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Welfare-Maximising Investors? – Utility Firm Performance with Heterogeneous Quality Preferences and Endogenous Ownership

Richard Meade & Magnus Söderberg

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Welfare-Maximising Investors? – Utility Firm Performance with Heterogeneous Quality Preferences and Endogenous Ownership

Richard Meade, Auckland University of Technology

Magnus Söderberg, University of Southern Denmark[1]

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Abstract

We model the endogenous ownership of a monopoly utility by either investors or the firm's customers. Ownership arises endogenously based on customers' quality preference, which affects each ownership type's viability. Customer ownership arises when quality preference falls below the threshold for profitable entry by investors, but above that for entry by customer-owners. When quality preferences diverge sufficiently, a profit-maximising investor-owned utility produces higher welfare than a welfare-maximising customer-owned firm, despite its higher prices. Otherwise, a customer-owned utility produces greater efficiency, quality and welfare, despite having lower-value customers. These predictions agree with empirical findings for US utilities, and find direct support using data from Electricity Distribution Businesses in New Zealand. To reflect ownership endogeneity, we instrument for ownership changes using the staggered rollout of regional air quality regulations. Our findings suggest that performance comparisons of customer- and investor-owned utilities should account for ownership endogeneity. This has implications for ownership debates, efficiency study specification, and the development of regulatory screens.

JEL Classifications: D24, L15, L51, L94, P13

Keywords: Utilities, Price, Efficiency, Quality, Welfare, Ownership.

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1 Introduction

Can we determine the ideal ownership form of a utility based just on relative performance? For example, can we say that a network monopoly – such as in electricity, gas, water or waste water – should be owned by investors, and not by some other class of owners, if utilities with certain types of owners exhibit superior efficiency, quality or welfare? How might performance rankings be affected by different ownership types catering to different types of customers?

Since the 1980s there has been a long-standing debate about the relative merits of public/government and private (i.e. investor) ownership, particularly in utility-type sectors with natural monopoly features.[2] That debate has largely centred on the potential efficiencies of investor ownership, as well as increased competition. It has received renewed interest in light of the impact of the global financial crisis on publicly-owned firms' ability to access the funds required for maintenance and investment, each of which affects service quality.[3]

With customers affected by the crisis unable to bear utility price rises, and investors also facing constraints on access to capital, transferring public ownership to investors is not always viable.[4] Furthermore, there is the risk of a downward spiral in which low prices or unpaid bills result in worsening service quality, which in turn reduces willingness to pay for service (Stanley et al., 2012). Hence, interest is increasing in the use of customer ownership as an alternative to either public or investor ownership for sustaining firm viability, and service levels, in a time of price restraint (Helm and Tindall, 2009; Brophy Haney and Pollitt, 2013; Mori, 2013). A hallmark of such ownership is that customers appoint the firm's governors, and share in its profits as well as consumer surplus.

Existing empirical studies on the relative performance of customer- and investor-owned utilities provide mixed results.[5] Furthermore, theoretical contributions on the relative performance of each ownership type - in particular, those accounting for service quality as well as efficiency (production costs) - are few. There is therefore a need for better theoretical and empirical analyses of relative utility performance under different ownership types. This is particularly relevant for debates about optimal ownership form. It is also relevant when assessing whether or not – and how – firms of each ownership type should be regulated.

Our contribution is to provide theoretical predictions of efficiency, quality, price and welfare, under both customer- and investor-ownership, when ownership arises endogenously in response to

[2] Megginson and Netter (2001) provide an extensive empirical survey. Pollitt (2012) surveys the impacts of liberalisation in energy sectors. Brophy Haney and Pollitt (2013) summarise some key theoretical contributions.

[3] For further details, see Helm and Tindall (2009), OECD (2009), Brophy Haney and Pollitt (2013), Stanley et al. (2012).

[4] Stanley et al. (2012) report on the crisis' impact on water and waste-water utilities. For example, investor participation in the sector has been constrained due to difficulties in accessing project financing.

[5] See the discussion in Söderberg (2011).

heterogeneous customer quality preferences. Notably, we predict that profit-maximising investor-owned firms produce higher welfare than welfare-maximising customer-owned firms when customers of each firm type diverge sufficiently in quality preference. In that sense, an investor-owned utility can be said to be welfare-maximising, despite formally seeking to maximise profits. When quality preferences are closer, however, customer-owned firms are predicted to be more efficient, and produce higher quality and efficiency, than investor-owned firms, despite their lower-value customers. We present supporting empirical evidence for the latter, using data from Electricity Distribution Businesses (EDBs) in New Zealand. As well as dealing with efficiency and quality being jointly determined, we add to existing empirical studies by addressing the endogeneity of ownership changes.

Our theory model assumes that different would-be utility customers are exogenously endowed with different preferences for quality. An investor-owned firm will serve those customers if their quality preference is sufficient to support profitable entry. Failing that, a customer-owned firm will serve those customers if their quality preference is not so high as to have induced entry by an investor-owned firm, but high enough to ensure that customer-owner total welfare exceeds entry costs. If the quality preference of customers is insufficient to induce entry by either owner type, then those customers remain unserved.

This setup is consistent with the often-made observation that customer-owned firms commonly arise in situations where customers are unprofitable for investors to serve.[6] Customers can be unprofitable when they are very costly to serve – for example due to being located in remote or sparse areas for which entry costs are high.[7] Alternatively, customers may have a relatively low willingness to pay for service. This can be because their incomes are relatively low (as in poor areas, or developing countries (ILO, 2013)), or because they are involved in relatively low-value activities (e.g. agriculture). Consistent with this observation, customer-owned utilities in electricity, water/sanitation and ICT often predominate in rural areas (Deller et al., 2009), [8] and they are common in developing countries (NRECA International, 2010).[9]

[6] So-called “cooperative” firms - which include customer-owned firms - historically arose as a form of “self-help” in struggling communities. For further background, see Hansmann (1996), Evans and Meade (2005a). According to Stumo-Langer (2016), “[t]here was a saying among [US] cooperatives in the 1930s: ‘if we don't do it, no one will.’”

[7] ILO (2014) observes that customer-owned water and sanitation firms serve remote locations that would otherwise have no service, providing quality services at reasonable cost. Also, customer-owned electricity distribution firms arise where the return on infrastructure investments is not sufficient to attract investor-owned utilities (ILO, 2013; 2014).

[8] See the surveys in NRECA International (2010) and ILO (2013, 2014).

[9] The UN has emphasised the development contribution of such stakeholder-owned firms, having declared 2012 the International Year of Cooperatives.

Our theory work extends existing studies that compare monopoly and welfare-maximising choices of price and quality (e.g. Spence, 1975). We do so by also modelling efficiency, and endogenising ownership choice when firms face heterogeneous customers. It also extends existing studies of optimal ownership form that consider price or quality.[10] In those studies different types of potential owners face the same distribution of customer types. In our case they each face a single type of customer class, with ownership choices reflecting differences in the type of each class. Finally, our model complements alternative explanations for non-investor firm ownership.[11]

In terms of empirical studies, our main contribution is to address the endogeneity of ownership. In the New Zealand context, most EDBs were historically customer-owned, but a number underwent ownership changes following their corporatisation (i.e. creation as organisations with tradable ownership rights) as part of wider economic liberalisation measures. We postulate that the likelihood of an EDB opting for tradable shares to be made available to investors – rather than retained on behalf of customers – is related to the "liberalness", or free-market orientation, of its initial owners. We instrument for this characteristic using the staggered rollout of air quality regulations by independent regional regulators. Air quality issues arise predominantly in dense urban areas, in which populations are typically higher educated, and wealthier. We postulate that these characteristics correlate with free-market orientation, and hence our choice of instrument should have explanatory power for observed ownership changes.

Our empirical work also contributes to the literature on the importance of simultaneously measuring costs and quality. It does so by exploring the impact of ownership on each, and allowing for both their endogeneity and temporal dimensions (extending Jamasb et al. (2012)). Our research also extends Jamasb and Söderberg (2010), who estimate costs, quality and price for Swedish electricity distributors. They find a cost advantage to investor-owned firms, but do not find ownership differences in terms of quality, and do not instrument for ownership. Likewise we extend Kwoka (2005), who finds that public ownership – an intermediate case between customer and investor ownership – is associated, in smaller utilities, with both lower costs and greater reliability than under investor ownership for a sample of US electric utilities.[12] His reliability comparisons, however, do not control

[10] Hart and Moore (1996) consider price choice as well as the impacts on ownership form of industry competitiveness. Hart and Moore (1998) also consider investment choices, which affect quality. Herbst and Prüfer (2005) examine optimal ownership when quality provision involves incentive problems. Meade (2014) analyses regulation and incentive issues under customer and investor ownership, but with ownership exogenous and customers homogeneous. A survey of ownership forms in the US, and framework for explaining observed ownership differences, is provided in Hansmann (1996).

[11] For example, Hueth et al. (2005) model the formation of supplier-owned firms as a means of relieving financing constraints, such as those arising in declining agricultural industries.

[12] This is somewhat contradicted by Boylan (2016) who finds that investor owned electricity distribution firms in the US are not adversely affected by storms, whereas municipality owned firms are.

for differences either between or within each ownership type, and nor does he account for endogeneity issues. We also contribute to the wider literature on the relative efficiency of electricity distributors under different ownership types, which to our knowledge is yet to control for ownership endogeneity and heterogeneity in customer preferences.[13]

Our findings raise a number of policy implications. The first is that regulators or policy-makers concerned with industry performance cannot rely on just direct performance comparisons when assessing the desirability of alternative ownership forms. Since customer-ownership arises in situations where customers have quality preferences that could make investor ownership nonviable, it would be inadvisable to prefer investor ownership simply because it might be found to display better performance.

Conversely, finding that an investor-owned utility produces higher welfare than customer-owned utilities could mistakenly be used to argue against regulation. Our work suggests that higher welfare under investor ownership could arise simply as a consequence of it having higher-value customers, and that this could in fact be masking poor quality or efficiency. Once again, observed performance must be conditioned on endogenous ownership choices and differences in customer types, in this case to avoid false positives or false negatives in applying regulatory screens. It should be noted that the empirical literature has largely ignored the fact that ownership choice is endogenous in network sectors.[14] This has implications for the types of efficiency studies often used in determining regulatory settings for regulated utilities.

