Utility Firm Performance with Heterogeneous Quality Preferences and Endogenous Ownership

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Abstract

We develop a theoretical model in which a utility firm (e.g. a network monopoly) can be owned by either its customers, or by investors. Owners of either type select the firm's efficiency (i.e. production technology), service quality, and price. Ownership choice is made endogenously – based on the quality preference of the firm's potential customers – resulting in either investor ownership, customer ownership, or non-service. We show that customer ownership arises endogenously when customers' preference for quality falls below the threshold required for profitable entry by investors, but above that required for entry by customer-owners. This means that customer-owned utilities necessarily have customers with a lower preference for quality. They are therefore predicted to have lower efficiency, quality and price than investor-owned firms, and provide lower welfare overall. We find support for these predictions using data from customer- and investor-owned Electricity Distribution Businesses (EDBs) in New Zealand, applying empirical specifications that address the endogeneity of quality and costs. Our findings indicate that whether utilities should be customer- or investor-owned cannot be determined based on simple performance comparisons. Account must also be taken of how differences in customers' quality preferences affect the viability of different ownership forms.

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

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1 Introduction

Can we determine the ideal ownership form of a utility based just on relative performance? So, for example, can we say that a network monopoly – e.g. in electricity, gas, water or waste water – should be owned by investors, and not by some other class of owners, if investor-owned utilities exhibit greater efficiency or quality? Or is it necessary to account for how differences across firms (or their customers) affects which class of owners is best-suited to own those firms?

Since the 1980s there has been a long-standing debate about the relative merits of public (i.e. government) and private (i.e. investor) ownership, particularly in utility-type sectors with natural monopoly features.[1] That debate has centred largely around 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 the ability of publicly-owned firms to access the capital required for both maintenance and investment, each of which affects service quality.[2]

With customers affected by the crisis unable to bear utility price rises, or even to pay their bills, and investors also facing constraints on access to capital, transferring public ownership to investors (i.e. privatisation) is not always viable.[3] 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.[4] Hence, interest is increasing in the use of mutual (i.e. customer) ownership as an alternative to either public or private/investor ownership as a means of sustaining firm viability, and service levels, in a time of price restraint.[5] A hallmark of such ownership is that customers participate in the profits of the firm, in addition to enjoying the consumer surplus generated by its services (which depends on service quality as well as price).

Existing studies on the relative performance of customer- and investor-owned utilities provide mixed results.[6] Furthermore, theoretical contributions on the relative performance of each ownership type – in particular, those accounting for service quality as well as efficiency (i.e. production costs) – are few.[7] There is therefore a need in the literature for better theoretical and empirical analyses of relative utility performance under different ownership types.

Our contribution is to provide theoretical predictions of how utility firms perform in terms of efficiency, quality and price, under both customer- and investor-ownership.

[1]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.

[2]Helm and Tindall (2009), OECD (2009), Brophy Haney and Pollitt (2013), Stanley et al. (2012).

[3]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.

[4]Stanley et al. (2012).

[5]Helm and Tindall (2009), Brophy Haney and Pollitt (2013), Mori (2013).

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

[7]Meade (2014) analyses monopoly price regulation, incentive power choice, and firm performance, when the firm is customer- or investor-owned, and its manager takes hidden actions affecting both efficiency and non-contractible quality.

We then present supporting empirical evidence, exploring how customer- and investor-ownership affect price, efficiency and quality (i.e. supply reliability) – and ultimately welfare. We do so using data from Electricity Distribution Businesses (EDBs) in New Zealand, and depart from the use of standard reduced form specifications by more fully accounting for endogeneity between cost and reliability.

Our theoretical model assumes that different would-be utility customers are endowed with potentially different preferences for quality. An investor-owned firm will serve those customers if their quality preference is sufficient to enable 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 is still high enough to ensure that customer-owner 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.[8] Customers can be unprofitable when they are very costly to serve – e.g. due to being located in remote areas for which entry costs are high.[9] Conversely, as in our setup, it can arise because customers 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)). Alternatively it can be because they are involved in relatively low-value activities (e.g. agriculture). Either way, this affects their preferences for service quality.

It should therefore come as little surprise that customer-owned utilities in electricity, water/sanitation and ICT often predominate in rural areas (Deller et al. (2009)). They are common in developing countries (NRECA International (2010)), with their contribution to development recognised by the UN General Assembly.[10] They are also prominent in many developed countries – including, notably, in rural and other less populous parts of the US – but also in other OECD countries (e.g. Sweden and New Zealand).[11]

We find in our theoretical analysis that the relative performance of each ownership type – with ownership determined endogenously rather than imposed – is necessarily affected when a firm's would-be customers are assumed to differ in their preference for quality. Since, in our setup, customer ownership endogenously arises when quality preferences are sufficiently high as to enable customers to be served, but not so high as to have induced profitable investor ownership, this affects firm performance. Specifically, customer-owned firms are predicted to exhibit lower efficiency, quality and price than investor-owned firms

[8]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.'"

[9]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)).

[10]The UN declared 2012 to be the International Year of Cooperatives. According to its then UN secretary General, "[c]ooperatives are a reminder to the international community that it is possible to pursue both economic viability and social responsibility."

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

– results that we also find in our empirical analysis. More fundamentally, differences in quality preferences affect the feasible ownership types for a given customer base. Hence a utility's welfare-maximising ownership assignment cannot be determined solely on the basis of observed relative performance. Instead, it must also account for the impacts of different potential firm customers having heterogeneous quality preferences.

Other theoretical research related to ours includes studies on optimal ownership. These include the noted survey of US ownership forms, and framework for assessing optimal ownership, provided in Hansmann (1996). Hart and Moore (1996) formalise Hansmann's prediction that customer ownership is more likely to be preferred when customer interests are relatively homogeneous (whereas investor ownership is predicted when those interests diverge).[12] Their focus is just on price choice, so they do not account for service quality or production efficiency (which are of particular interest for utilities). Hart and Moore (1998) also consider investment choices, which affect quality. They again predict that customer ownership results in efficient investment (hence quality) levels when customer interests are homogeneous, but that investor ownership is efficient otherwise (and also in competitive environments). Our approach differs to theirs in that we assume different groups of would-be customers of a utility may have different preferences for quality, but within each such group their preference is the same. We also focus just on the situation of a monopoly utility.

Hueth et al. (2005) model the formation of supplier-owned cooperatives as a response to difficulties in raising external financing.[13] While they differ from us in focusing on supplier- rather than customer-owned firms, they too find that cooperatives are viable in a larger class of environments than investor-owned firms, with the latter dominating when both ownership forms are viable.[14] Instead of cooperative formation being driven by differences in customer quality preferences, in their setup it is a result of improving access to external capital by pooling pledgeable income.

The theoretical studies closest to ours are Herbst and Prüfer (2005), and Meade (2014). The former analyses the endogenous choice between investor-, customer- or not-for-profit ownership when a firm's manager exerts unobserved effort affecting output quality. Customer-owned firms result in the highest quality when collective decision-making costs are low, while not-for-profits do so otherwise. However, while these authors allow customers to differ in their preference for quality, like Hart and Moore they do not model our situation in which different groups of potential firm customers have the same preference for quality (with that preference instead differing across customer groups). Meade (2014) models optimal price regulation and managerial incentive power choice in customer- and investor-owned firms, when the firm's manager exerts efforts affecting both

[12] They also analyse how optimal ownership – whether by customers or investors – is affected by industry competitiveness, with investor ownership preferred in more competitive situations.

[13] In supplier-cooperatives, supplier-owners are interested in maximising profits from both their own supply activities and their ownership stake in the cooperative. Conversely, in customer-cooperatives, customer-owners seek to maximise the sum of their consumer surplus and their share of the firm's profits.

