Ownership, Pricing, and Productivity: Evidence from Electric Distribution Cooperatives[*]

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Abstract

This paper investigates pricing and productivity differences across a sample of rural electric distribution cooperatives in the United States. State-level statutes governing operation as a cooperative corporation differ somewhat across states, but common across all statutes are explicit price constraints on financial capital supplied by investors (non-members), prohibition of control rights tied to directly to the provision of financial capital, and requirements obligating each entity to assign board membership to patron members using a democratic procedure. Further, subgroups of distribution cooperatives, which across all groups constitute a majority share of total power distribution, themselves own and operate (via agency through a board of directors, and subject to long-term full-requirement contracts) upstream generation and transmission cooperatives (G&T's) that provide members a significant fraction of total power needs. We develop and estimate a cost-minimization model for distribution cooperatives in this context, and use panel data for the period 2006-2011 to estimate pricing and productivity differences across distribution cooperatives. Results reveal a statistically and economically important difference between cooperatives that purchase all power on open markets, and those that source from a G&T, with member cooperatives operating at high productivity and lower marginal cost.

Introduction

We examine pricing and productivity differences across a sample of electric distribution cooperatives, and estimate marginal cost savings from ownership of Generation and Transmission (G&T) by distribution cooperatives. The U.S. government helped establish electric cooperatives in the mid-1930s with assistance under the Rural Electrification Act. Estimates suggest that less than 10% of rural farm homes had electric services in the mid-1930s, but by mid-century this fraction had increased dramatically to nearly 90%. Electric cooperatives exist at present as mixed ownership (invividual and community businesse owners) retail power distributors, and as cooperative owned G&Tpower providers for cooperative distributors. When a G&Tprovides wholesale power to its member distribution cooperatives, typically it does so under long-term full-requirement contracts that commit members to purchase all power generated by the G&T. In 2014, there were 833 rural distribution coopertives, and 65 G&Tcooperatives. Collectively, the system of rural cooperative G&T's and distribution cooperatives account for roughly 5% of total power production in the United States, and serve a approximately 12% of the U.S. population.

Although the electric power industry is highly regulated, not all states regulate electric cooperatives. Currently, there are 14 states with regulatory jurisdiction over the rates that cooperatives can charge their members[1], but in some of these states cooperatives can opt-

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[1]These states include Alaska, Arkansas, Arizona, Indiana, Kansas, Kentucky, Louisiana, Maryland, Maine, Michigan, New Mexico, Vermont, Virginia, and Wyoming.

out of state oversight, and choose effectively to self regulate through consumer ownership; other states without explicit jurisdication allow cooperatives to opt-in (Dakota Electric in Minnosta is currently the only electric cooperative that exercised the option and is regulated by the Public Utilities Commission in Minnesota).

A large body of the literature has examined various aspects of the electric power industry, with many previous studies focusing the performance of investor-owned utilities in regulated and deregulated environments. Nerlove (1963) and Christensen and Green (1976) estimate cost functions to analyze economies of scale for regulated investor-owned electric generation utilities. Both studies found substantial scale economies in the U.S. power industry, but also that average cost of production becomes virtually flat at a moderate level of electricity generation. Bushnell and Wolfram (2005), Fabrizio et al. (2007), and Davis and Wolfram (2012) find that the vertical separation of electricity generation resulting from industry restructuring during the late 1990s to early 2000s increased the efficiency of power plants. In contrast, a number of studies also show that there exists scale economies and cost complementarities associated with vertical integration of the three functions of electricity, generation, transmission, and distribution. These results suggest that integrated electric utilities could be efficient with declining average costs (Joskow (2003)). Greer (2003) is one of the few studies that examine electric cooperatives. Greer (2003) finds that electric distribution cooperatives are too small to capture the scale economies that are inherent in the industry, and that there exist inefficiencies in the relationship between G&Tand member distribution cooperatives, with substantial potentiakl cost savings from full integration of G&Tand members.