Another implication is that changes in customer quality preferences might give rise to beneficial ownership changes. For example, an initially rural area with low customer preferences for quality might initially be served only by a customer-owned firm because those customers are insufficiently profitable to be served by an investor-owned firm. However, if that area becomes more wealthy, and its customers' quality preference rises, this could shift the balance in favour of welfare-improving - and now viable - investor-ownership. The reverse might also be true - with a customer group served by an investor-owned firm experiencing a fall in quality preference (for example due to economic decline in the region) resulting in only customer-ownership being viable, even if that entails reduced performance.

Our paper is organised as follows. Section 2 presents our theoretical model and its predictions, including about performance comparisons. Section 3 describes our empirical methodology, addressing interrelationships between efficiency and quality, and including details about how we instrument for ownership changes. Section 4 describes our data, while Section 5 presents our empirical results. Finally, Section 6 concludes.

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[13] For example, see Kumbhakar and Hjalmarsson (1998) in relation to Sweden, Estache and Rossi (2005) for Latin America, and Claggett et al. (1995) for the US.

[14] See Söderberg (2008) for a review of studies based on electricity distribution.

2 Theoretical Model

2.1 Demand and Costs

We consider a natural monopoly producing distribution/transportation services, such as in electricity, gas, water/sanitation or ICT. Demand for the firm's output is:

$$q(p,s) = 1 - p + \delta s, \tag{1}$$

where q is output, p is price, s is service quality, and $\delta \geq 0$ represents the preference for quality of that firm's customers.[15] We allow that preference to vary between would-be customers of different firms, but not within any would-be customers of a given firm. Service quality acts as a positive demand shifter, with inverse demand having a vertical intercept at $1 + \delta s$. Higher quality therefore increases consumer surplus, all else equal.

The firm's costs are assumed to be fixed, in the sense that they do not vary with the quantity of services the firm supplies.[16] Entry requires that a certain level of fixed cost, F, must be incurred by the firm's owners, for example representing the basic cost of setting up a network. However, the overall level of fixed costs depends on choices made by the firms' owners regarding both production efficiency e, and quality s. Specifically, we assume fixed costs are:

$$c(s,e) = F + \frac{1}{2}e^2 + \frac{1}{2}s^2 - e - \gamma es, \tag{2}$$

Thus e reduces the firm's fixed costs, but achieving cost savings is assumed itself to be costly, with such costs being convex in e. Additionally, quality is costly to achieve, with costs that are likewise convex in s.

The final term in the firm's fixed costs involves an interaction term γes, with $\gamma \geq 0$ assumed. This means s and e are either independent, or complements – higher quality reduces the cost of achieving cost efficiency, and vice versa. We assume $\gamma \geq 0$ to ensure that quality is positive at the optimum for all cases we consider. It is also natural, since many quality-related investments can be expected to improve efficiency.[17]

[15] Writing demand as $q = a - bp + \delta s$ does not change the model's qualitative predictions. For the sake of parsimony we therefore impose $a = b = 1$.

[16] Kumbhakar and Hjalmarsson (1998) report that labour costs in electricity distribution firms, which costs are largely fixed and relate more to capacity than output per se, constitute up to 50% of total supply-related costs. Also, the marginal cost of transporting an additional (e.g.) electron is negligible.

[17] Stanley et al. (2012) report that water supply in Ireland involves leakage rates of 40%. Investments that improve the reliability of water supply - such as installing pipes less prone to rupture – would improve service quality while also reducing costly wastage.

A firm's owners are assumed to choose efficiency e and quality s, and also the firm's output price p.[18] Sufficient conditions for all second order conditions to be satisfied, and for well-defined optimum values, are $0 \leq \delta < \frac{1}{2}\sqrt{2}$ and $0 \leq \gamma < \frac{1}{2}\sqrt{2}$, which we maintain as assumptions throughout.

2.2 Owners' Objectives

The firm's owners are assumed to maximise the α-weighted sum of profits and net consumer surplus, with $0 \leq \alpha \leq 1$:

$$\pi(p, s, e) + \alpha CS(p, s), \tag{3}$$

Here, $\pi(p, s, e) = pq(p, s) - c(s, e)$, which after substitution from (1) and (2) is:

$$\pi(p, s, e) = p(1 - p + \delta s) - \left[F + \frac{1}{2}e^2 + \frac{1}{2}s^2 - e - \gamma es\right]. \tag{4}$$

Furthermore, using (1) we have that:

$$CS(p, s) = \frac{1}{2}(1 - p + \delta s)^2. \tag{5}$$

This specification of the owners' objective function takes in investor ownership ($\alpha = 0$) and customer ownership ($\alpha = 1$) as special cases. Thus investor-owners maximise profits, while customer-owners maximise the sum of profits and net consumer surplus.[19] Note that once a firm's owners have determined their optimal values of e, s and p in terms of model parameters γ, δ and F,[20] but taking δ and F as technological givens applying equally across all firm types, we can write:

$$\begin{gathered} \pi = \pi(\delta, F) \\ CS = CS(\delta) \\ \pi(\delta, F) + CS(\delta) \end{gathered} \tag{6}$$

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[18] We therefore abstract from issues of monopoly price regulation, meaning our analysis can inform the case for or against regulation. Optimal regulation when both efficiency and quality are of interest is explored further in Meade (2014) under both investor- and customer-ownership, though with ownership taken as exogenous.

[19] We do not rule out intermediate values of α, which takes in other cases such as partial customer ownership, or possibly municipal ownership. Analysis of other such cases is left to future work.

[20] More generally we could write $F = F(\delta)$. However, for the sake of parsimony, and to focus on how quality preferences affect the viability of investor or customer ownership more generally, we simply treat F as exogenous. Likewise, adding non-zero costs of firm formation would add little to the analysis.

Doing so emphasises that the respective objective functions of investor- and customer-owners depend on the quality preference of their would-be customers, as well as entry cost. This is important when endogenously determining firm ownership.

2.3 Timing of Ownership Choices

Ownership choice is endogenised through the following assumed sequence:

1. Nature exogenously determines the quality preference δ of a would-be group of customers.[21] Ample evidence exists for utility customers having heterogeneous preferences for quality. For example, estimates of utility customers' willingness-to-pay for supply quality varies according to income (Tanellari, 2010; UNDP, 1999), between urban and rural customers (Brouwer et al., 2015), and according to customer type and size (Schröder and Kuckshinrichs, 2015).

2. If δ is of a level that investor-owners enjoy non-negative profits $\pi(\delta, F)$, then an investor-owned firm is costlessly formed to serve those customers. Specifically, an investor-owned firm is formed if $\pi(\delta, F) \geq 0$.

3. If no such investor-owned firm was formed (because δ was not sufficient to ensure non-negative profits), then a customer-owned firm is costlessly formed to serve those customers, provided δ is of a level that the sum of profits and consumer surplus is non-negative. Formally, this occurs when $\pi(\delta, F) + CS(\delta) \geq 0$ but $\pi(\delta, F) < 0$.

4. If δ is not of a level such that either a customer- or investor-owned firm could viably have been formed, then the would-be customers remain unserved. Conversely, if a firm has been formed, the firm's owners make the following sequence of choices:

   (a) First they choose their cost efficiency (that is, production technology), e;
   (b) Second, they choose their service quality, s; and
   (c) Finally, they choose their output price, p.

[21] For example, this might occur indirectly, by those customers being born in a particular country or region. This affects features such as their wealth, productivity, climate, access to markets, or other endowments (such as market institutions or natural resources), all of which could affect their preference for the utility firm's service quality.

This timing is natural because it allows customer ownership to form in situations where investor-owners have not found it profitable to enter service, but allows for investor-ownership to dominate where investor entry is profitable. Conversely, if neither ownership form is viable (in the sense that quality preference δ is not sufficient to ensure a firm's owners generate enough return – either non-negative profits, or profits plus net consumer surplus – then customers remain unserved.[22]

This sequence of ownership choices aligns well with experience that communities placing a low value on a service might receive no service at all. Conversely, those with an intermediate valuation on the service might only be viably supplied by a customer-owned firm, while only profitable customers are served by investor-owned firms. Furthermore, a firm's choice of production technology represents a long-term investment decision (i.e. what plant and equipment to install). Conversely, quality choices relate not just to installed plant and equipment, but also to how that plant and equipment is deployed and maintained, reflecting shorter-term choices. Finally, pricing choices can be changed relatively easily and quickly.

2.4 Solution

We solve for the owner's optimum by backward induction. Starting with the owners' price choice maximising (3) – taking δ and hence ownership type, and also s and e, as given – we find:[23]

$$p(s|\delta) = \frac{(1-\alpha)(1+\delta s)}{2-\alpha}. \tag{7}$$

Anticipating this optimal price choice (that is, substituting (7) into (3)) – and taking δ and hence ownership type, as well as e, as given – the owners' optimal quality choice is:

$$s(e|\delta) = \frac{\delta + (2-\alpha)e\gamma}{(2-\alpha)-\delta^2}. \tag{8}$$

Anticipating these optimal quality and price choices (using (7) and (8) in (3)) – still taking δ and hence ownership type as given – the owners' optimal efficiency choice is:

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[22] As in Herbst and Prüfer (2005), a further possibility in this case might be not-for-profit provision. We leave that extension to future work, noting that not-for-profit provision of network utility services is uncommon, most likely due to prohibitive capital requirements.

[23] Notice that this implies $p = 0$ under customer ownership ($\alpha = 1$). This is an artifact of our simplifying assumption that all the firm's costs are fixed, with no variable costs. Allowing the firm to have some positive level of marginal costs would produce a positive price under customer ownership, but not otherwise add to the analysis. Notice also that F does not affect the optimal choice of p, and nor the optimal choices of s and e.

$$e(\delta) = \frac{(2-\alpha) + \delta(\gamma - \delta)}{(2-\alpha)(1-\gamma^2) - \delta^2}. \tag{9}$$

Using (9) in (8) and (7) we can then also express the owners' optimal quality and price choices in terms of δ (treating γ as a given for both ownership types):

$$s(\delta) = \frac{(2-\alpha)\gamma + \delta}{(2-\alpha)(1-\gamma^2) - \delta^2} \tag{10}$$

$$p(\delta) = \frac{(1-\alpha)(1-\gamma(\gamma-\delta))}{(2-\alpha)(1-\gamma^2) - \delta^2} \tag{11}$$

Thus, for a given δ, customer ownership is predicted to result in lower price,[24] higher quality, and higher efficiency than investor ownership.