[14] Hueth et al. observe that cooperatives are often formed in declining industries, or alternatively, that they seem to be sustainable in relatively low-return environments that do not support investor-owned firms.

efficiency and unobservable quality. Like ours, his model predicts different price, quality and efficiency choices for customer- and investor-owned firms. However, ownership is exogenous in his setup, and he does not allow for differences in customers' preferences for quality. Hence this study is complementary to both of these studies.

In terms of empirical studies, our research 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 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 isolate customer ownership. Likewise we extend Kwoka (2005), who finds that public ownership – though not customer ownership per se – is associated, in smaller utilities, with both lower costs and greater reliability than under investor ownership for a sample of US electric utilities. His reliability comparisons, however, do not control for differences either between or within each ownership type, and nor does he account for the likely endogeneity of costs and quality. We also contribute to the wider literature on the relative efficiency of electricity distributors under different ownership types.[15] In the New Zealand data that we use, we focus specifically on customer ownership, rather than public ownership more generally.

Our findings raise a number of policy implications. The first is that regulators or policy-makers concerned with industry efficiency cannot rely on just direct performance comparisons when assessing the desirability of alternative ownership forms. Since customer-ownership arises in situations where customers have preferences for quality that could make investor ownership nonviable, it would be inadvisable to prefer investor ownership simply because it might be found to display better performance. As per Williamson's "remediableness criterion", a key ingredient of any recommended change in institutional form is that the alternative be viable.[16] Hence a proper performance comparison between investor- and customer-owned utilities must control for differences that endogenously give rise to each such form.[17]

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 with time, 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 (e.g. due to economic de-

[15] 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.

[16] Williamson (2000, p. 601) states that "... an extant mode or organization for which no superior feasible alternative can be described and implemented with expected net gains is presumed to be efficient. ... analysts can no longer condemn extant modes because they deviate from a hypothetical ideal..."

[17] We maintain in our own empirical analysis that quality preferences within firms are stable over our sample period. Due to data limitations it was not possible for us to assess this directly.

cline in the region) resulting in only customer-ownership being viable, even if that entails lower performance. In either case, it is possible that one ownership form efficiently arose in response to the then prevailing customer preference for quality, but due to subsequent changes that form becomes nonviable (resulting in a decline in performance), or a superior form becomes viable (allowing improved performance).

Our paper is organised as follows. Section 2 presents our theoretical model and its predictions. Section 3 describes our empirical methodology, estimation approach and data. Section 4 presents our empirical results. Finally, Section 5 concludes.

2 Theoretical Model

2.1 Setup

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.[18] 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 other things being 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.[19] 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 $\gamma \geq 0$ because this

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

[19]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.

is sufficient 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.[20]

A firm's owners, whether they are customers or investors, are assumed to choose efficiency e and quality s, and also the firm's output price p.[21] 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 $0 < \gamma < \frac{1}{2}\sqrt{2}$, which we maintain as assumptions throughout.

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) writes as:

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

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.[22] 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,[23] but taking γ as a technological given that applies equally across all firm types, we can write:

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

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

[20] 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.

[21] We therefore abstract from issues of monopoly price regulation. This is explored further in Meade (2014) under both investor- and customer-ownership, though with ownership being taken as exogenous.

[22] 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.

[23] 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.

Timing of Ownership and Other Choices

Ownership choice is endogenised through the following assumed sequence of events and decisions:

1. Nature exogenously determines the quality preference δ of a would-be group of customers.[24] 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 (i.e. production technology),e;

    (b) Second, they choose their service quality, s; and

    (c) Finally, they choose their output price, p.

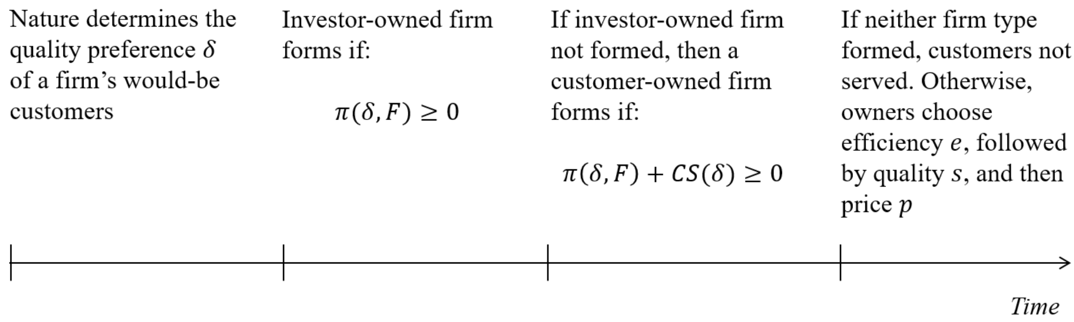
This timing is depicted in Figure 1. It is considered natural because it allows customer ownership to form in situations where investor-owners have not found it profitable to enter service, but allows for investor-ownership to dominate where investor entry is profitable. Conversely, if neither ownership 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.[25]

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,

[24] 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.

[25] 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.

Figure 1: Timing of Entry and Production Decisions by Possible Firm Owners



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. Hence our assumed timing of a firm's decisions regarding e, s and p, assuming that firm has entered service.

2.2 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:[26]

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

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

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

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

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

[26] 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 for 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, being fixed, does not affect the optimal choice of p, and nor the optimal choices of s and e.

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):

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

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

Turning now 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:

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

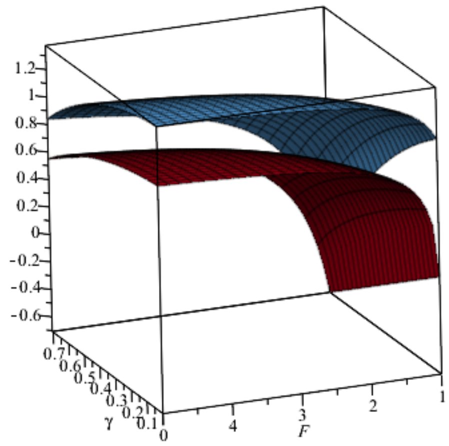
Finally, we allow for investor-owners to have the first choice over whether or not to form a firm (failing which customer-owners may then elect to do so, as just discussed), given the δ determined by nature for their would-be customers. They will do so if and only if $\pi(\delta, F) \geq 0$. Once again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

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

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:

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

Figure 2: Quality Preference (δ) Thresholds Required to Induce Firm Entry



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

It is easily verified that $\delta^{IO}_{crit}(F,\gamma) - \delta^{CO}_{crit}(F,\gamma) \geq 0$ 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 2. 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.

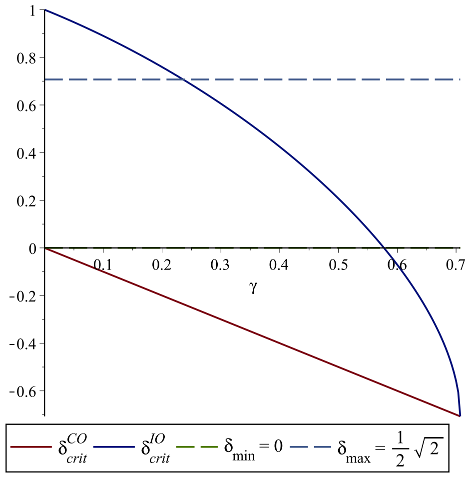
Since it is nature that ultimately determines a would-be group of customer's quality preference, $\delta \geq 0$, under our assumed timing we have that:

1. No firm is formed, and customers are not served, if and only if $\delta < \delta^{CO}_{crit}(F,\gamma)$;
2. A customer-owned firm is formed if and only if $\delta^{CO}_{crit}(F,\gamma) \leq \delta < \delta^{IO}_{crit}(F,\gamma)$; and
3. An investor-owned firm is formed if and only if $\delta \geq \delta^{IO}_{crit}(F,\gamma)$.