The objective of this paper is to analyze price-cost margin and productivity of electric distribution cooperatives, and to estimate cost differences from G&Townership by member cooperatives. In doing so, we construct a model of cost minimization and estimate the model using a panel data of electric distribution cooperatives from 2006 to 2011, where some of the cooperatives particpate in ownership while others do not. The results show that cooperatives that are members of a G&Thave on average 6% higher price-cost margins that are the result of lower operating costs. We do not find significant retail electricity price differences between the two group of cooperatives, and we find member cooperatives have higher productivity.

The remainder of paper is organized as follows. In Section we discuss the data and present some descriptive statistics. In Section and we discuss the method to obtain reliable estimates of the price-cost margin and productivity. We present a model of cost minimization and demonstrate how it allows us to measure the effects of ownership of G&Ton the cost of operation. Section provides the empirical results and the last section concludes the paper.

Data and Descriptive Statistics

Data

The analysis in this paper is based on annual firm-level data collected by USDA's Rural Utilities Services (RUS Form 7) for electricity distribution cooperatives that are RUS borrowers. The data consists of 623 firms or 3479 observations from 2006 to 2011, which covers

about 70% of the distribution cooperatives existing in the industry. In the data, we have 167 cooperatives that are not members of G&T, and 448 cooperatives that are members and owners of G&T. We also have 8 cooperatives that are not members of G&T, but all of the three functions of electricity are integrated within the firm, i.e., generation, transmission, and distribution of electricity. The number of observation is 867, 2568, and 44, respectively. While the member cooperatives are obligated to purchase electricity from their G&Ts often under long-term full-requirement contracts, the non-member cooperatives buy from public power systems, investor-owned utilities, or other electric power producers[2]. The integrated cooperatives usually locate in geographically separated areas, with 6 in Alaska, 1 in Hawaii, and 1 in Rhode Island.

Table 2 provides summary statistics for electric operations of member, non-member, and integrated cooperatives. The amount of commercial, residential, and total kwh sold and corresponding revenue are available from the power requirements database - annual summary in Form 7. Total kwh and revenue include not only commercial and residential electricity, but also other electricity sales including irrigation, public street and highway lighting, and other sales to public authorities. Cost of power purchases and generation is also collected from the power requirements account. Number of hours worked and total payroll are obtained from employee-hour and payroll statistics. Employee hours worked is the sum of regular and overtime hours that all employees at the firm worked during a year. Total payroll is the total compensation received by the employees during a year. Total cost indicates the total operation and maintenance expenses available in the statement of operations. This includes, for example, cost of purchased power, transmission and distribution expenses, and customer service expenses. It does not include depreciation, tax expenses, and interests on long-term debt. Total miles is the sum of transmission and distribution miles collected from transmission and distribution plant account. In the bottom panel of Table 2, commercial and residential prices are calculated by dividing the commercial and residential revenue by corresponding kwh, respectively. Commercial and residential share of revenue indicates the portion of commercial and residential revenue in total revenue, respectively. Total revenue to cost ratio is the ratio of total revenue to total cost. Ratio of total kwh generated or purchased to sold is total kwh purchased or generated divided by total kwh sold by the firm during a year. Hourly wage is calculated by dividing total payroll by employee hours worked. Power purchases price is the cost of purchases and generation divided by total kwh purchased or generated. Finally, average cost is the total cost divided by total kwh.

In Table 2, the last column tests the null hypothesis that the mean of the variable is equal across the non-member and member cooperatives. From the top panel of the table, we find that comparing the non-member with member cooperatives, the non-members have higher commercial and residential electricity sales than the members, both kwh and revenue, but we cannot reject the null that the mean of the number of transmission and distribution miles is same across the groups. This suggests that while electric cooperatives were generally

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[2]In Greer (2008), 17% of cooperatives in the study are not members of G&T. About half of the non-members are served by federal-owned suppliers, with the rest of the non-members having electricity provided by investor-owned utilities or others. Our data shows similar statistics.

formed in rural areas, the non-members tend to be in relatively more populated areas than the members do. Or, being in less populated areas, member cooperatives serve less kilowatt hours of electricity per mile of transmission and distribution lines. In the bottom panel of Table 2, we also find that the non-member cooperatives charge higher prices for commercial electricity, while residential prices are statistically not different at the mean. Cooperatives in both groups charge higher retail price for residential electricity relative to commercial electricity. Member cooperatives have higher shares of commercial and residential sales in total kilowatt hours of electricity, although the magnitudes are not very different. Non-members show higher average cost per unit of electricity, but also have higher revenue to cost ratio, suggesting that the non-members tend to have higher ratio of retail price to average cost. While non-members purchase about 7% more of electricity than they actually sold to their customers, members buy about 6% more electricity than the amount sold by the firms, with the difference being statistically significant at the mean. Finally, the non-member group shows higher hourly wage compared with the member group. Power purchases price is lower for member cooperatives, but not statistically significant.