Turning to endogenous ownership choice, under our assumed timing customer-owners can elect to form a customer-owned firm if investor-owners have not already formed a firm for the given set of customers (with those customers' associated δ determined by nature). Supposing an investor-owned firm has not been formed, then customer-owners will form a firm provided $\pi(\delta, F) + CS(\delta) \geq 0$. Using (9), (10) and (11) in (3) with $\alpha = 1$, this condition writes as:

$$\frac{\delta^2 - \gamma(2\delta - \gamma) - 2}{2(\delta^2 + \gamma^2 - 1)} - F \geq 0. \tag{12}$$

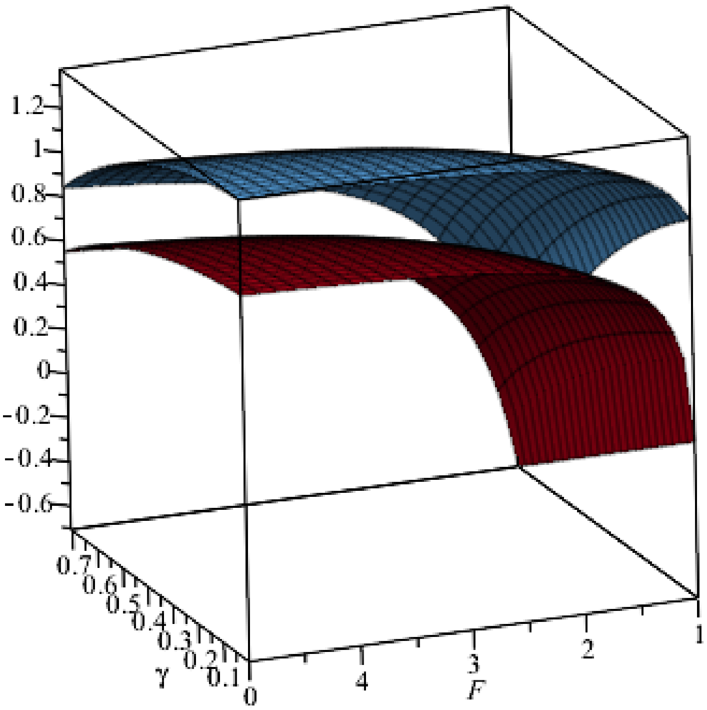
It is easily verified that (12) is increasing in δ, so the value δ_{crit}^{CO} that satisfies (12) with equality is the minimum threshold above which δ must fall for entry by customer-owners to be viable. Since we assume that $0 \leq \delta, \gamma < \frac{1}{2}\sqrt{2}$, and further assuming that $F \geq 1$ to ensure the threshold is well-defined (and $c \geq 0$), the relevant root of (12) is:

$$\delta_{crit}^{CO}(F,\gamma) = \frac{\gamma - \sqrt{2 - 2F(3 - 2\gamma^2) + 4F^2(1-\gamma^2)}}{1 - 2F}. \tag{13}$$

Finally, we allow for investor-owners to have the first choice over whether or not to form a firm (failing which customer-owners may then elect to do so, as just discussed), given the δ determined by nature for their would-be customers. They will do so if and only if $\pi(\delta, F) \geq 0$. Once again using (9), (10) and (11) in (3), but now with $\alpha = 0$, this writes as:

[24] In fact, we predict that price is zero under customer ownership, since to maximise total surplus customer owners set price equal to marginal production cost, which here is nil.

Figure 1: Quality preference (δ) thresholds required to induce firm entry



$\delta_{crit}^{CO}(F,\gamma)$ in red. $\delta_{crit}^{IO}(F,\gamma)$ in blue.

$$\frac{\delta^2 - \gamma(2\delta - \gamma) - 3}{2(\delta^2 + 2\gamma^2 - 2)} - F \geq 0. \tag{14}$$

As for the customer-owners' entry criterion, (14) can easily be shown to be increasing in δ, so the value δ_{crit}^{IO} satisfying (14) with equality is the minimum threshold above which δ must fall to induce entry by investor-owners. With the parameter value restrictions as above, the relevant root of (14) is:

$$\delta_{crit}^{IO}(F,\gamma) = \frac{\gamma - \sqrt{3 - 2F(5 - 3\gamma^2) + 8F^2(1 - \gamma^2)}}{1 - 2F}. \tag{15}$$

It is easily verified that $\delta_{crit}^{IO}(F,\gamma) - \delta_{crit}^{CO}(F,\gamma) \geq 0$ given our assumed parameter value restrictions. Thus, as expected, the threshold value above which δ must fall in order to induce entry by investor-owners is higher than that required to induce entry by customer-owners. This is illustrated in Figure 1. Notice that neither threshold is everywhere positive for our assumed parameter ranges. A positive threshold is not necessary to induce entry by either firm type – rather, a negative threshold indicates that at least one firm type must always be viable since we assume that $0 \leq \delta < \frac{1}{2}\sqrt{2}$.

Conversely, if the lower-most threshold is so positive that it requires $\delta > \frac{1}{2}\sqrt{2}$ in order to induce entry by even customer-owners, then that indicates a situation in which neither firm type is viable, and customers would not be served.

Since it is nature that ultimately determines a would-be group of customer's quality preference, $\delta > 0$, under our assumed timing we have that:

1. No firm is formed, and customers are not served, if and only if $\delta < \delta_{crit}^{CO}(F, \gamma)$;

2. A customer-owned firm is formed if and only if $\delta_{crit}^{CO}(F, \gamma) \leq \delta < \delta_{crit}^{IO}(F, \gamma)$; and

3. An investor-owned firm is formed if and only if $\delta \geq \delta_{crit}^{IO}(F, \gamma)$.

Figure 2 illustrates three sets of possibilities for different values of $F \geq 1$, and our assumed parameter restrictions $0 \leq \delta, \gamma < \frac{1}{2}\sqrt{2}$. In Panel (a), with $F = 1$, we see that even with δ at its lowest limit $\delta_{min} = 0$, we have $\delta \geq \delta_{crit}^{CO}(F = 1, \gamma)$ for all permitted values of γ. Hence a customer-owned firm is viable for all permitted γ in this case. Conversely, even with δ at its upper limit $\delta_{max} = \frac{1}{2}\sqrt{2}$, we require $\gamma \geq \frac{1}{6}\sqrt{2}$ before we have $\delta \geq \delta_{crit}^{IO}(F = 1, \gamma)$, with only customer-ownership viable below this limit. Thus investor ownership is viable only for γ sufficiently large in this case.

In Panel (b), with $F = 1.25$, even when δ is at its minimum, customer ownership is only viable for γ sufficiently large. Similarly, with δ at its upper limit, investor-ownership is viable over a smaller range of γ than in Panel (a).

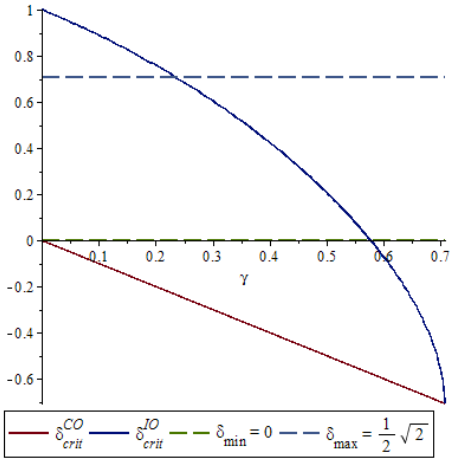
Finally, in Panel (c), with $F = 2$, we have a case in which neither firm type is viable when δ takes its minimum value. Moreover, even when it takes its maximum value, customer ownership becomes viable only when γ is sufficiently large. In this case investor ownership is viable for a much smaller range of γ than in the other two panels. As can be seen, the viability of either ownership form falls as entry cost F rises.

2.5 Performance Comparisons

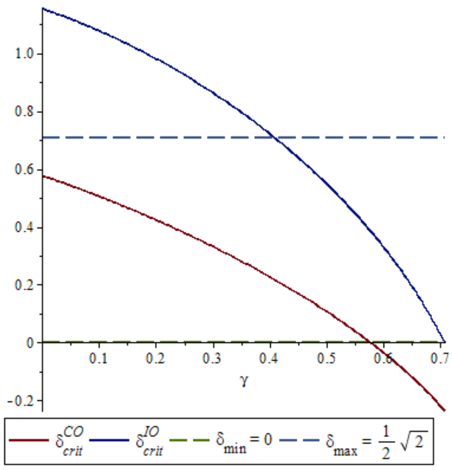
When ownership choice is endogenous as above, comparing the performance of investor- and customer-owned firms necessarily involves comparing dissimilar entities. In our setup ownership choice is driven by differences in quality preference, δ, with a higher δ required to support investor ownership than customer ownership. Consequently, it is natural to compare the performance of a customer-owned firm having a lower quality preference with an investor-owned firm having a higher quality preference.