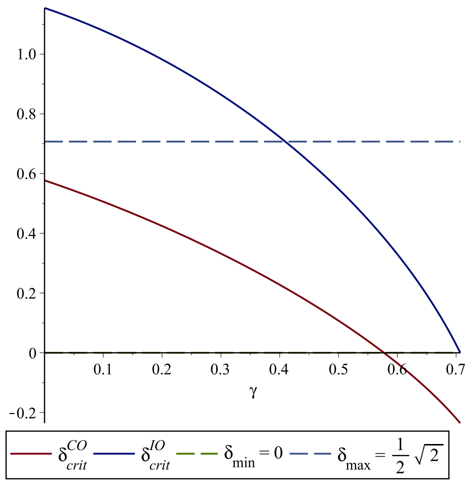
Figure 3 illustrates three sets of possibilities for different values of $F \geq 1$, and our assumed parameter restrictions $0 \leq \delta, \gamma < \frac{1}{2}\sqrt{2}$. In Panel (a), with $F = 1$, we see that even with δ at its lowest limit $\delta_{min} = 0$, we have $\delta \geq \delta^{CO}_{crit}(F = 1, \gamma)$ 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 $\delta \geq \delta^{IO}_{crit}(F = 1, \gamma)$, with only customer-ownership viable below this limit. Thus investor ownership is viable only for γ sufficiently large in this case.

Figure 3: Ownership Scenarios for Different Levels of Entry Cost F

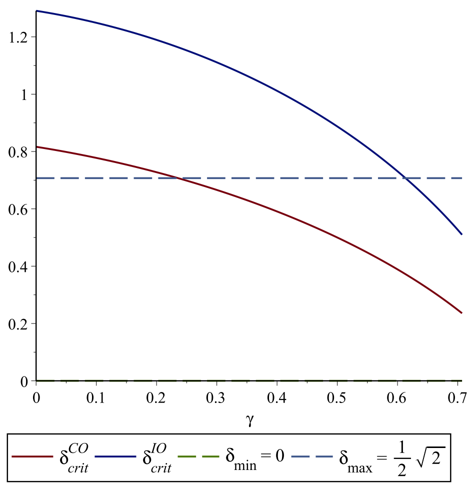
Panel (a): δ thresholds and admissable values, versus γ, for $F = 1$



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



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



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.

2.3 Performance Comparisons

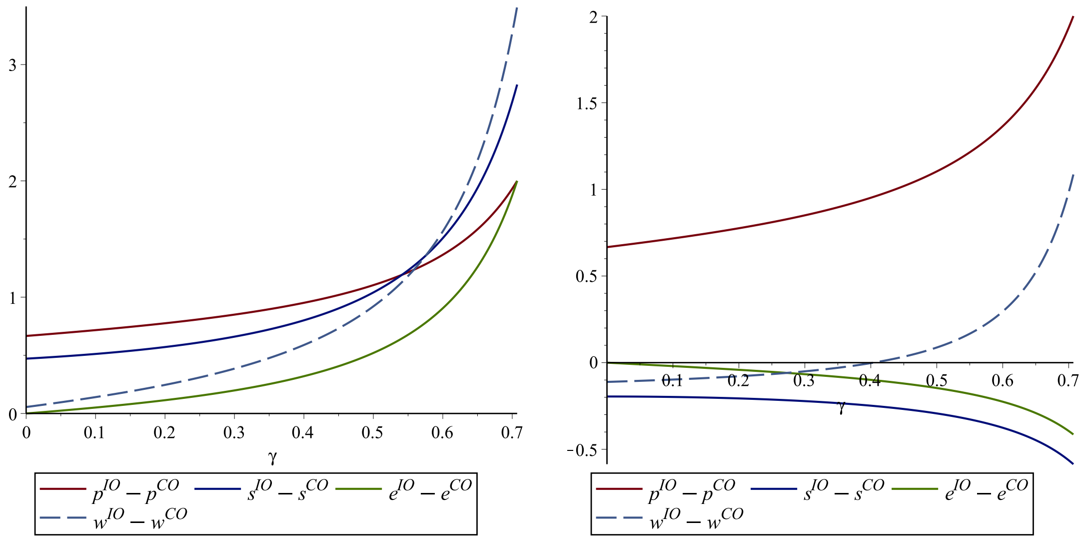
When ownership choice is endogenous as above, comparing the performance of investor- and customer-owned firms necessarily involves comparing dissimilar entities. In our setup ownership choice is driven by differences in quality preference, δ, with a higher δ required to support investor ownership than 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. Two cases are illustrated in Figure 4, which plots the difference in price, quality, efficiency, and overall welfare ($w \equiv \pi + CS$, i.e. "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 $\delta^{CO} = \delta_{min}$. The former case is consistent with the coexistence of customer- and investor-owned firms as in Figure 3(a), with $\delta^{CO} \geq \delta^{CO}_{crit}$ for all admissable γ , and $\delta^{IO} \geq \delta^{IO}_{crit}$ for $\gamma \geq \frac{1}{6}\sqrt{2}$. The latter case is consistent with coexisting customer- and investor-owned firms as in Figures 3(a) and 3(b), for γ sufficiently large in the admissable range.

In Figure 4(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, implying higher welfare under customer ownership. 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 4(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 so 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

Figure 4: 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):* $\delta^{CO} = \frac{1}{2},\ \delta^{IO} = \frac{1}{2}\sqrt{2}$



lower preference for quality.

From Figure 4 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 take as a reference point the case of maximal separation between the two taste parameters as in Figure 4(a). Hence we predict that price should be lower under customer ownership, which is also the prediction of the alternative case in Figure 4(b). We further predict that investor ownership should be associated with higher efficiency, quality and welfare than customer ownership.

3 Empirical Methodology, Estimation and Data

Given the above theoretical predictions, we now 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, the majority of which are customer-owned. A hallmark of that ownership is that customers are either charged low prices, or are rebated some of their service charges each year (either by way of a discount on their power bill, or direct payment).

To estimate the relative performance of customer- and investor-owned EDBs, we separately estimate empirical models for costs (i.e. efficiency), quality and price, maintaining the assumption that firm ownership in our sample period is exogenous. We regard this assumption as reasonable on the basis that ownership is highly persistent, with ownership changes driven by long-term and significant shifts in economic factors such as income and industrial structure. Short-term ownership changes over our sample period are therefore exogenous, and incorporate a substantial amount of pre-sample information. In particular, ownership changes in the sector resulted largely from regulatory changes directed at other parts of the industry (specifically, electricity retailing).[27] Evidence in support of this assumption is presented in Section 4.1. Furthermore, customer quality preferences will have remained materially unchanged in our sample period. This is because there were no major changes of customer income, EDB customer bases, or the economy more generally, that could have been expected to have changed those preferences enough to induce ownership changes.

In this section we describe the methodology we used to specify the empirical models reported in Section 4, as well as our estimation approach and data.

3.1 Empirical Methodology

Quality Measurement

Following other empirical studies of electricity distribution company performance, we define service quality in terms of reliability.[28] This is most commonly measured by the System Average Interruption Duration Index (SAIDI). That index measures average interruption duration, in minutes per customer per year. Since it measures the extent to which a distribution network is not reliable, it measures the *inverse* of quality (i.e. higher SAIDI implies lower reliability and hence lower quality).

