight on the case of quality of service in electricity networks in New Zealand. Higher capacity utilization significantly worsens interruptions, with respect to both frequency and duration. Higher levels of capital seem to bring the duration of interruptions down, but with no effect on their frequency.

The effect of unbundling seems to be stronger in bringing the duration of interruptions down when compared to their frequency, but the effect is strong and clear and positive in both cases. Given that many factors are already accounted for, and this result is robust even if the time trend is not included, this is very strong evidence in favor of unbundling as a key driver of quality of service improvements in New Zealand.

One possible counterargument is that there are other extreme events not accounted for that could bias results, for example the large snowstorm of June 2006. This causes an increase in quality of service issues in the fiscal year of 2007 that includes that month. The rainfall variable does not particularly capture this effect well as the effect of snow can be much more extreme in electricity networks. However, the unbundling variable remains significant at the 5% level for both SAIDI and SAIFI when removing the year of 2007 from estimation. Similar results are rendered when removing only the biggest outlier of the 2007-year in terms of service interruptions (Electricity Ashburton, operating in an area that experienced heavy snowfall in the June snow storm).

The coefficient of rainfall is positive as expected; although the standard errors are rather large even if the coefficients for extreme low temperature and large rainfall are not significant. The robustness of results is strong given that snowstorms are the other major events that could cause damage and interruptions. Removing the observations that could suffer from that unmeasured set of events does not change results. In all these cases, and also in the case of no time trend to account for exogenous technological change, the point estimate for the effect of unbundling on decreasing SAIDI and SAIFI is always above 20%.

Table 4 shows the impact of different variables on distribution network electricity losses. The estimation is performed with the logarithm of percentage of distribution losses as the dependent variable.

Table 4: Impact on losses

	LOSSES
Chosen Model (P-value of test of overidentifying restrictions)	FE (0.0008)
Load Factor	-0.251 (0.253)
Capacity Util.	-0.263 (0.228)
Cust. Density	-0.260 (0.098)**
Capital Per Cust.	0.189 (0.121)
En. Supplied Per C.	-0.463 (0.173)**
Unbundling	0.027 (0.032)
Rainfall	0.008 (0.01)
Temperature	0.004 (0.004)
Time trend (linear and quadratic coef.)	0.024 (0.025) -0.002 (0.002)
***, ** and * denote significance at 1%, 5% and 10% levels respectively. Standard errors in parenthesis, except in Hansen test where p-value is presented. Constant and fixed effects coefficients are omitted in the results.	

A concern with the validity of results arises due to the rejection of the null of no serial correlation using the Wooldridge test at the 5% level. Therefore, AR (1) regression with fixed effects was also conducted for additional robustness – leading to an unexplained positive and significant coefficient for capital per customer. If taking into account autoregressive disturbances is, indeed, necessary this raises concerns about the results. The proposed exogeneity test does not show evidence of endogeneity of capital at the 5% level indicating previously discussed issues when dealing with outliers. As such, the year 2007 is dropped from estimation as a robustness check. The Wooldridge test no longer rejects the null even at the 10% level, and both FE and FE with AR (1) disturbances show the significance of customer density and energy supplied per customer. We also note that, once again, temperature and rainfall variables are not significant, although they show the expected signs.

The significance of the energy supplied per customer with a negative coefficient could raise some issues about the possible endogeneity of the variable, as a very large amount of distribution losses effectively reduces the energy available to deliver to customers. However this argument concerning reverse causality is not supported by a test of significance of the lead of energy supplied in the losses regression, showing no signs of endogeneity. This coefficient can be explained by the average kind of customer the network deals with, their specific needs and their network requirements. In fact, networks with higher amount of average energy delivered per customer consist of large customers such as large commercial or industrial users connected with high voltage networks than for smaller households with limited electricity needs. Similarly, the negatively significant coefficient of customer density is also expected, as tight grids mostly composed of urban areas are less likely to incur distribution losses than networks that have to deal with a grid of sparse customers, which describes by a more rural framework for the electricity network. The coefficient for unbundling is not significant for changing distribution losses in any of the regressions, implying that, while vertical separation improves the quality of service by decreasing the frequency and duration of interruptions, it does not necessarily translate into a decrease in distribution losses as well.

We consider the effect of additional weather effects that might not be controlled for in the data as a final robustness check. This includes the fiscal year of 1997 with Cyclones Drena and Fergus, and the year 2004 with Cyclone Ivy. Therefore, all regressions considered had the years of 1997, 2004 and 2007 removed (this is only a last resort robustness check due to the removal of many observations). This still shows the unbundling coefficient is significant for both SAIDI and SAIFI. An alternative robustness check is to avoid dropping observations and include a dummy interaction between extreme low temperature and extreme large rainfall measures, which can be a proxy for combined extreme winter events. No major changes in the results occur. Therefore, we do not believe extreme weather events are biasing results and that the result of unbundling as a key driver of quality of supply improvements in New Zealand is a robust result with important policy implications.

6. Conclusions

This study analyzed the impacts of liberalized reform measures, such as ownership unbundling, on the security of distribution electricity supply by controlling for a range of internal and external characteristics of the firm. We focused on quality of service as this remains an integral aspect of electricity supply security. The electricity distribution sector of New Zealand was considered, as it is the only country in the world to have introduced mandatory ownership unbundling of electricity distribution from rest of the ESI as early as 1998. This study provides additional evidence on the relationship of firm ownership structure and product service quality in the context of a liberalized network industry.

We find robust evidence that ownership unbundling significantly reduces the average duration of interruptions and average frequency of interruptions in distribution electricity supply. Hence, the introduction of forced ownership unbundling has improved the quality of service in New Zealand electricity distribution in relation to impacts on interruptions. This also implies that ownership unbundling minimizes the economic losses associated with interruptions in distribution electricity supply. However, the evidence suggests that unbundling produced no significant impact on reducing distribution network losses. The overall results indicate that the impacts of unbundling on the quality of electricity distribution are ambiguous. One possible reason might be due to the simultaneous introduction of other reforms alongside ownership unbundling, which are hard to capture in any econometric studies.

The lesson to be learned by other electricity markets is that the quality of service impacts of ownership unbundling should be driven by an extensive cost-benefit analysis and not only rely on indicative econometric evidence of reform impacts elsewhere. A cost-benefit analysis can consider several country-specific local conditions, which a generalized econometric study cannot capture. Furthermore, given that electricity distribution networks are natural monopolies, improvement in quality of service also hinges on underlying incentives to improve quality which are embedded in the network regulatory regime given that electricity distribution networks are regulated natural monopolies. In that sense, ownership unbundling alone may not drive the improvements in quality suggested by our results.

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