Figure 2: Ownership scenarios for different levels of entry cost *F*

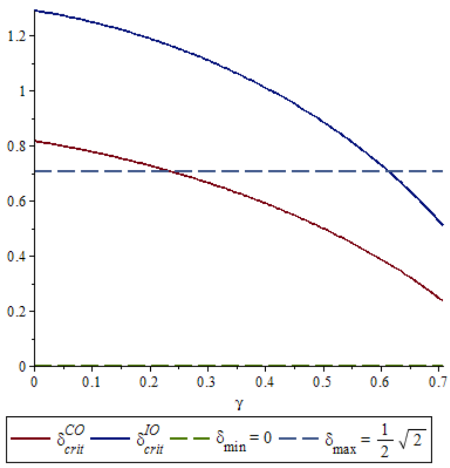
Panel (a): δ thresholds and admissable values, versus γ, for $F = 1$



Panel (b): δ thresholds and admissable values, versus γ, for $F = 1.25$



Panel (c): δ thresholds and admissable values, versus γ, for $F = 2$



Two cases are illustrated in Figure 3, which plots the difference in price, quality, efficiency, and overall welfare ($w \equiv \pi + CS$, that is "total surplus") between investor- and customer-owned firms. In Panel (a), we have the case of maximal separation of customers' quality preferences. This means that we assume the customer-owned firm's customers have quality preference $\delta^{CO} = \delta_{min} \equiv 0$, while the investor-owned firm's customers have preference $\delta^{IO} = \delta_{max} \equiv \frac{1}{2}\sqrt{2}$. Conversely, in Panel (b), we have a case with less separation in quality preferences, assuming $\delta^{CO} = \frac{1}{2}$ instead of $\delta^{CO} = \delta_{min}$, and $\delta^{IO} = \frac{2}{3}$ instead of $\delta^{IO} = \delta_{max}$. Case (a) is consistent with the coexistence of customer- and investor-owned firms as in Figure 2(a), with $\delta^{CO} \geq \delta^{CO}_{crit}$ for all admissable γ, and $\delta^{IO} \geq \delta^{IO}_{crit}$ for $\gamma \geq \frac{1}{6}\sqrt{2}$. Conversely, Case (b) is consistent with coexisting customer- and investor-owned firms as in Figures 2(a) and 2(b), for γ sufficiently large in the admissible range.

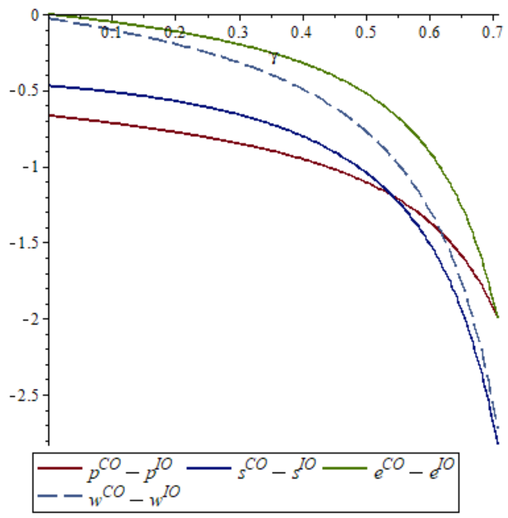
In Figure 3(a) we see that price is lower under customer ownership than investor ownership, which is positive for welfare in the customer ownership case. However, investor ownership results in greater quality and efficiency in this case, improving welfare. Indeed, for these parameters, we see that overall welfare is higher under investor ownership throughout the admissable range for γ. Customer ownership directly involves the maximisation of welfare (customer owners maximise (3) with $\alpha = 1$), whereas investor ownership does not (investor owners maximise (3) with $\alpha = 0$). However, because δ^{CO} is assumed to be sufficiently lower than δ^{IO} in this case, investor ownership delivers greater overall welfare.

In Figure 3(b) a different result emerges. Once again, customer ownership exhibits lower price than investor ownership, favouring welfare under customer ownership. Moreover, with δ^{CO} less than δ^{IO} in this case, but not as much as in Panel (a), customer ownership also exhibits greater quality and efficiency. In this case overall welfare is higher under investor ownership if γ is sufficiently large, but is higher under customer ownership otherwise. Hence, in this case, it is possible that customer ownership is superior to investor ownership in welfare terms despite the disadvantage of having customers with a lower preference for quality.

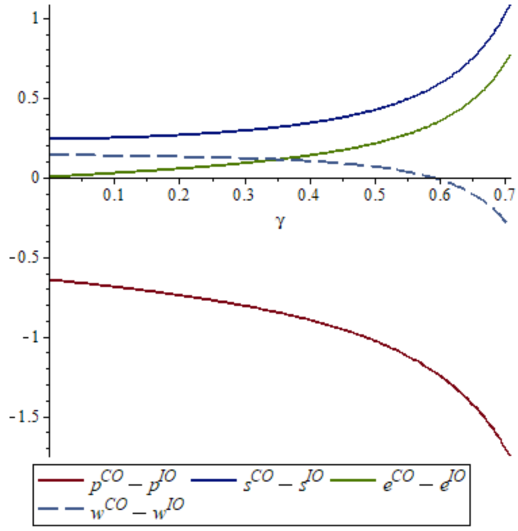
From Figure 3 we see that whether or not an investor-owned firm's performance is apparently superior to that of a customer-owned firm depends on the extent to which δ^{IO} exceeds δ^{CO}. In our empirical analysis we find that price is lower under customer ownership, but efficiency, quality and welfare are higher. This scenario is consistent with the case in Figure 3(b), in which quality preferences are relatively proximate across both firm types. Despite its simple setup, our theory model is able to generate quite diverse sets of predictions, and identifies a clear mechanism for these differences.

Figure 3: Comparing price, quality, efficiency and welfare given $\delta^{CO} < \delta^{IO}$

Panel (a): $\delta^{CO} = 0, \delta^{IO} = \frac{1}{2}\sqrt{2}$



Panel (b): $\delta^{CO} = \frac{1}{2}, \delta^{IO} = \frac{2}{3}$



3 Empirical Methodology

Given the above theoretical predictions, we turn to empirically estimating the relative performance of customer- and investor-owned utilities. To do so we use data from electricity distribution businesses (EDBs) in New Zealand, separately estimating empirical models for costs, quality and price, and maintaining the assumption from Section 2 that firm ownership is endogenous. In Section 3.3 we explain in detail our instrumentation strategy, but first we explain the relationship between cost and quality used to inform our empirical specifications for each.

3.1 Cost and Quality Interrelations

Cost and quality in electricity distribution are closely related but in subtle ways. Before cost and quality models can be estimated it is necessary to identify these links, and to clearly define both 'cost' and 'quality'. As in most previous empirical studies, we define quality in terms of reliability,[25] which is most commonly measured by the System Average Interruption Duration Index (SAIDI). To relate this quality measure to costs, we decompose costs into *corrective* operating expenditures (repairs), *preventative* operating expenses (maintenance), *depreciation* on past capital expenditures (longer-term investments in network assets made in the past), and current *capital* expenditures.[26] The aggregate of corrective and preventative expenditures is described as *Opex*, while capital expenditures are described as *Capex*. Depreciation allocates the up-front cost of capital expenditures to each of the years of the relevant asset's useful life. We make this decomposition because changes in quality should not only affect a firm's costs, but also the very nature of the firm's cost function.

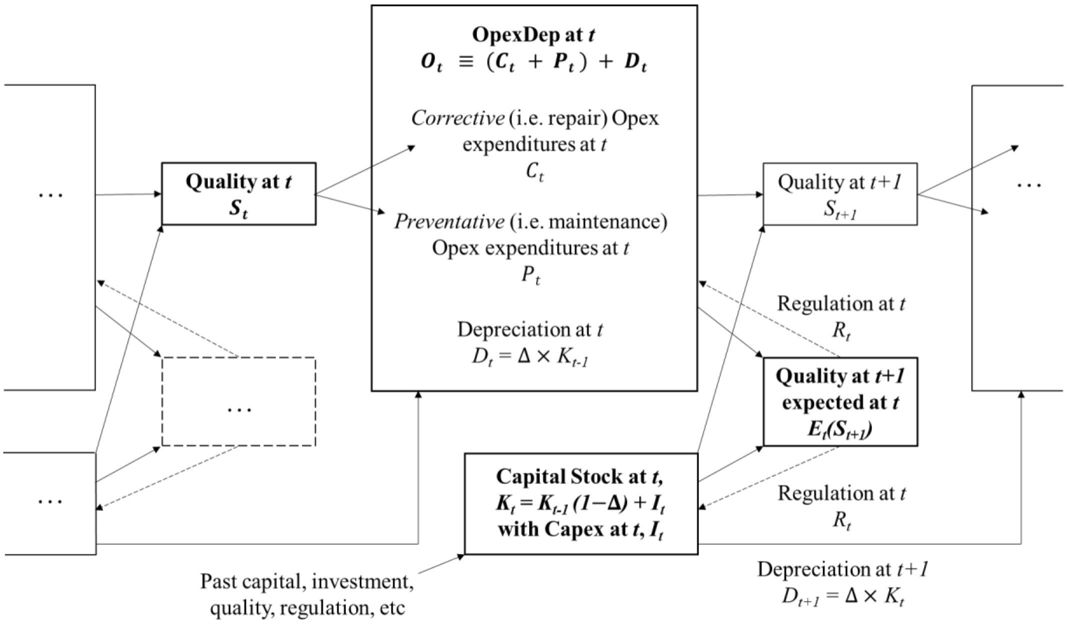
Figure 4 illustrates the interactions between cost and quality. Begin by considering a quality realisation at time t, denoted S_t. The severity of a particular fault is a function of past repairs, maintenance and capital expenditures, as well as past quality, and regulatory incentives. This gives rise to contemporaneous corrective expenditure C_t (repairs), designed to simply restore the status quo network output capacity. It might also give rise to contemporaneous preventative expenditure P_t (maintenance) to make the network more robust against eventualities like wind-related faults recurring in the future. Together these expenditures make up contemporaneous Opex.

At the same time, the firm makes capital expenditures I_t, adding to its existing capital stock K_{t-1} inherited from the preceding period. That capital stock depreciates at some rate Δ per period, so current period capital stock follows the usual dynamics, with $K_t = K_{t-1}(1 - \Delta) + I_t$, and current period depreciation is $D_t = \Delta \times K_{t-1}$. Since capital expenditures are often large and lumpy, involve long lead-times, and can be very long-lived, they are assumed to be chosen based on factors over and above just quality realised at t.

[25] Quality in the electricity distribution context is generally regarded as comprising three dimensions - commercial quality, voltage (or power) quality, and service reliability (Ajodhia and Hakvoort (2005)). The first relates to the quality of commercial arrangements between the distributor and its customers (for example customer service arrangements, terms and conditions for new connections, or for re-/de-connections). The second relates to the physical quality of the electrical waveform. The third - service reliability - is typically regarded as the most important quality dimension for research purposes and in regulatory contexts.

[26] This framework adapts and extends that presented in Jamasb et al. (2012). Unlike us, those authors focus on just preventative expenditures because they wish to estimate the cost of marginal improvements in quality. We also consider corrective expenditures, since we seek to identify the interaction between total expenditures and quality.