Cost Decomposition

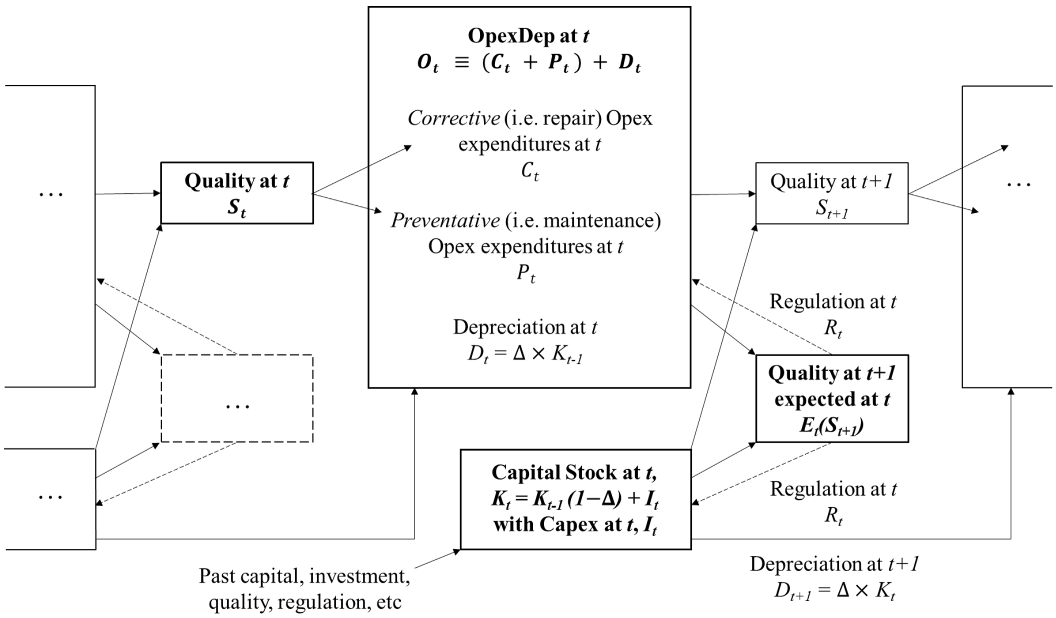
To relate this quality measure to costs, we decompose costs into *corrective* operating expenditures (i.e. repairs), *preventative* operating expenses (i.e. maintenance), *depreciation* on past capital expenditures (i.e. longer-term investments in network assets made in the past) and current *capital* expenditures.[29] 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. This recognises that long-lived assets are not completely consumed when purchased or created, but rather their productive capacity is consumed over time until they are disposed of or no longer have productive use. We make this

[27] For a history of New Zealand's electricity reforms, including a discussion of EDB ownership changes, see Evans and Meade (2005b).

[28] 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 (e.g. customer service arrangements, terms and conditions for new connections, or for re-/de-connections, etc). 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.

[29] 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 5: Cost and Quality Schematic



decomposition because changes in quality should not only affect a firm's costs, but also the very nature of the firm's cost function.

Relationship between Cost and Quality

We characterise these interactions between cost and quality using the schematic in Figure 5. Using this we derive empirical specifications for our cost and quality models, which we use to empirically measure the interaction between costs and quality.

Begin by considering a quality realisation at time t, denoted S_t. For example, suppose strong winds caused a tree to fall on overhead lines and created a fault, with the severity of the fault 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 (i.e. repairs), designed to simply restore the status quo network output capacity. It might also rise to contemporaneous preventative expenditure P_t (i.e. maintenance) to make the network more robust against eventualities like wind-related faults recurring in the future. Together these expenditures make up contemporaneous Opex – i.e. Opex is $C_t + P_t$.

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 in electricity distribution can be very long-lived, they are assumed to be chosen based on factors over and above just quality realised at t. Irrespective of how I_t is determined though, we assume that both Opex (e.g. repair intensity, or maintenance) and Capex I_t (e.g. undergrounding) will affect future quality realisations, which certainly 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, we measure a firm's aggregate expenditures in any given year by Opex plus depreciation, which we describe as “OpexDep”:

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

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 5 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 a succession of (i.e. 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, etc.

Cost and Quality Specifications

The above schematic suggests specifications for both costs and quality. In particular, they suggest a simultaneous equation framework (i.e. with endogeneity of costs and quality) as well as temporal dependencies. Specifically, we write OpexDep and quality (i.e. SAIDI) at time t as follow:

$$O_t = O_t\left(S_t, E_t\left(S_{t+1}\right), O_{t-1}, I_{t-1}, R_t, X_t\right) \tag{16}$$

$$S_t = S_t\left(O_t, S_{t-1}, I_{t-1}, R_t, X_t\right) \tag{17}$$

Thus O_t depends on current quality realisation S_t, on future expected quality $E_t\left(S_{t+1}\right)$, and also on the influence of current regulation R_t in shaping how the firm responds to expected future quality in terms of current OpexDep and Capex. Current OpexDep will also depend on past OpexDep for the reasons given above (e.g. "cutting corners" – or "gold-plating" at the other extreme – will affect expenditures in later years). We might have also allowed for lagged regulation, but since O_t will also depend on past investment choices, and those choices will in turn reflect past regulation, then we treat past Capex as being sufficient for past regulation.

We use X_t to represent all other relevant exogenous variables, including ownership, customer numbers, customer density, capacity utilisation (i.e. 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), S_t depends on past OpexDep. It also depends on past quality realisations (i.e. a damaged network in one year leads to greater risk of network failure in the next, etc). 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 current regulation and past Capex (which is treated as sufficient for past regulation).

Endogeneity Issues

An important endogeneity issue arises in the expression for O_t in (16). It is specified to depend on $E_t\left(S_{t+1}\right)$, but when choosing O_t each firm will be aware that this has an impact on $E_t\left(S_{t+1}\right)$.[30] 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 (i.e. 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.

[30] 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 $E_t\left(S_{t+1}\right)$. 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.

A second and more obvious endogeneity issue also arises due to current quality S_t depending on current O_t. Alternatively, our specifications for cost and quality could be expressed in reduced form, in which case each will be a function of shared exogenous explanatory variables. Specifically, (16) and (17) write as:

$$S_t = S_t\left(Weather_{t+1}, S_{t-1}, O_{t-1}, I_{t-1}, R_t, X_t\right) \tag{18}$$

$$O_t = O_t\left(Weather_{t+1}, S_{t-1}, O_{t-1}, I_{t-1}, R_t, X_t\right) \tag{19}$$

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 the cost and quality models we estimated, as well as our price model.

3.2 Estimation

As a baseline we use ordinary least squares (OLS) with utility firm and year fixed effects and standard errors clustered over firms to estimate all models. The major weakness of OLS is that it does not control for the persistence in economic data that typically characterises utility sectors. Network industries rely on long-term investments and it is sometimes not possible, or excessively costly, to react quickly to sudden environmental changes. This long-term nature is likely to influence both cost and quality models. Prices are often smoothed over time to help consumers adapt to external shocks. If this persistence is not controlled for, estimated standard errors will be biased downwards, meaning that OLS significance levels are overstated. In addition to OLS, we therefore also estimate all models using feasible generalised least squares (FGLS) which explicitly includes an AR(1) process and correct standard errors under firm-specific heteroscedasticity.[31]

More generally, our empirical strategy has involved specifying models that consists of only exogenous variables. That solves the problem of finding valid and strong instruments which is a substantial challenge in many practical situations. Also, we use only EDB customer numbers to capture ‘size’. Number of customers is strongly correlated with network length and delivered energy, and both network length and delivered energy are (weakly at least) endogenous. Throughout we estimate equations separately rather than jointly.

Quadratic cost models were initially estimated, but in our final cost model specifications squared terms were removed due to multicollinearity.

3.3 Data

Firm-level information disclosures regarding New Zealand 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 New

[31] Dynamic panel data models using first-difference generalised method of moments (GMM) were also evaluated but those generally produced unstable estimates, which we attribute to limitations in our sample size and level of variation in our dataset.

Zealand Commerce Commission were augmented with firm-level annual disclosure statements sourced directly from the relevant firms' websites. Table 1 defines, and provides summary statistics for, the variables considered in our analysis. Financial variables have been deflated using the consumers price index.