We note that integrated cooperatives are considerably different than the non-member and member cooperatives. The integrated cooperatives are much smaller than the other groups, as seen by commercial and residential kwh and revenue, and total transmission and distribution miles. The integrated cooperatives charge substantially higher electricity prices and have higher average cost of production. However, this is not surprising once we consider that these cooperatives locate in geographically separated areas. In the subsequent empirical analysis, we do not include these cooperatives and consider only the two groups of firms, the non-member and member cooperatives.

Empirical Model

The paper distinguishes residential and commercial electricity outputs under a cost minimization model, denoted by Q_{it}^R and Q_{it}^C, respectively. In year t, cooperative i provides residential and commercial electricity outputs through the process represented by

$$Q_{it}^j = Q\left(L_{it}, K_{it}, Q_{it}^P, \omega_{it} | \alpha^j\right) \tag{1}$$

where $j = R$ or C, and α^j is a vector of parameters characterizing the electricity distribution process that is allowed potentially be different across the commercial and residential outputs. To meet the customers' load, cooperative i uses labor (L_{it}), transmission and distribution miles (K_{it}), and purchases electricity (Q_{it}^P) from G&Ts or other firms depending on the membership of G&T. ω_{it} denotes the firm-specific productivity that is known to the firm but not observed by the econometrician. Although not necessarily profit maximizing, we assume that cooperative i wants to minimize the operating cost C_{it} which is defined by

$$
\begin{aligned}
C_{it} = \min_{L_{it}, Q_{it}^P} & \; P_{it}^L L_{it} + P_{it}^P Q_{it}^P \quad \text{subject to } Q_{it}^P \geq Q_{it}^R + Q_{it}^C \\
& \equiv C\left(\mathbf{P_{it}}, K_{it}, \mathbf{Q_{it}}, \omega_{it}\right)
\end{aligned}
\tag{2}
$$

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where $\mathbf{P_{it}} \equiv \left(P_{it}^L, P_{it}^P\right)$ denotes the vector of labor and purchased power prices, and $\mathbf{Q_{it}} \equiv \left(Q_{it}^R, Q_{it}^C\right)$ denotes the vector of residential and commercial electricity outputs. Equation (2) states that cooperative i chooses the optimal levels of labor and electricity purchases inputs so as to minimize the cost of operation, subject to the constraint that the firm should purchase the amount of electricity that is equal to or greater than the consumers' demand for residential and commercial electricity. Equation (2) is a conditional cost function in the sense that it includes the fixed capacity (K_{it}) and the productivity (ω_{it}) in a given year t.

In the estimation of (2), an issue is the potential for simultaneity in the relationship between $\mathbf{Q_{it}}$ and C_{it}. This would arise if firms adjusted their outputs, e.g., energy losses, to accommodate the productivity shocks (ω_{it}) which is also correlated with C_{it}. This is analogous to the simultaneity of inputs in the literature of production function estimation. For example, the demand for material input is correlated with the productivity which also affects the output produced in the firm (e.g., Olley and Pakes (1996), Levinsohn and Petrin (2003), and Ackerberg et al. (2006)). To control for the unobserved productivity in the estimation of the cost function in (2), this paper conceptually follows the estimation method suggested by Gandhi et al. (2013) in the production function literature. The crucial insight of Gandhi et al. (2013) is that in the estimation of the production function we can use the first order condition of the profit maximization with respect to the endogenous input, and explicitly correct for the simultaneity of the unobserved productivity. We begin by further specifying the cost function as follows.