Figure 4: Cost and Quality Schematic



Irrespective of how I_t is determined though, we assume that both Opex (for example repair intensity, or maintenance) and Capex I_t (for example undergrounding) will affect future quality realisations, which depend on the total capital stock K_t. Indeed, they will affect not just actual future quality, but also expected future quality as we discuss further below. For convenience, we treat I_t as exogenous to our consideration of "short-term" costs and quality.

Giannakis et al. (2005) observe that electricity distribution firms face not just tradeoffs between costs and quality, but also between capital and operating expenditures. For example, firms might elect to maintain an old asset rather than replace it, so as to defer incurring large capital expenditures. They - like Growitsch et al. (2009) and Jamasb et al. (2012) - model "Totex", being the sum of Opex and Capex. However, Coelli et al. (2013) in turn observe that this can be a poor measure of a firm's actual expenditures in any given year for the reasons noted above. Specifically, if a firm replaces a major asset in any given year, its Capex could be particularly large in that year, whereas the capital services of that asset are consumed over multiple years. Accordingly, since depreciation "smoothes" Capex over an asset's life, we measure a firm's aggregate expenditures in any given year by Opex plus depreciation, which we describe as "OpexDep" (denoted O_t):

$$OpexDep_t \equiv O_t = Opex_t + D_t = (C_t + P_t) + D_t$$

We use this terminology to distinguish our expenditure measure from either Opex or Totex. Thus OpexDep includes current year corrective and preventative expenditures, but also an annualised charge for all preceding year capital expenditures, being depreciation D_t. Since depreciation allocates the cost of capital expenditures over the years to which the associated assets are consumed, OpexDep provides a more reasonable measure of annual firm expenditures, suffering from neither of the criticisms applying respectively to Opex and Totex.

Furthermore, following Jamasb et al. (2012), we assume that OpexDep will be determined by expected future quality as well as actual current quality. This is relevant where regulatory incentives punish or reward quality deviations from regulatory quality targets. Hence we draw a dashed feedback loop in Figure 4 between expected quality at $t+1$ and OpexDep at t, emphasising that regulation will play a role in determining OpexDep. Indeed, just as this feedback will affect short-term OpexDep, it will also affect longer-term Capex at t, as also drawn, interacting with the firm's usual investment decision-making criteria.

In turn, OpexDep and Capex at t will affect quality at $t+1$, and that in turn will affect future corrective and maintenance expenditures, as well as depreciation charges, at $t+1$, and so on. Indeed, faults in any year may give rise to persistence in future quality issues and expenditures. For example, if storm damage is not properly fixed in one year, then the network will remain vulnerable in the following year, necessitating higher future corrective expenditures if the storm recurs.

3.2 Cost and Quality Specifications

The above schematic suggests specifications for both costs and quality. In particular, they suggest a simultaneous equation framework as well as temporal dependencies. Specifically, we write OpexDep O_t and quality S_t at time t as follows:

$$O_t = O_t(S_t, E_t(S_{t+1}), O_{t-1}, I_{t-1}, ShCO_t, X_t) \quad (16)$$

$$S_t = S_t(O_{t-1}, S_{t-1}, I_{t-1}, ShCO_t, X_t) \quad (17)$$

Thus O_t depends on current quality realisation S_t, and on future expected quality $E_t(S_{t+1})$. Current OpexDep will also depend on past OpexDep for the reasons given above (for example "cutting corners" – or "gold-plating" at the other extreme - will affect expenditures in later years). Here $ShCO_t$ represents share of customer ownership, varying from 0 (no customer ownership – i.e. investor ownership) to 1 (full customer ownership). We use X_t to represent all other relevant exogenous variables, including customer numbers, capacity utilisation (load factor) and weather. Also included in X_t are year fixed effects and EDB fixed effects. We measure Capex using changes in network length, since this is an objective measure of capacity change. Unlike financial Capex measures, it directly correlates with changes in physical capacity.

In (17), current quality S_t depends on past OpexDep O_{t-1}. It also depends on past quality realisations (that is, a damaged network in one year leads to greater risk of network failure in the next). Since those past realisations will have been affected by past OpexDep, we treat past quality as sufficient for past OpexDep. For the same reasons as above, we specify quality as depending on just past Capex (which is treated as sufficient for past regulation).

A specific empirical challenge is how to deal with the expected future quality, i.e. $E_t(S_{t+1})$, in (16). The specification illustrates that when choosing O_t each firm will be aware that this has an impact on $E_t(S_{t+1})$.[27] To resolve this, we proxy for expected future quality using actual future weather variables, which are clearly exogenous to the firm. Adverse weather influences peak demand, which in turn affects how close the network is to capacity and hence its risk of failure due to breaching capacity constraints. In addition, adverse weather can directly create faults by physically damaging network assets even when demand is not at its peak. Notably, New Zealand is subject to the El Niño/La Niña (Southern Oscillation) phenomenon, meaning its climate is subject to predictable inter-annual variations. In particular, El Niño is associated with colder winters, while La Niña is associated with more rainfall in some parts of the country.

A second and more obvious interrelationship arises due to S_t depending on current O_t. To address both this interrelationship and that between O_t and $E_t(S_{t+1})$, our specifications for cost and quality are expressed in reduced form, in which case each is a function of shared exogenous explanatory variables. Specifically, (16) and (17) rewrite as:

$$O_t = O_t(Weather_{t+1}, S_{t-1}, O_{t-1}, I_{t-1}, X_t) \quad (18)$$

$$S_t = S_t(Weather_{t+1}, S_{t-1}, O_{t-1}, I_{t-1}, X_t) \quad (19)$$

where $Weather$ denotes weather variables, proxying for expected future quality. This is the approach we adopt in Section 4, which sets out detailed specifications of our empirical cost and quality models, as well as our price model.

3.3. Instrumenting for Ownership Endogeneity

In the New Zealand context, most EDBs were historically customer-owned, but a number underwent ownership changes following their corporatisation (i.e. creation as organisations with tradable ownership rights) as part of wider economic liberalisation measures. We postulate that the likelihood of an EDB opting for tradable shares to be made available to investors – rather than retained on behalf of customers – is related to the "liberalness", or free-market orientation, of its initial owners.

[27] Jamasb et al. (2012) also specify costs to be a function of expected future quality. In their case, however, instead of endogeneity bias they emphasise the unobservability of $E_t(S_{t+1})$. They therefore proxy that variable by actual future quality, and argue that the resulting measurement error should lead to a downward bias in their estimate of its coefficient.

We instrument for this characteristic using the staggered rollout of air quality regulations by independent regional regulators. This variable takes the value 1 in the year the regulation was implemented, and stays at that value in all subsequent periods in which the regulation remained active. It takes the value 0 in pre-regulatory periods, and in all periods in regions that never implemented air quality regulation.[28]

This instrument is relevant because air quality issues in New Zealand arise predominantly in dense urban areas, for which populations are typically more highly-educated, and wealthier. We postulate that these characteristics correlate with free-market orientation, and hence our choice of instrument should be positively related to the share of investor ownership.

The instrument is also valid because air quality issues in New Zealand – unlike in most other developed countries – are not related to electricity sector production. Specifically, over our sample period the renewable share of electricity production (hydro, geothermal, wind and solar) averaged 71% of total production, while coal-based production averaged just 5%.[29] Hence the rollout of air quality regulation was not causally related to pollution caused by electricity sector (including EDB) decisions, meaning our instrument is valid.

4 Data

Historically, New Zealand EDBs were predominantly customer-owned, but following structural reforms in the 1990s they now exhibit a variety of ownership forms.[30] There are currently 29 EDBs, of which 18 are substantially customer-owned, and 12 of those 18 are exempt from price-quality regulation as applied by the New Zealand Commerce Commission. Firm-level information disclosures regarding those EDBs' electricity distribution activities have been required since the introduction of disclosure regulations in 1994. Based on these disclosures, we have data for the years ending March 1995 through 2013 inclusive in our sample. Where necessary, disclosure compilations from the Commerce Commission were augmented with firm-level annual disclosure statements sourced directly from the relevant firms' websites. Table 1 defines the variables considered in our analysis and provides summary statistics. Financial variables have been deflated using the consumer price index.

Following the discussion in Section 3, our measure of total annualised operating expenditures, OpexDep, is defined to be total operating expenditure (including depreciation), net of transmission charges, customer rebates, rebates of transmission loss rentals to retailers/customers, and amortisation. Depreciation, unlike capital expenditure, is a non-lumpy measure of annualised capital charge. Transmission charges, customer rebates, and rebates of transmission loss rentals to retailers/customers are treated as pass-through costs, rather than controllable operational costs borne by the firm, and

[28] Details about when regulation was implemented were taken from Pendly et al. (2015).

[29] Figures based on electricity data tables available at: www.mbie.govt.nz.

[30] See Evans and Meade (2005b) for a summary of the relevant reforms, and their wider context.

Table 1: Variable definitions and summary statistics

Variable	Description	All obs (n=296) Mean (SD)	Customer owned[a] (n=216) Mean (SD)	Investor owned[b] (n=44) Mean (SD)
Length	Distribution lines length, both overhead and underground, in km.	4,578 (4,105)	3,603 (2,115)	8,265 (6,992)
Cust	Number of customers (specifically, installation control points, or ICPs).	54,723 (73,650)	34,602 (38,817))	123,145 (129,676)
Load	Energy entering the network as a ratio of (maximum demand × hours in year), multiplied by 100 — a measure of network capacity utilization	61.51 (7.48)	62.39 (6.74))	61.68 (10.43)
Price	Network revenue (before customer rebates) per MWh of energy entering the network, in NZ$/MWh.[c]	48.19 (13.63)	49.65 (15.10)	45.08 (8.78)
OpexDep	Operating expenditure (including depreciation) per MWh of energy entering the network, in NZ$/MWh.[c]	21.77 (9.41)	23.66 (10.24)	17.30 (2.70)
SAIDI	System Average Interruption Duration Index (SAIDI), i.e. average interruption duration, in minutes per customer per year	184.80 (117.86)	206.66 (115.16)	169.93 (118.49)
Wind20	Number of days per year in which wind speed averaged more than 20 metres per second.	0.0016 (0.0137)	0 (0)	0.0074 (0.0278)
Rain100	Number of days per year in which rainfall exceeded 100 millimetres.	0.2472 (0.5232)	0.3076 (0.5861)	0.1371 (0.2892)
Temp0	Number of days per year in which maximum temperature was below zero degrees Celsius.	0.0128 (0.0850)	0.0012 (0.0170)	0.0805 (0.2064)
ShCO	Share of customer ownership, equal to 1 when firm is purely customer-owned, 0.5 if purely municipally-owned, and 0 if purely investor-owned. Actual customer ownership share used when firm is majority customer-owned.[d]	0.8111 (0.3238)	n.a.	n.a.
Exempt	Dummy equalling 1 for years in which a firm is exempt from price-quality regulation, otherwise 0.	0.1216 (0.3274)	0.1667 (0.3735)	0 (0)

[a] Defined as ShCO>0.5. [b] Defined as ShCO<0.5. [c] As at March 2013, NZ$1 = US$0.83. [d] Line-length weighted-averages of ownership shares used where regulatory database pro forma combined data for firms that merged in subsequent years.

hence deducted from total operating expenditure. Amortisation, unlike depreciation, is deducted on the basis that it is more abnormal in character (for example writing down goodwill on acquisitions, or redundant intellectual property) rather than representing core capital charges.