Following the discussion in Section 3.1, 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 hence deducted from total operating expenditure. Amortisation, unlike depreciation, is deducted on the basis that it is more abnormal in character (e.g. writing down goodwill on acquisitions, or redundant intellectual property) rather than representing core capital charges.

$SAIDI$ is an inverse measure of reliability commonly used to measure electricity distribution quality. 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, in particular, to fail. Stormy conditions are also often associated with lightning strikes on power lines and other exposed assets (e.g. 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[32] These ownership histories were cross-checked against ownership details for 2001 through 2004 inclusive provided by PricewaterhouseCoopers.

We excluded EDBs with ownership other than pure customer ownership (CO) or pure investor ownership, to isolate the effect of the former relative to the latter. Thus we exclude municipal EDBs (i.e. those owned by local governments), and EDBs with mixed ownership. We likewise exclude customer-owned EDBs that acquired networks whose customers do not participate in the owning EDB's profits, except where those networks are separately reported. In the latter case we treat separately-reported EDBs as purely investor-owned, on the basis that their parent company or companies are not operating them on behalf of their customers, but rather for the financial benefit of those owners.

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

Table 1: Variable Definitions and Summary Statistics

Variable	Description	Mean	SD	Min.	Max.
Length	Distribution lines length, both overhead and underground, in km.	3,681	2,691	196	14,188
ΔLength	Year-on-year change in distribution lines length, in km.				
Cust	Number of customers (i.e. installation control points, or ICPs).	40,599	47,504	4,108	274,000
Dens	Customer density, measured as customers per line km.	11.47	8.03	3.12	38.52
Load	Energy entering the network as a ratio of (maximum demand × hours in year), multiplied by 100 – a measure of network capacity utilization	61.92	7.27	30.41	84.71
Price	Network revenue (before customer rebates) per MWh of energy entering the network, in NZ$/MWh.[a]	47.87	13.20	23.86	103.35
OpexDep	Operating expenditure (including depreciation) per MWh of energy entering the network, in NZ$/MWh.[a]	21.63	9.56	3.37	62.88
SAIDI	System Average Interruption Duration Index (SAIDI).	192.5	117.3	15	504
Wind20	Number of days per year in which wind speed averaged more than 20 metres per second.	0.0006	0.0090	0	0.1429
Rain100	Number of days per year in which rainfall exceeded 100 millimetres.	0.2402	0.5129	0	3
Temp0	Number of days per year in which maximum temperature was zero degrees Celsius.	0.0176	0.1074	0	1
CO	Dummy equaling 1 for years in which the firm is purely customer-owned, otherwise 0.	0.6524	0.4768	0	1
Exempt	Dummy equaling 1 for years in which a firm is exempt from targeted control, otherwise 0.	0.1084	0.3112	0	1

[a] As at March 2013, NZ$1 = US$0.83.

Details of the EDBs exempted since 1 April 2009 from the targeted control regulatory regime (*Exempt*) were sourced directly from the Commerce Commission's website. We did not include a separate dummy variable for whether targeted control 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 labor have not been included as variables as they are not available on a regional basis in New Zealand. 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), large network length ($Length$ above 15,000 km), and extreme SAIDI values (above 505 minutes per customer per year). Thus our dataset has 364 observations consisting of 32 utilities covering 11.4 years on average.

Customer numbers ($Cust$) and hence customer density ($Dens$) are regarded as exogenous since customers' location choices will normally reflect a number of considerations over and above electricity distribution characteristics. Likewise capacity utilisation 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 typically require long lead-times.

Finally, ownership type (CO) is also treated as exogenous, since it was largely settled prior to our sample period (by the Energy Companies Act 1992). Furthermore, the bulk of ownership changes in our sample period occurred due to forced ownership unbundling of network and competitive activities in 1999 (Electricity Industry Reform Act 1998). That reform was driven by concerns about the pace of electricity retail competition, rather than by the cost and quality of electricity distribution.

4 Empirical Results

4.1 Ownership Persistence

As discussed in Section 3, we treat ownership as being exogenous in our sample period on the assumption that it is highly persistent, and changes in response to significant and long-term changes in factors such as incomes and industrial structure. Table 2 presents evidence in support of this assumption, regressing population-averaged customer ownership against population-averaged earnings (i.e. average customer income in each EDB region). Specifically, we estimate:

$$\overline{CO}_i = \alpha + \beta \overline{Earnings}_i + \varepsilon_t \tag{20}$$

where:

$$\overline{CO}_i = \frac{1}{T} \sum_{t=1995}^{2013} CO_{it} \quad \text{and} \quad \overline{Earnings}_i = \frac{1}{T} \sum_{t=1995}^{2013} Earnings_{it}$$

Table 2: Ownership Persistence Model – Dependent Variable: $\overline{CO}_i$

	OLS	
Variable	Mean (SE)	
$\overline{Earnings}_i$	-4.2E-5 (1.6E-5)	***
Constant	1.0759 (0.1384)	***
No. observations	307	

*** Sig. at 1%, ** Sig. at 5%, * Sig. at 10%.

If ownership is affected by long-term income changes, and if customer preference for quality rises with income, then we would expect $\beta < 0$, as we found. Hence it is consistent to assume that ownership is endogenous as in our theory model, yet exogenous in our empirical model, given this evidence supporting the persistence of ownership over relatively short horizons such as our data period.

4.2 Quality Model

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

$$\begin{aligned} ln\left(SAIDI_{it}\right) = \sum_{j\in\{-1,0,1\}} & \alpha_{2+j}Wind20_{it-j} + \alpha_{5+j}Rain100_{it-j} + \alpha_{8+j}Temp0_{it-j} \\ & +\alpha_{10}ln\left(\Delta Length_{it-1}\right) + \alpha_{11}Exempt_{it} + \alpha_{12}CO_{it} \\ & +\alpha_{13}ln\left(Cust_{it}\right) + \alpha_{14}ln\left(Dens_{it}\right) + \alpha_{15}Load_{it} \\ & +\eta_t + \mu_i + \varepsilon_{it} \end{aligned} \tag{21}$$

Note that lagged values of $SAIDI$ have been omitted because in our preferred FGLS specifications we instead allow for serial dependency via the error terms ε_{it}. Notice also that (21) omits $OpexDep_{it-1}$, since it proved to be highly collinear in this model.

In (21) 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.

The next explanatory variable, $\Delta Length_{it-1}$, captures past investment effects on current quality. We expect $\alpha_{10} > 0$, since past investments are expected to improve current quality (as opposed to simply increase the extent of network assets at risk of failure).

The next two variables in (21) capture regulatory and ownership impacts on quality. We expect $\alpha_{11} \geq 0$, since a regulatory regime for all EDBs introduced in 2004 sought to maintain or better historical quality levels. So when exemption from this regime was later introduced for certain customer-owned EDBs in 2009, this should have either left quality levels for those firms unchanged, or possibly worsened (to the extent the regulatory constraint had been binding). Likewise, we expect $\alpha_{12} > 0$, since our theoretical model predicts lower quality (i.e. higher SAIDI) under customer ownership in our reference case of maximal separation between δ^{IO} and δ^{CO}.

In addition to the year fixed effects η_t and EDB fixed effects μ_i, the remaining three explanatory variables complete X_t in (18). We are neutral on the sign of α_{13}, since higher customer numbers are either associated with greater network strain or greater network redundancy, with opposite implications for reliability. Conversely, we expect $\alpha_{14} < 0$, since higher customer density likely correlates with less sparse and hence less weather-exposed networks. Finally, we expect $\alpha_{15} > 0$ because higher capacity utilisation should correlate with increased risk of equipment failure.