$$C_{it} = F\left(\mathbf{P_{it}}, K_{it}, \mathbf{Q_{it}}\right) e^{-\omega_{it}} e^{\epsilon_{it}} \tag{3}$$

Equation (3) restricts our attention to the cost function with the scalar Hicks-neutral productivity and a common set of cost function parameters across firms. The latter does not imply that the cost elasticities across firms are constant, except for the special case of Cobb-Douglas. Firms with higher productivity (ω_{it}) will incur lower cost of operation holding the other variables constant. ϵ_{it} is an unanticipated i.i.d shock to the cost including the measurement error. Taking the partial derivative of the cost function in (3) with respect to the residential output Q_{it}^R and multiplying both sides by $\frac{Q_{it}^R}{C_{it}}$ and rearranging the terms yields the following relationship.

$$S_{it} = \Lambda_{it} G\left(\mathbf{P_{it}}, K_{it}, \mathbf{Q_{it}}\right) e^{-\epsilon_{it}} \tag{4}$$

where $S_{it} \equiv \frac{P_{it}^R Q_{it}^R}{C_{it}}$ is the nominal share of residential revenue to total operation cost, $\Lambda_{it} \equiv \frac{P_{it}^R}{MC_{it}^R}$ is the ratio of residential price to marginal cost of residential electricity distribution, and $G\left(\mathbf{P_{it}}, K_{it}, \mathbf{Q_{it}}\right) \equiv \frac{F_{Q^R}(\mathbf{P_{it}}, K_{it}, \mathbf{Q_{it}}) Q_{it}^R}{F(\mathbf{P_{it}}, K_{it}, \mathbf{Q_{it}})}$ is the residential output elasticity of cost. Taking the log of both sides gives

$$s_{it} = \lambda_{it} + \ln G\left(\mathbf{P_{it}}, K_{it}, \mathbf{Q_{it}}\right) - \epsilon_{it} \tag{5}$$

where the small-case letters indicate the logs of the corresponding upper-case letters. The log of the residential price-cost margin, λ_{it}, is equal to 0 if the residential price is equal to the marginal cost of residential electricity distribution. If we assume that λ_{it} varies across

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the groups but is constant over time and within each group of member and non-member cooperatives, equation (5) becomes

$$s_{it} = \lambda_d + \ln G\left(\mathbf{P_{it}}, K_{it}, \mathbf{Q_{it}}\right) - \epsilon_{it} \tag{6}$$

where d indexes the member and non-member groups. That is, λ_d is equal to one if cooperative i is a member cooperative and zero if it is a non-member cooperative. Since we observe $s_{it} \equiv \ln \frac{P_{it}^R Q_{it}^R}{C_{it}}$ in the data and ϵ_{it} is i.i.d. by construction, once we specify a functional form of $\ln G\left(\mathbf{P_{it}}, K_{it}, \mathbf{Q_{it}}\right)$ the regression of (6) identifies the residential price-cost margin (λ_d) and the residential output elasticity of cost ($\ln G\left(\mathbf{P_{it}}, K_{it}, \mathbf{Q_{it}}\right)$). To identify the cost function in (3) as a whole, note that $\frac{G(\mathbf{P_{it}}, K_{it}, \mathbf{Q_{it}})}{Q_{it}^R} = \frac{\partial}{\partial Q_{it}^R} \ln F\left(\mathbf{P_{it}}, K_{it}, \mathbf{Q_{it}}\right)$. Integrating on both sides gives

$$\int \frac{G\left(\mathbf{P_{it}}, K_{it}, \mathbf{Q_{it}}\right)}{Q_{it}^R} dQ_{it}^R = \ln F\left(\mathbf{P_{it}}, K_{it}, \mathbf{Q_{it}}\right) + \Upsilon\left(\mathbf{P_{it}}, K_{it}, Q_{it}^C\right) \tag{7}$$

where $\Upsilon\left(\mathbf{P_{it}}, K_{it}, Q_{it}^C\right)$ denotes a constant of integration. Hence, the regression of equation (6) allows us to identify the function $F\left(\mathbf{P_{it}}, K_{it}, \mathbf{Q_{it}}\right)$ up to a constant of integration $\Upsilon\left(\mathbf{P_{it}}, K_{it}, Q_{it}^C\right)$. Furthermore, note that we can write the log of the cost function (3) as