Weather variables have been included given their likely importance as exogenous predictors of reliability. In particular, faults are often due to high winds, heavy rainfall, or icy conditions, any of which can cause overhead lines to fail. Stormy conditions are also often associated with lightning strikes on power lines and other exposed assets (for example transformers), which also affects reliability. Very low temperatures are associated with peak network demand, as well as physical strain on network assets exposed to ice, each of which can cause faults. While icy conditions primarily affect only the very southern and alpine areas of New Zealand, heavy wind and rain can occur countrywide, particularly in the north east of the country's northern main island. Each variable represents the average of weather observations for a sample of points in each distribution network area, using virtual climate station estimates of daily weather data as published by the New Zealand National Institute for Water and Atmospheric Research.

Ownership data is not included in EDBs' annual information disclosures or the Commerce Commission's disclosure compilations. Ownership histories were compiled using information from websites of EDBs or their owning entities. In some cases it was necessary to also refer to newspaper reports on ownership changes, and/or to vesting orders passed when the EDBs were first corporatised under the Electricity Act 1992.[31] These ownership histories were cross-checked against ownership details for 2001 through 2013 inclusive provided by PricewaterhouseCoopers.

Details of specific customer-owned EDBs exempted from price-quality regulations since 1 April 2009 ($Exempt$) were sourced directly from the Commerce Commission's website. We did not include a separate dummy variable for whether regulation was in place since this applied to all EDBs and hence is captured by time fixed effects. Likewise, as in Nillesen and Pollitt (2011), input prices for capital and labour have not been included as they are not available on a regional basis. Hence input prices are also captured by our time fixed effects.

Other exclusions from our dataset include observations with very extreme weather events ($Wind20$ greater than 1.22), very large customer numbers ($Cust$ above 300,000) and large network length ($Length$ above 15,000 km). Our dataset has 296 observations consisting of 22 utilities and covering 13.5 years on average.

Number of customers ($Cust$) is regarded as exogenous since customers' location choices will normally reflect a number of considerations over and above electricity distribution characteristics. Likewise capacity utilisation ($Load$) depends on energy transported, which is exogenous to the firm (Giannakis et al. (2005)). We treat $Length$ as exogenous since material changes to network size are very long-term decisions and typically require long lead-times.

5 Empirical Results

5.1 Quality Model

Based on the general reduced form specification for quality in (19), we adopt the following detailed specification, indexing firms by i and years by t:

$$ln(SAIDI_{it}) = \Sigma_{j\epsilon\{-1,0,1\}}\left(\alpha_{2+j}Wind20_{it-j} + \alpha_{5+j}Rain100_{it-j} + \alpha_{8+j}Temp0_{it-j}\right) + \alpha_{10}\ln(\Delta Length_{it-1}) + \alpha_{11}Exempt_{it} + \alpha_{12}ShCO_{it} + \alpha_{13}\ln(Cust_{it}) + \alpha_{14}Load_{it} + \eta_t + \mu_i + \varepsilon_{it}. \quad (21)$$

Variable definitions are as in Table 1, and η_t and μ_i denote year fixed effects and EDB fixed effects respectively. Past values of $SAIDI$ and $OpexDep$ are excluded from (21) since neither has a

[31] See, for example, the Energy Companies (Powerco Limited) Vesting Order 1993.

robust and significant impact on $SAIDI_t$.[32] We include current, lagged and next-period weather variables. As discussed in Section 3, next-period weather variables exogenously proxy for expected future quality, which enters into *SAIDI* via its dependence on $OpexDep_{it}$. To the extent that higher expected future SAIDI results in increased $OpexDep_{it}$, that should reduce $SAIDI_{it}$. Conversely, current and lagged weather variables are expected to directly and positively influence *SAIDI*. Lagged weather variables proxy for $SAIDI_{it-1}$ in this specification.

Based on Figure 3, we can have $\alpha_{12} > 0$ (higher customer ownership share increases *SAIDI* – i.e. lowers quality) if the quality preferences of each firm type's customers are sufficiently divergent (Figure 3(a)). Conversely, we can have $\alpha_{12} < 0$ (higher customer ownership share decreases *SAIDI* – i.e. improves quality) if the quality preferences of each firm type's customers are sufficiently proximate (Figure 3(b)).

Our results are summarised in Table 2, with all variables being at year t unless stated otherwise. We pass the underidentification tests and the instrument is sufficiently strong (first stage F-statistic > 10) in both 2SLS estimations. Results that are significant at the 5% level suggest that higher shares of customer ownership improve reliability, while extreme temperature occurrences reduce reliability. These findings are consistent across OLS and 2SLS estimations. The negative relationship between *SAIDI* and *ShCO* is consistent with the prediction of our theory model in the case of low separation between δ^{IO} and δ^{CO} (as illustrated in Figure 3(b)).

5.2 Cost Model

Based on the general reduced form specification for costs in (18), we adopt the following detailed specification, again indexing firms by i and years by t:

$$ln(OpexDep_{it}) = \Sigma_{j\epsilon\{-1,0,1\}}\left(\beta_{2+j}Wind20_{it-j} + \beta_{5+j}Rain100_{it-j} + \beta_{8+j}Temp0_{it-j}\right) + \\ +\beta_{10}\ln(\Delta Length_{it-1}) + \beta_{11}Exempt_{it} + \beta_{12}ShCO_{it} + \\ +\beta_{13}\ln(Cust_{it}) + \beta_{14}Load_{it} + \eta_t + \mu_i + \varepsilon_{it}. \quad (22)$$

As for our quality model, we omit a lagged dependent variable in (22) since its effect is insignificant.[33] We proxy $SAIDI_{it-1}$ using lagged weather variables, while current year weather variables exogenously account for $SAIDI_{it}$.[34] Increases in either should result in increased $OpexDep_{it}$. As in Section 3, next period weather variables are our exogenous proxies for expected future quality.

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[32] Results for when $SAIDI_{t-1}$ and $OpexDep_{t-1}$ are included in (21) are provided in Appendix A.

[33] These results are provided in Appendix B.

[34] In their analysis of ownership unbundling in New Zealand electricity distribution, Nillesen and Pollitt

Table 2: Quality Model — Dependent Variable: ln(SAIDI)

	OLS				2SLS			
Variables	Mean (SE)[a]		Mean (SE)[a]		Mean (SE)[a]		Mean (SE)[a]	
ln(Wind20$_{t+1}$)	0.1568 (0.8112)		0.2635 (0.8232)		0.1419 (0.9042)		0.2482 (0.9002)	
ln(Rain100$_{t+1}$)	0.0424 (0.0831)		0.0105 (0.0851)		0.0418 (0.1060)		0.0110 (0.1126)	
ln(Temp0$_{t+1}$)	0.2473 (0.1958)		0.0889 (0.2066)		0.1756 (0.3636)		0.0004 (0.3806)	
ln(Wind20)	-2.2021 (1.1490)	*	-1.9890 (1.1581)		-2.1622 (1.1423)	*	-1.9695 (1.1845)	*
ln(Rain100)	0.1914 (0.1233)		0.1721 (0.1325)		0.1956 (0.1250)		0.1761 (0.1325)	
ln(Temp0)	0.7209 (0.1757)	***	0.6335 (0.2313)	**	0.6451 (0.2628)	**	0.5583 (0.2811)	**
ln(Wind20$_{t-1}$)			0.2504 (1.2232)				0.2766 (1.0965)	
ln(Rain100$_{t-1}$)			-0.0538 (0.1934)				-0.0431 (0.1149)	
ln(Temp0$_{t-1}$)			-0.4066 (0.1833)	**			-0.4962 (0.3252)	
ln(ΔLength$_{t-1}$)	0.3820 (0.2711)		0.3168 (0.3104)		0.3646 (0.2599)		0.2849 (0.2828)	
Exempt	0.0088 (0.0623)		0.0420 (0.0616)		0.0348 (0.0978)		0.0715 (0.1047)	
ShCO	-0.5006 (0.2245)	**	-0.4627 (0.2481)	*	-0.6617 (0.3052)	**	-0.6475 (0.3571)	*
ln(Cust)	0.4613 (0.3636)		0.6487 (0.4901)		0.4555 (0.2426)	*	0.6669 (0.4070)	
Load	-0.0098 (0.0107)		-0.0137 (0.0118)		-0.0126 (0.0102)		-0.0164 (0.0102)	
Year fixed effects	Yes		Yes		Yes		Yes	
EDB fixed effects	Yes		Yes		Yes		Yes	
R^2	0.296		0.247		0.293		0.243	
Kleibergen-Paap rk LM stat, P-value					0.0000		0.0000	
Kleibergen-Paap rk Wald F-stat					25.92		18.72	
No. observations	259		242		259		242	

Notes. *** Sig. at 1%, ** Sig. at 5%, * Sig. at 10%. [a] SEs robust to heteroscedasticity and autocorrelation.

Based on Figure 3, we can have $\beta_{12} > 0$ (higher customer ownership share increases costs – i.e. lowers efficiency) if the quality preferences of each firm type's customers are sufficiently divergent

(2011) find SAIDI itself to be significant in their cost specification. However, they do not account for the likely endogeneity of SAIDI and operating expenditures as highlighted in our empirical framework. Hence we prefer our specification.