Our results are summarised in Table 3, with all variables being at year t unless stated otherwise. Since our FGLS estimations reveal evidence of persistence in $SAIDI$, with error term AR(1) coefficients of 0.267 for Model FGLS I and 0.454 for Model FGLS II, we prefer our FGLS quality model specifications to our OLS specifications, and therefore focus on their results. This persistence is notable, indicating that poor reliability in one year is associated with ongoing reliability problems in the following year.

The clear results of these FGLS specifications is that each of CO, $Rain100_t$ and $Rain100_{t-1}$ are positively and highly significant associated with $SAIDI$. Furthermore, customer density ($Dens$) is negatively and highly significantly associated with $SAIDI$, while customer number ($Cust$) is negative and significant.

Thus higher customer numbers and customer density are each associated with improved reliability. Specifically, a 1% increase in $Cust$ is associated with a 0.1% decrease in SAIDI, while a 1% increase in $Dens$ is associated with a 0.59% decrease. These can be interpreted as economies of scale and economies of density respectively, with respect to quality.

Of particular note is that we indeed find customer ownership to be positively associated with SAIDI (i.e. negatively associated with reliability) all other things being equal, and highly significantly so. This is consistent with the prediction of our theory model in the reference case of maximal separation between δ^{IO} and δ^{CO} (as illustrated in Figure 4(a)).

As expected, severe weather – specifically severe rainfall – is associated with worsened reliability. Notably, we find persistence in this effect, with a 1% increase in current year extreme rainfall associated with a 0.22% increase in SAIDI, and a 1% increase in previous year severe rainfall associated with a 0.13% increase. This is consistent with severe rainfall having cumulative adverse impacts on network assets and hence reliability across years.

We note that we do not find either severe wind events or severe cold events to explain $SAIDI$ in our preferred specifications. The latter is the less surprising of the two, given New Zealand's temperate climate, meaning that severe cold events are confined to very southern and alpine networks only. However, given the country's oceanic climate and geography, much of the New Zealand is exposed to severe wind events, causing faults.

Table 3: Quality Model – Dependent Variable: ln(SAIDI)

	OLS I		OLS II		FGLS I[b]		FGLS II[c]	
Variable	Mean (SE)[a]		Mean (SE)[a]		Mean (SE)[d]		Mean (SE)[d]	
$\ln(\text{Wind20}_{t+1})$	-0.6944		-0.5208		-1.1324		-0.5247	
	(0.4416)		(0.4415)		(1.2516)		(1.2820)	
$\ln(\text{Rain100}_{t+1})$	0.0056		0.0024		0.0534		-0.0022	
	(0.1402)		(0.1460)		(0.0795)		(0.0775)	
$\ln(\text{Temp0}_{t+1})$	0.1745		0.4037	**	-0.0190		0.1850	
	(0.2124)		(0.1701)		(0.2634)		(0.6915)	
$\ln(\Delta\text{Length}_{t-1})$	-0.0376		-0.0373		0.1983		0.1726	
	(0.2920)		(0.3906)		(0.2299)		(0.3564)	
Exempt	-0.0605		-0.0694		-0.1235		-0.0948	
	(0.0851)		(0.0829)		(0.1164)		(0.1260)	
CO	-0.2061	*	0.0168		0.2649	***	0.3124	***
	(0.1151)		(0.1424)		(0.0819)		(0.1197)	
ln(Cust)	0.6573		0.9993		-0.0635	*	-0.0971	**
	(0.5770)		(0.6711)		(0.0374)		(0.0484)	
ln(Dens)	-0.4402		-0.6282		-0.5920	***	-0.5883	***
	(0.4663)		(0.4660)		(0.0667)		(0.0875)	
Load	-0.0045		-0.0070		0.0040		0.0013	
	(0.0071)		(0.0075)		(0.0040)		(0.0046)	
ln(Wind20)	-0.6309		-0.2185		-0.8498		0.6492	
	(0.8240)		(0.8352)		(2.6012)		(2.6024)	
ln(Rain100)	0.1722		0.1491		0.2886	***	0.2170	***
	(0.1088)		(0.1246)		(0.0769)		(0.0737)	
ln(Temp0)	0.8205	***	0.9080	***	-0.0190		0.6839	
	(0.2577)		(0.2022)		(0.2634)		(0.7505)	
$\ln(\text{Wind20}_{t-1})$			0.8600				0.6071	
			(1.3340)				(1.2887)	
$\ln(\text{Rain100}_{t-1})$			0.0706				0.1286	*
			(0.1486)				(0.0752)	
$\ln(\text{Temp0}_{t-1})$			0.6397				-0.2025	
			(0.9927)				(0.6906)	
Year fixed effects	Yes		Yes		Yes		Yes	

Variable	OLS I	OLS II	FGLS I[b]	FGLS II[c]
	Mean (SE)[a]	Mean (SE)[a]	Mean (SE)[d]	Mean (SE)[d]
EDB fixed effects	Yes	Yes	Yes	Yes
R^2	0.226	0.188		
Wald χ^2			378.97	228.07
No. observations	334	309	334	305

[a] SE clustered over utilities. [b] Common AR(1) coefficient for all panels (0.267).
[c] Common AR(1) coefficient for all panels (0.454). [d] SE heteroscedasticity corrected.
*** Sig. at 1%, ** Sig. at 5%, * Sig. at 10%.

Finally, the negative – though insignificant – coefficients on *Exempt* in our two FGLS models are suggestive of New Zealand's EDB regulatory regime having resulted in *worsened* quality, despite it having imposed quality maintenance requirements. Furthermore, to the extent that the regulatory exemption applying only to certain customer-owned firms since 2009 has contributed to improved reliability, this mitigates the adverse impact of customer ownership identified more directly. A possible explanation for this regulatory exemption effect is that New Zealand's price-quality thresholds were screening devices to be used by the regulator as a means of identifying where to target regulatory control actions. For the same reasons that quality is non-contractible (e.g. its measurement is subject to the confounding effects of weather), it is also possibly less actionable in a legal sense, in that EDBs might find it relatively easy in regulatory judicial proceedings to attribute threshold breaches to weather events beyond their control.

4.3 Cost Model

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

$$\begin{aligned} ln(OpexDep_{it}) = & \sum_{j\in\{-1,0,1\}} \beta_{2+j}Wind20_{it-j} + \beta_{5+j}Rain100_{it-j} + \beta_{8+j}Temp0_{it-j} \\ & +\beta_{10}ln\left(\Delta Length_{it-1}\right) + \beta_{11}Exempt_{it} + \beta_{12}CO_{it} \\ & +\beta_{13}ln\left(Cust_{it}\right) + \beta_{14}ln\left(Dens_{it}\right) + \beta_{15}Load_{it} \\ & +\eta_t + \mu_i + \varepsilon_{it} \end{aligned} \tag{22}$$

As for our quality model, we omit a lagged dependent variable in this model due to adopting an autoregressive error specification. Likewise, we proxy $SAIDI_{it-1}$ using lagged weather variables, while current year weather variables exogenously account for

$SAIDI_{it}$.[33] Increases in either should result in increased $OpexDep_{it}$. Furthermore, as in Section 3, next period weather variables are our exogenous proxies for expected future quality. To the extent that regulatory quality constraints are binding an EDB should increase $OpexDep_{it}$ if severe weather is anticipated in year $t+1$, so the coefficients on next year weather variables should be positive. It is not unreasonable to expect EDBs to be aware of their general climatic conditions, including cyclical weather patterns across years. Future weather variables are therefore reasonable proxies for expected future reliability.

Also as discussed in Section 3, higher past investment (i.e. $\Delta Length_{it-1}$) could result in either higher or lower current $OpexDep$, so we are neutral on the sign of β_{10}, treating this as a key empirical question. Since regulation imposed price-controls intended to improve efficiency, we expect that exemption from that regulation should result in $\beta_{11} > 0$. Likewise, we expect $\beta_{12} > 0$. As discussed in Section 2, our theoretical model predicts that customer ownership will be associated with lower efficiency (i.e. higher costs), in our reference case of maximal separation between δ^{IO} and δ^{CO}.