$$\ln C_{it} - \int \frac{G\left(\mathbf{P_{it}}, K_{it}, \mathbf{Q_{it}}\right)}{Q_{it}^R} dQ_{it}^R - \epsilon_{it} = -\Upsilon\left(\mathbf{P_{it}}, K_{it}, Q_{it}^C\right) - \omega_{it} \tag{8}$$

where we know the left hand side from the estimation of (6). Let Ψ_{it} denote the left hand side, i.e., $\Psi_{it} \equiv \ln C_{it} - \int \frac{G(\mathbf{P_{it}}, K_{it}, \mathbf{Q_{it}})}{Q_{it}^R} dQ_{it}^R - \epsilon_{it}$.

In this paper, we identify $F\left(\mathbf{P_{it}}, K_{it}, \mathbf{Q_{it}}\right)$ by putting a structural assumption on the evolution of the productivity. Specifically, we assume that ω_{it} follows an exogenous first-order Markov process. Under the assumption of the first-order Markov process, the current productivity can be written as the sum of the expected productivity conditional on the productivity at $t-1$ ($\mathbb{E}\left[\omega_{it}|\omega_{it-1}\right]$) and unexpected productivity shock at t (ξ_{it}). That is,

$$\omega_{it} = \mathbb{E}\left[\omega_{it}|\omega_{it-1}\right] + \xi_{it} = \mathrm{g}\left(\omega_{it-1}\right) + \xi_{it} \tag{9}$$

The Markov process in (9) nests more traditional approaches such as OLS and fixed effect, where the productivity process is given by $\mathrm{g}\left(\omega_{it-1}\right) = 0$ and $\mathrm{g}\left(\omega_{it-1}\right) = \omega_i$, respectively, and ξ_{it} is an i.i.d. in both cases (Loecker (2013)). Equation (9) can be written as

$$-\Psi_{it} - \Upsilon\left(\mathbf{P_{it}}, K_{it}, Q_{it}^C\right) = \mathrm{g}\left(-\Psi_{it-1} - \Upsilon\left(\mathbf{P_{it-1}}, K_{it-1}, Q_{it-1}^C\right)\right) + \xi_{it} \tag{10}$$

By the construction of the Markov process, the error term ξ_{it} is uncorrelated with any lagged variables in $\mathrm{g}\left(\cdot\right)$. Furthermore, using the standard assumption that the firm's productivity does not affect prices in input markets and capital stock is made by decisions in the past, either current or previous variables can be used to form the moment conditions associated with $\left(\mathbf{P_{it}}, K_{it}\right)$. We use the moment conditions $\mathbb{E}[\xi_{it}|\mathbf{P_{it}}, K_{it}, Q_{it-1}^C] = 0$ to identify the coefficients in (10). Since we can recover $\Upsilon\left(\mathbf{P_{it}}, K_{it}, Q_{it}^C\right)$ by nonparametrically estimating (10), the productivity can also be calculated from (8) using the coefficient estimates.

Estimation

The model is estimated in two steps. In the first step, we obtain the estimates for the residential price-cost margin (λ_d) and the residential output elasticity of cost ($G(\cdot)$) by estimating the share equation in (6). In the second step, we proceed to estimate the Markov process in (10) to recover the coefficients for the constant of integration which allows us to calculate the elasticities for the other variables and compute the productivity estimates.

We specify a translog for $G(\mathbf{P_{it}}, K_{it}, \mathbf{Q_{it}})$ in (6). We have

$$
\begin{aligned}
G(\mathbf{P_{it}}, K_{it}, \mathbf{Q_{it}}) = {} & \alpha_0 + \alpha_1 \tilde{p}_{it}^p + \alpha_2 k_{it} + \alpha_3 q_{it}^c + \alpha_4 q_{it}^r + \alpha_5 \tilde{p}_{it}^{p2} + \alpha_6 k_{it}^2 + \alpha_7 q_{it}^{c2} + \alpha_8 q_{it}^{r2} \\
& + \alpha_9 \tilde{p}_{it}^p k_{it} + \alpha_{10} \tilde{p}_{it}^p q_{it}^c + \alpha_{11} \tilde{p}_{it}^p q_{it}^r + \alpha_{12} k_{it} q_{it}^c + \alpha_{13} k_{it} q_{it}^r + \alpha_{14} q_{it}^c q_{it}^r
\end{aligned} \tag{11}
$$