Table 3: Cost Model — Dependent Variable: ln(OpexDep)

Variables	OLS				2SLS			
	Mean (SE)[a]		Mean (SE)[a]		Mean (SE)[a]		Mean (SE)[a]	
$ln(Wind20_{t+1})$	0.5139 (0.3329)		0.5462 (0.2952)	*	0.4741 (0.3846)		0.5034 (0.3477)	
$ln(Rain100_{t+1})$	0.0521 (0.0530)		0.0612 (0.0568)		0.0501 (0.0565)		0.0639 (0.0591)	
$ln(Temp0_{t+1})$	0.3587 (0.1468)	**	0.2973 (0.1204)	**	0.1829 (0.1649)		0.0891 (0.1843)	
$ln(Wind20)$	0.6987 (0.3973)	*	0.8571 (0.4035)	**	0.7887 (0.4480)	*	0.8923 (0.4359)	**
$ln(Rain100)$	-0.0575 (0.0543)		-0.0559 (0.0541)		-0.0527 (0.0533)		-0.0523 (0.0534)	
$ln(Temp0)$	0.0135 (0.1522)		0.0101 (0.1183)		-0.1701 (0.1787)		-0.1601 (0.1647)	
$ln(Wind20_{t-1})$			0.3165 (0.2698)				0.3691 (0.3155)	
$ln(Rain100_{t-1})$			-0.0034 (0.0419)				0.0128 (0.0480)	
$ln(Temp0_{t-1})$			0.1385 (0.1460)				-0.0738 (0.1998)	
$ln(\Delta Length_{t-1})$	-0.1251 (0.1353)		-0.0373 (0.1462)		-0.1627 (0.1413)		-0.1089 (0.1546)	
Exempt	-0.0446 (0.0466)		-0.0375 (0.0441)		0.0151 (0.0625)		0.0276 (0.0660)	
ShCO	-0.0893 (0.0590)		-0.0771 (0.0544)		-0.4821 (0.2467)	*	-0.5119 (0.2792)	*
ln(Cust)	0.0808 (0.1705)		-0.1227 (0.2334)		0.0673 (0.1663)		-0.0799 (0.2270)	
Load	-0.0051 (0.0038)		-0.0085 (0.0033)	**	-0.0116 (0.0056)	**	-0.0145 (0.0055)	**
Year fixed effects	Yes		Yes		Yes		Yes	
EDB fixed effects	Yes		Yes		Yes		Yes	
R^2	0.382		0.401		0.317		0.318	
Kleibergen-Paap rk LM stat, P-value					0.0000		0.0000	
Kleibergen-Paap rk Wald F-stat					26.78		19.73	
No. observations	274		256		274		256	

Notes. *** Sig. at 1%, ** Sig. at 5%, * Sig. at 10%. [a] SEs robust to heteroscedasticity and autocorrelation.

(Figure 3(a)). Conversely, we can have $\beta_{12} < 0$ (higher customer ownership share decreases costs – i.e. increases efficiency) if the quality preferences of each firm type's customers are sufficiently proximate (Figure 3(b)).

Our cost model results are summarised in Table 3. As for the quality model, we pass both the underidentification and the weak identification tests in both 2SLS estimations. Focusing on the 2SLS results, we see that once again $ShCO$ is significant (at the 10% level) and negative, consistent with quality preferences under each ownership type being relatively proximate, as in Figure 3(b). Increased network utilisation and fewer extreme wind occurrences also reduce *OpexDep* significantly in the 2SLS models. We now turn to the last welfare dimension, namely price.

Table 4: Price Model — Dependent Variable: ln(Price)

Variable	OLS Mean (SE)[a]		2SLS Mean (SE)[a]	
ln($OpexDep_{t-1}$)	0.2076 (0.0835)	**	0.2041 (0.0821)	**
$ShCO_{t-1}$	-0.2310 (0.0357)	***	-0.3194 (0.1143)	***
$Exempt_{t-1}$	-0.0672 (0.0309)	**	-0.0566 (0.0365)	
Year fixed effects	Yes		Yes	
EDB fixed effects	Yes		Yes	
R^2	0.325		0.317	
Kleibergen-Paap rk LM stat, P-value			0.0000	
Kleibergen-Paap rk Wald F-stat			29.45	
No. observations	293		293	

Notes. *** Sig. at 1%, ** Sig. at 5%, * Sig. at 10%. [a] SEs robust to heteroscedasticity and autocorrelation.

5.3 Price Model

Adapting the price model specification in Jamasb and Söderberg (2010), we use the following detailed specification for average price, indexing firms by i and years by t as before:[35]

$$\ln(Price_{it}) = \gamma_1 \ln(OpexDep_{it-1}) + \gamma_2 ShCO_{it-1} + \gamma_3 Exempt_{it-1} + \eta_t + \mu_i + \varepsilon_{it}. \qquad (23)$$

All explanatory variables other than fixed effects are lagged one year on the basis that we expect prices to be set in advance based on past realisations of price-relevant variables.

Since our theoretical model clearly predicts that price should be lower under customer ownership (in either panel of Figure 3), we expect $\gamma_2 < 0$.

Our results are summarised in Table 4. As shown, the underidentification and weak identification tests are safely passed. In our 2SLS estimation we find that prices are on average negatively associated with customer ownership, and highly significantly so. Strikingly, this remains so even though $Price$ is defined using lines revenue before allowing for profit rebates to customers. If lines revenue after deducting such rebates was used, this finding would be even more pronounced. Our findings are in line with our clear theoretical prediction in Section 2, that customer-owned firms should have lower

[35] Jamasb and Söderberg (2010) also include $SAIDI$ as an explanatory variable in their price model. For the reasons discussed above, we instead capture the exogenous influencers of $SAIDI$ via $OpexDep$, which in reduced form shares those variables.

Table 5: Approximate Welfare Calculations

	Customer Ownership	Investor Ownership	Change
Expected price (NZ$/MWh)[a]	43.91	63.92	+46%
Expected quantity (MWh/Customer)[a]	15.83	16.82	+6%
Expected cost (NZ$/MWh)[a]	18.00	31.67	+76%
Consumer surplus (NZ$/Customer	55.82	41.72	-25%
Firm profits (NZ$/Customer)	42.91	45.76	+7%
Total surplus	98.73	87.49	-11%

Notes: [a] Expected values in logs (μ) converted into expected values in levels using $\exp(\mu + \sigma^2/2)$ where σ is the root MSE.

prices than investor-owned firms irrespective of how proximate or divergent are the quality preferences of each firm type's customers.

5.4 Welfare

Our empirical results above are consistent with the predictions of our Section 2 theory model assuming the case of quality preferences between the customers of investor- and customer-owned firms being relatively proximate rather than divergent (as in Figure 3(b)). Specifically, customer ownership is found to be associated with lower price, but also with higher efficiency and quality. The question remains, however, as to whether these welfare benefits under customer ownership are offset by investor-owned firms enjoying higher-value customers, and hence possibly being able to generate higher overall welfare despite their higher prices and lower quality and efficiency. According to Figure 3(b), the overall welfare effect of customer ownership is predicted to be positive (when δ^{CO} and δ^{IO} are relatively proximate).

Due to data limitations, we estimate a simple demand model (no persistence, and with price assumed to be exogenous), controlling for ownership, weather, losses related to network length and pressure on the system (*Load*), and customer income. In Table C.1 of Appendix C, we present the results of this demand model estimation, which we then use to calculate the change in welfare due to customer ownership for our New Zealand EDB dataset.

We use this approximate demand model to estimate average quantity per customer for investor- and customer-owned EDBs, based on the average prices predicted for each ownership type using our price model in Table 4. Using this price and quantity data we can then estimate consumer surplus. The expected cost for each ownership type from our cost model in Table 3 can be used to also estimate the profits for each ownership type. These are added to our estimates of consumer surplus to arrive at estimated total surplus for each ownership type. Table 5 summarises our results.

As can be seen, both expected price and quantity are higher under investor ownership than under customer ownership. This is because the demand curve in the investor ownership case lies above that under customer ownership. However, the resulting consumer surplus is estimated to be lower under investor ownership than customer ownership, although profits of the investor-owned firm are estimated to be higher. Combined, these results imply that estimated total surplus based on expected prices and quantities is 11% lower under investor ownership than under customer ownership.[36] As for our quality, cost and price results, this too is consistent with the case illustrated in Figure 3(b). Hence our results using New Zealand EDB data are consistent with our theoretical predictions assuming quality preferences between customers of each firm type are relatively proximate rather than divergent.

6 Conclusions

In this paper we analysed the relative performance of investor- and customer-owned utilities, focusing on how the owners of each firm type optimally choose price, quality and efficiency. Our contribution has been to endogenise ownership choice rather than performing a comparative static exercise treating ownership as exogenous. This was motivated by the often-made observation that customer-owned firms commonly serve customers that investor-owned firms find unprofitable.

Our setup explains this phenomenon in terms of the customers of each firm type differing exogenously in their preferences for quality. It also does so by assuming that if an investor-owned firm is viable based on the would-be customers' quality preference, it will serve those customers even though a customer-owned firm would also be viable in that case. This implies that customers with a sufficiently high preference for quality will be served by an investor-owned firm. Customers with a preference for quality sufficient to justify entry by a customer-owned firm will be served by such a firm, provided those customers are not sufficiently profitable to be served by an investor-owned firm.

Our theory model highlights a complication when comparing the performance of firms of different ownership types. Since, in our setup, ownership is endogenously determined according to customers' quality preferences, and customers with higher quality preferences yield both higher profits and consumer surplus, this means investor-owned firms – despite maximising profits – automatically enjoy an advantage in any welfare comparison, to be traded against the fact that customer owners directly seek to maximise welfare. It is therefore possible for investor-owned firms to deliver higher welfare than customer-owned firms, even though the latter are assumed to maximise total surplus/welfare, while the former maximise just profits.