We expect $\beta_{13} < 0$, given that electricity distribution is regarded as involving economies of scale, with $Cust$ being a measure of such scale. Likewise, we expect $\beta_{14} < 0$ since it is also regarded as benefiting from economies of density.[34] We expect $\beta_{15} > 0$ on the basis that increased network utilisation should result in capacity-constraint related higher faults.

Our cost model results are summarised in Table 4, with all variables being for year t unless stated otherwise.

Unlike for our quality models, here we find no conclusive evidence that $OpexDep$ is persistent. Specifically, in model FGLS II we find an error term AR(1) coefficient of just -0.063. We prefer the fuller specifications in model OLS II and FGLS II, and focus on their results, noting that in principle the OLS II specification is to be preferred to FGLS II in the absence of persistence.

Focusing on these two specifications, we see that once again CO is highly significant and positive for $OpexDep$. Conversely, $Cust$ and $Exempt$ are each negative and significant. Indeed, our findings for both CO and $Dens$ are consistent across all four specifications, not just our preferred two.

Once again, of particular note are our findings regarding CO. Just as we found that customer ownership is associated with lower reliability (subject to any mitigating effects arising from regulatory exemption), we also find that customer ownership is associated with higher operating cost, as predicted in our reference case (as illustrated in Figure 4(a)).

This apparently suggests that customer ownership is an inefficient organisational form, particularly in the light of our findings regarding the adverse impact of customer ownership on quality. However, these findings must be considered in the light of any price advantages of customer ownership, and their overall impact on welfare (see Section 4.4).

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

[34] We did not also include *Length* in this model because it is perfectly collinear with *Cust* and *Dens*.

Table 4: Cost Model – Dependent Variable: ln(OpexDep)

	OLS I		OLS II		FGLS I[b]		FGLS II[c]	
Variable	Mean (SE)[a]		Mean (SE)[a]		Mean (SE)[d]		Mean (SE)[d]	
$\ln(\text{Wind20}_{t+1})$	0.3114 (0.2682)		0.2389 (0.2319)		0.2090 (0.3231)		0.2027 (0.5293)	
$\ln(\text{Rain100}_{t+1})$	0.0177 (0.0490)		0.0348 (0.0497)		-0.0093 (0.0289)		0.0057 (0.0551)	
$\ln(\text{Temp0}_{t+1})$	0.2682 (0.1826)		0.4078 (0.1460)	***	0.0850 (0.1598)		0.0016 (0.4366)	
$\ln(\Delta\text{Length}_{t-1})$	-0.3705 (0.1540)	**	-0.2360 (0.2054)		-0.3985 (0.0995)	***	-0.1826 (0.1889)	
Exempt	-0.0797 (0.0471)		-0.0868 (0.0448)	*	-0.0111 (0.0476)		-0.1035 (0.0465)	**
CO	0.1332 (0.0687)	*	0.1464 (0.0510)	***	0.1612 (0.0550)	***	0.2999 (0.0350)	***
ln(Cust)	0.1848 (0.4243)		0.0411 (0.4220)		-0.0355 (0.0247)		-0.0628 (0.0151)	***
ln(Dens)	-0.6496 (0.2793)	**	-0.5524 (0.2647)	**	-0.1933 (0.0403)	***	-0.1611 (0.0254)	***
Load	0.0006 (0.0034)		-0.0024 (0.0034)		-0.0013 (0.0017)		-0.0051 (0.0020)	***
ln(Wind20)	0.6166 (0.3126)	*	0.7391 (0.3535)	**	0.7367 (0.7400)		1.9864 (1.9125)	
ln(Rain100)	-0.0399 (0.0573)		-0.0621 (0.0565)		-0.0304 (0.0291)		-0.0615 (0.0547)	
ln(Temp0)	0.0556 (0.2536)		0.3162 (0.1642)	*	-0.0809 (0.1441)		-0.0890 (0.4366)	
$\ln(\text{Wind20}_{t-1})$			0.0304 (0.1370)				-0.2313 (0.5319)	
$\ln(\text{Rain100}_{t-1})$			-0.0058 (0.0390)				0.0232 (0.0560)	
$\ln(\text{Temp0}_{t-1})$			0.1051 (0.0355)	***			-0.2802 (0.4340)	
Year fixed effects	Yes		Yes		Yes		Yes	

	OLS I	OLS II	FGLS I[b]	FGLS II[c]
Variable	Mean (SE)[a]	Mean (SE)[a]	Mean (SE)[d]	Mean (SE)[d]
EDB fixed effects	Yes	Yes	Yes	Yes
R^2	0.411	0.439		
Wald χ^2			212.44	502.57
No. observations	334	309	334	305

[a] SE clustered over utilities. [b] Common AR(1) coefficient for all panels (0.726).
[c] Common AR(1) coefficient for all panels (-0.063). [d] SE heteroscedasticity corrected.
*** Sig. at 1%, ** Sig. at 5%, * Sig. at 10%.

Unlike in our quality model, here we find *Exempt* to be significant across our preferred specifications, and it is consistently negative across all four models. This indicates that electricity distribution regulation in New Zealand has been associated with *increased* operating costs. A simple interpretation is that regulation has increased the compliance costs borne by EDBs. A more subtle explanation is that while New Zealand's regulatory regime has involved the use of incentive-based thresholds, the prosecution of breaches of those thresholds has features more like rate-of-return regulation. This type of regulation is known to favour greater investment and quality over cost efficiencies and lower prices, which might also therefore explain our findings.

Interestingly, we do not find evidence of economies of scale in relation to costs (as we did for quality), with *Cust* being negative and highly significant for *OpexDep* in model FGLS II, but positive and insignificant in model OLS II. However, we do find evidence of economies of density, though with differing orders of magnitude depending on specification. In particular, a 1% increase in *Dens* is associated with either a 0.55% (model OLS II) or 0.16% (model FGLS II) decrease in *OpexDep*. Our results are also suggestive of *OpexDep* being decreasing in *Load*.

Also of interest is that model OLS II indicates that current year extreme wind ($Wind20_t$) and cold ($Temp0_t$) are significantly associated with increased *OpexDep*. This is to be contrasted with our quality model in which only $Rain100_t$ and $Rain100_{t-1}$ were significant. Hence our results suggest that severe rainfall is associated with persistent falls in reliability, while severe wind and cold are instead associated with increased operating costs.

Notably, next period weather – specifically, $Temp0_{t+1}$ in model OLS II – is both positive and highly significant. This suggests that EDBs increase current year *OpexDep* if they anticipate particularly cold weather in the following year, for example as a result of cyclical weather patterns like El Niño. Our finding compares with that in Jamasb et al. (2012), who find that actual future unreliability (as a proxy for expected future quality) is positively associated with current period operating costs. However, they do not allow for the clear endogeneity that our analysis identifies between current operating expenditures and future reliability. Furthermore, our specifications are more generally suggestive of expected future quality being positive for current period costs, with next period weather coefficients being positive across all variables in both OLS II and FGLS II.

Finally, past investment (i.e. $\Delta Length_{t-1}$) is negatively but not significantly associated with *OpexDep*. This weakly confirms our expectation that greater network length is more likely associated with better network reinforcement than with greater network exposure.

4.4 Price Model

Adapting the price model specification in Jamasb and Söderberg (2010), we use the following detailed specification for average price (i.e. lines revenue per MWh of energy entering the network), indexing firms by i and years by t as before:[35]

$$\begin{aligned} ln\left(Price_{it}\right) = \gamma_1 ln\left(OpexDep_{it-1}\right) + \gamma_2\left(ln\left(OpexDep_{it-1}\right) \times CO_{it-1}\right) \\ + \gamma_3 CO_{it-1} + \gamma_4 Exempt_{it-1} \\ + \eta_t + \mu_i + \varepsilon_{it} \end{aligned} \tag{23}$$

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.