Specifically, if it is assumed that the quality preferences of customer- and investor-owned firms are highly divergent, our theory model predicts that while customer-owned firms will deliver lower prices, they will also deliver lower efficiency, quality and welfare. In that sense, an investor-owned

[36] In calculating expected consumer surplus when using a parabolic demand function in levels (as produced from a linear model in logs), it was necessary to place an upper limit on price. We used the maximum observed price in the dataset, plus a margin of 15%.

utility can be said to be welfare-maximising, despite formally seeking to maximise profits. This does not imply that customer-owned firms are per se inefficient relative to investor-owned firms. Rather it simply reflects exogenous differences in their underlying profitability due to differences in their customers' preference for quality. Conversely, where quality preferences are more proximate, customer ownership is predicted to result in higher welfare, as well as higher quality and efficiency, despite involving lower-value customers.

We took these predictions to data using regulatory disclosure data from EDBs in New Zealand over 1995-2013. To address the endogeneity of ownership, we instrumented for ownership changes using data on the staggered rollout of air quality regulations by independent regional regulators. We postulated that such regulations are more likely for dense, urban areas, in which populations are more educated and wealthier. We further postulated that these characteristics correlate with “liberalness”, or free-market orientation, which explains why industry reforms resulted in customer-owned firms changing ownership in some areas, but not others. This instrument appears to have good explanatory power for observed ownership changes.

In our empirical analysis we also paid close attention to how EDB costs interact with quality. This was motivated by observations that a distribution firm's investments and operational expenditures could have ambiguous impacts on future reliability and hence operating expenditures. To frame our empirical specifications for costs and quality, we developed a framework addressing the fact that they are jointly determined, and involve both retrospective and forward-looking temporal dependencies.

Our empirical analysis of New Zealand EDBs suggests customer ownership is associated with lower prices, and also with higher quality, efficiency and welfare. These empirical findings are comparable with those of Kwoka (2005), who found public ownership – rather than customer ownership per se – of US electric utilities to be associated with lower costs and higher quality relative to investor ownership. Both sets of findings are explicable under our framework if we assume that customer quality preferences are relatively proximate between each ownership type, as depicted in Figure 3(b). This is to be contrasted to the scenario depicted in Figure 3(a), in which more divergent quality preferences could result in higher welfare under investor ownership, despite profit-maximisation being formally pursued. Our separate empirical models for quality, cost and price, and approximate welfare, produce an overall set of results consistent with predictions of our theory model, providing support for our approach.

Making sense of relative performance assessments for customer- and investor-owned firms therefore requires that regard be had to underlying differences in the quality preferences of each firm type's customers. Observing that an investor-owned firm delivers higher welfare than a customer-owned firm cannot be taken as prima facie evidence that the customer-owned firm is inefficient and should be demutualised (that is, converted to investor ownership). The performance difference could simply stem from differences in customer quality preferences, to the extent that an investor-owned firm would not be viable for the customers served by the customer-owned firm.

Indeed, any advantage enjoyed by an investor-owned firm in terms of having higher-value customers could in fact be masking poor quality and efficiency performance. Thus observing higher welfare under investor ownership might be mistaken to mean the customer-owned firm should be regulated, while the investor-owned firm should not. That could give rise to both false positives and false negatives respectively if simple welfare comparisons are used as a screen for identifying when regulation is needed. Conversely, if both firm types are regulated, failing to account for differences in customers' quality preferences could bias efficiency analyses used for benchmarking regulatory settings.

Another implication of an investor-owned firm potentially being observed to deliver higher welfare than a customer-owned firm is that investor-ownership is not necessarily to be preferred in that situation. This is because a customer-owned firm will also be viable in situations where an investor-owned firm is viable. An interesting question therefore remains as to whether customer ownership is inefficiently being crowded out by investor ownership. Addressing that question requires paying attention to other differences between each ownership type not addressed by our analysis, such as how internal firm incentive issues arise and are addressed by different owner types. That analysis is left to future work, with Meade (2014) providing theoretical insights.

Finally, our framework provides insight to regulators and policy analysts concerned with efficient utility firm organisation. It not only highlights how relative performance assessments need to control for differences in customer characteristics (here, quality preference). It also provides a framework for assessing how ownership might efficiently evolve in response to changing customer preferences. In particular, as customers become wealthier, for example, and their preference for quality rises, this suggests investor ownership might increasingly become viable in situations where previously only customer ownership was viable. Alternatively, it suggests that customer ownership might become viable where previously customers were not able to be served by either firm type. Conversely, quality preferences might decline for reasons such as falling incomes in declining regions. While this might result in investor-owned firms becoming nonviable, it is possible that customer-owned firms might still be able to provide service (as opposed to service no longer being provided at all), even if with lower efficiency and quality. A fully dynamic analysis of ownership change is also left to future work.

In conclusion, any relative performance assessment of different firm ownership types benefits by accounting for the impacts of endogenous ownership selection. This research provides a framework for doing so, highlighting heterogeneity in customer quality preferences as a possible mechanism. In addition to research on incentive issues affecting each ownership form, and on the dynamics of changes between ownership types, we leave to future research the additional important questions as to how efficiency studies, and the regulatory screens on which they often rely, should be modified to account for endogenous ownership selection.

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Appendix A. Eq (21) with past values of $SAIDI$ and $OpexDep$.

In this appendix we show the estimation results when eq (21) includes past values of $SAIDI$ and $OpexDep$. When we treat $\ln(SAIDI_{t-1})$ as exogenous we get results that are qualitatively very similar to the once displayed in Table 2. However, a lagged dependent variable is endogenous but when we instrument $\ln(SAIDI_{t-1})$ with past weather variables, we get useless results.

Table A1: Quality Model — Dependent Variable: $ln(SAIDI)$.

Variables	Mean (SE)		Mean† (SE)[a]		Mean‡ (SE)[a]	
ln(SAIDI $_{t-1}$)			0.1467 (0.0599)	**	-0.3352 (0.3253)	
ln(OpexDep $_{t-1}$)	0.0555 (0.0967)		0.0398 (0.0942)		0.1077 (0.1335)	
ln(Wind20$_{t+1}$)	0.1376 (0.8952)		0.5001 (0.9581)		-0.5025 (1.1298)	
ln(Rain100$_{t+1}$)	0.0394 (0.1055)		-0.0029 (0.1027)		0.0990 (0.1482)	
ln(Temp0$_{t+1}$)	0.2063 (0.3749)		0.0809 (0.3724)		0.3824 (0.4011)	
ln(Wind20)	-2.1594 (1.1517)	*	-2.2959 (1.3279)	*	-1.4678 (1.0949)	
ln(Rain100)	0.1963 (0.1271)		0.1805 (0.1231)		0.2065 (0.1526)	
ln(Temp0)	0.6658 (0.2649)	**	0.6030 (0.2611)	**	0.5905 (0.2983)	**
ln(ΔLength$_{t-1}$)	0.3617 (0.2589)		0.4042 (0.2648)		0.1319 (0.3293)	
Exempt	0.0225 (0.0980)		0.0008 (0.0957)		0.1010 (0.1421)	
ShCO	-0.5868 (0.3161)	*	-0.4875 (0.3135)		-0.6776 (0.4924)	
ln(Cust)	0.4599 (0.2403)	*	0.3896 (0.2225)	*	0.8904 (0.5077)	*
Load	-0.0113 (0.0102)		-0.0094 (0.0100)		-0.0187 (0.0133)	
Year fixed effects	Yes		Yes		Yes	
EDB fixed effects	Yes		Yes		Yes	
R^2	0.295		0.319		0.059	
Kleibergen-Paap rk LM stat, P-value	0.0000		0.0000		0.1156	
Kleibergen-Paap rk Wald F-stat	25.98		23.69		2.94	
No. observations	258		258		241	

Notes. *** Sig. at 1%, ** Sig. at 5%, * Sig. at 10%. All estimations made with 2SLS. [a] SEs robust to heteroscedasticity and autocorrelation. †Endogenous variable: $ShCO$. ‡ Endogenous variables: $ShCO$ and $SAIDI_{t-1}$. As instrument for $SAIDI_{t-1}$ we use $\ln(Wind20_{t-1})$, $\ln(Wind20_{t-1})$, $\ln(Rain100_{t-1})$ and $\ln(Temp0_{t-1})$.

Appendix B. Eq (22) with past values of $OpexDep$.

In this appendix we show the estimation results when eq (22) includes past values of $OpexDep$.

Table B1: Cost Model — Dependent Variable: ln(OpexDep)

Variables	**2SLS** **Mean (SE)[a]**	
ln(OpexDep $_{t-1}$*)*	0.3176 (0.2322)	
ln(Wind20 $_{t+1}$*)*	0.4892 (0.2395)	**
ln(Rain100 $_{t+1}$*)*	0.0428 (0.0458)	
ln(Temp0 $_{t+1}$*)*	0.1586 (0.1128)	
ln(Wind20)	1.0113 (0.3903)	***
ln(Rain100)	-0.0683 (0.0407)	*
ln(Temp0)	-0.1698 (0.1392)	
ln(ΔLength $_{t-1}$*)*	-0.1462 (0.1492)	
Exempt	0.0016 (0.0401)	
ShCO	-0.2566 (0.1558)	*
ln(Cust)	-0.0769 (0.1810)	
Load	-0.0105 (0.0035)	***
Year fixed effects	Yes	
EDB fixed effects	Yes	
R^2	0.536	
Kleibergen-Paap rk LM stat, P-value	0.0000	
Kleibergen-Paap rk Wald F-stat	10.06	
No. observations	252	

Notes. *** Sig. at 1%, ** Sig. at 5%, * Sig. at 10%. [a] SEs robust to heteroscedasticity and autocorrelation.

Appendix C. Approximate Demand Model

Table C.1: Demand Model - Dependent Variable: ln(MWh/Customer)

Variables	OLS Mean (SE)[a]	
ln(Price)	-0.0866 (0.0638)	
ShCO	-0.0931 (0.0449)	*
Ln(Wind20)	0.2740 (0.1944)	
ln(Rain100)	-0.0275 (0.0114)	**
ln(Temp0)	-0.0065 (0.0238)	
Length	-9.35e-8 (9.61e-6)	
Earnings[b]	0.0002 (0.0001)	***
Load	0.0044 (0.0046)	
Year fixed effects	Yes	
EDB fixed effects	Yes	
R^2	0.954	
No. observations	245	

Notes. All variables are for year t. [a] SEs robust to heteroscedasticity and autocorrelation. [b] Average income for customers in EDB region. *** Sig. at 1%, ** Sig. at 5%, * Sig. at 10%.