We expect $\gamma_1 > 0$, since prices should be positively related to costs. Since we predict that customer-owned firms will have higher costs (i.e. lower efficiency) and lower prices, we hypothesise that $\gamma_2 > 0$, given the breakeven constraint typically applied by such firms. Likewise, since our theoretical model clearly predicts that price should be lower under customer ownership (in either panel of Figure 4), we expect $\gamma_3 < 0$. In principle we expect $\gamma_4 > 0$, since the purpose of regulation was to impose incentive-based price thresholds intended to improve EDB efficiency.

Our results are summarised in Table 5, with all variables being at year t unless stated otherwise. In our preferred, FGLS specification we find evidence of persistence in prices (i.e. error terms in our price model having an AR(1) coefficient of 0.457). Thus a firm with high prices in one year is likely to continue having high prices in subsequent years.

As expected, prices are positively and highly significantly related to *OpexDep*, with a 1% increase in $OpexDep_{it-1}$ leading directly to a 0.16% increase in *Price*. Consistent with our hypothesis, we find that the sensitivity of price to costs is indeed higher under customer ownership.

We notably find that prices are on average highly 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.

[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: Price Model – Dependent Variable: ln(Price)

	OLS		FGLS[a]	
Variable	Mean (SE)[b]		Mean (SE)[c]	
$\ln(\text{OpexDep}_{t-1})$	0.0943		0.1600	***
	(0.0839)		(0.0332)	
$\ln(\text{OpexDep}_{t-1})\times\text{CO}_{t-1}$	0.1093		0.1605	***
	(0.0983)		(0.0461)	
CO_{t-1}	-0.5902	**	-0.4666	***
	(0.2852)		(0.1401)	
Exempt_{t-1}	-0.0691		-0.0373	
	(0.0353)		(0.0330)	
Year fixed effects	Yes		Yes	
EDB fixed effects	Yes		Yes	
R^2	0.305			
Wald χ^2			201.20	
No. observations	358		356	

[a] Common AR(1) coefficient for all panels (0.457). [b] SE clustered over utilities. [c] SE heteroscedasticity corrected. *** Sig. at 1%, ** Sig. at 5%, * Sig. at 10%.

Our findings are in line with our clear theoretical prediction in Section 2 that customer-owned firms should have lower prices than investor-owned firms.

4.5 Welfare

Our empirical results above are consistent with the predictions of our Section 2 theory model assuming the case of maximal separation in quality preferences between the customers of investor- and customer-owned firms (i.e. $\delta^{IO} = 0$ and $\delta^{CO} = \frac{1}{2}\sqrt{2}$). Specifically, customer ownership is found to be associated with lower price, but also with lower efficiency and quality. The question therefore remains as to whether the welfare benefits of lower price under customer ownership are offset by its welfare costs of lower efficiency and quality. According to Figure 4(a), the overall welfare effect of customer ownership is predicted to be negative (when comparing a customer-owned firm having a relatively low δ^{CO} with an investor-owned firm having a relatively high δ^{IO}).

Table 6: Approximate Welfare Calculations

	Customer Ownership	Investor Ownership	Change
Expected price[a] (NZ$/MWh)	41.23	55.90	36%
Expected quantity[a] (MWh/Customer)	15.58	16.83	8%
Expected costs[a] (NZ$/MWh)	22.89	20.04	-12%
Consumer surplus (NZ$/Customer)	64.93	49.46	-24%
Firm profits (NZ$/Customer)	31.26	52.39	68%
Total surplus	96.19	101.85	6%

[a] Expected values in logs (μ) converted into expected values in levels using $exp\left(\mu + \frac{1}{2}\sigma\right)$ where σ is root MSE of model residuals.

Due to data limitations, we estimate a simple demand model (i.e. with 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. It is expected that investor-ownership will shift the demand curve outward because it results in higher quality. In Table A.1 of Appendix A 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 5. 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 4 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 (i.e. welfare) for each ownership type. Table 6 summarises our results.

As can be seen, both expected price and quantity is 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. The resulting consumer surplus is estimated to be lower under investor ownership than customer ownership. However, profits of the investor-owned firm are estimated to be substantially higher.

Combined, these results imply that estimated consumer surplus based on expected prices and quantities is 6% higher under investor ownership than under customer ownership.[36] As for our quality, cost and price results, this too is consistent with the situation

[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

illustrated in Figure 4(a). Hence our results using New Zealand EDB data are consistent with our theoretical predictions assuming maximal difference in quality preferences between customers of each firm type.

5 Conclusions

In this paper we have analysed the relative performance of investor- and customer-owned utility firms, with a particular focus 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. Finally, customers with a lower quality preference than that required for even customer-ownership will simply not be served.

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 yields both higher profits and consumer surplus, this means investor-owned firms are automatically at an advantage in any such comparison. 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 (i.e. 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. 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 and attractiveness to customers (due to differences in those customers' preference for quality).

We take these predictions to data using regulatory disclosure data from EDBs in New Zealand over 1995–2013. The New Zealand dataset is well-suited to addressing these questions because customer ownership is an important feature of the country's electricity distribution sector. It also has the advantage that ownership changes have arisen largely as a consequence of legislative changes directed towards wider electricity reform objectives.

maximum observed price in the dataset, plus a margin of 15%. Adding this margin is conservative, in that it downward biases welfare under investor ownership.

In our empirical analysis we paid close attention to how costs interact with quality in such firms. 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. Thus it remains an empirical question as to how quality-related expenditures change the nature of a distribution firm's cost function. To frame our empirical specifications for costs and quality we developed a framework showing how they are endogenous, and involve both retrospective and forward-looking temporal dependencies.

As per our theoretical predictions, the data for New Zealand EDBs suggests customer ownership is statistically significantly associated with lower prices, but also with lower quality (i.e. higher SAIDI) and efficiency (i.e. higher costs). Based on approximate calculations, this results in lower welfare overall for customer-owned EDBs. These empirical findings contrast with those in Kwoka (2005), who finds that public ownership (rather than customer ownership per se) of US electric utilities is associated with lower costs and higher quality relative to investor ownership. However, Kwoka's findings are explicable under our framework if we assume a lower level of divergence between customers' quality preferences than that assumed in our reference case. While our New Zealand findings reflect the situation illustrated in Figure 4(a), Kwoka's US findings are consistent with the situation depicted in Figure 4(b).

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 (i.e. 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.

However, an interesting implication of our analysis is that the reverse might be true. Specifically, even if an investor-owned firm is observed to deliver higher welfare than a customer-owned firm, this is not to suggest that investor-ownership is 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 important difference, though, is that an investor-owned firm maximises profits, whereas a customer-owned firm serving the same customers would maximise welfare (since customer-owners are assumed to maximise the same objective function as a social planner). 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), albeit 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 for customer- and investor-owned utilities.

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A Approximate Demand Model

Table A.1: Demand Model – Dependent Variable: ln(MWh/Customer)

	OLS	
Variable	Mean (SE)[a]	
ln(Price)	-0.0959	
	(0.0576)	
CO	-0.1624	***
	(0.0289)	
ln(Wind20)	0.1003	
	(0.1309)	
ln(Rain100)	-0.0061	
	(0.0152)	
ln(Temp0)	-0.0943	**
	(0.0372)	
Length	0.0000	
	(0.0000)	
Earnings[b]	0.0002	***
	(0.0000)	
Load	0.0010	
	(0.0026)	
Year fixed effects	Yes	
EDB fixed effects	Yes	
R^2	0.9481	
No. observations	307	

All variables are for year t.[a] SE clustered over utilities. [b] Average income for customers in EDB region.
*** Sig. at 1%, ** Sig. at 5%, * Sig. at 10%.