where the small-case letters refer to the logs of the corresponding variables. By the duality theory, the cost function is homogeneous of degree one in input prices. This is imposed by normalizing the purchased power price (P_{it}^P) and the cost (C_{it}) by hourly wage (P_{it}^L), the logs of which are represented by $\tilde{p}_{it}^p$ and $\tilde{c}_{it}$, respectively. Using the specification in (11), the nonlinear regression of (6) allows us to obtain the estimates for the residential price-cost margin and the residential output elasticity of cost.

We use the first stage estimates to calculate $\hat{\Psi}_{it} \equiv \ln \tilde{C}_{it} - \int \frac{\hat{G}(\mathbf{P_{it}}, K_{it}, \mathbf{Q_{it}})}{Q_{it}^R} dQ_{it}^R + \hat{\epsilon}_{it}$, which is the left-hand side in (8). A benefit of the translog specification is we have a closed form expression for the integration. Specifically,

$$
\begin{aligned}
& \int \frac{\hat{G}(\mathbf{P_{it}}, K_{it}, \mathbf{Q_{it}})}{Q_{it}^R} dQ_{it}^R = \\
& \left(\alpha_0 + \alpha_1 \tilde{p}_{it}^p + \alpha_2 k_{it} + \alpha_3 q_{it}^c + \alpha_5 \tilde{p}_{it}^{p2} + \alpha_6 k_{it}^2 + \alpha_7 q_{it}^{c2} + \alpha_9 \tilde{p}_{it}^p k_{it} + \alpha_{10} \tilde{p}_{it}^p q_{it}^c + \alpha_{12} k_{it} q_{it}^c \right) \ln q_{it}^r \\
& + \left(\alpha_4 + \alpha_{11} \tilde{p}_{it}^p + \alpha_{13} k_{it} + \alpha_{14} q_{it}^c \right) q_{it}^r \\
& + \left(\alpha_8 q_{it}^r \right) q_{it}^r
\end{aligned} \tag{12}
$$

In the second step, we use the moment conditions $\mathbb{E}[\xi_{it}|\mathbf{P_{it}}, K_{it}, Q_{it-1}^C] = 0$ to recover the constant of integration in (10) where we specify the constant of integration as

$$
\Upsilon(\mathbf{P_{it}}, K_{it}, Q_{it}^C) = \beta_1 \tilde{p}_{it}^p + \beta_2 k_{it} + \beta_3 q_{it}^c \tag{13}
$$

Since $\omega_{it} = -\Psi_{it} - \Upsilon(\mathbf{P_{it}}, K_{it}, Q_{it}^c)$, by running a regression of (10) we can obtain the parameters for the constant of integration specified in (13) and the estimates for the productivity using the moment conditions. Finally, the elasticities for $\tilde{p}_{it}^p$, k_{it}, and q_{it}^c are calculated as

$$
\frac{\partial F(\cdot)}{\partial P_{it}^P} \frac{P_{it}^P}{F(\cdot)} = (\alpha_1 + 2\alpha_5 \tilde{p}_{it}^p + \alpha_9 k_{it} + \alpha_{10} q_{it}^c) \ln q_{it}^r + \alpha_{11} q_{it}^r - \beta_1 \tag{14}
$$

$$
\frac{\partial F(\cdot)}{\partial K_{it}} \frac{K_{it}}{F(\cdot)} = (\alpha_2 + 2\alpha_6 k_{it} + \alpha_9 \tilde{p}_{it}^p + \alpha_{12} q_{it}^c) \ln q_{it}^r + \alpha_{13} q_{it}^r - \beta_2 \tag{15}
$$

$$
\frac{\partial F(\cdot)}{\partial Q_{it}^c} \frac{Q_{it}^c}{F(\cdot)} = (\alpha_3 + 2\alpha_7 q_{it}^c + \alpha_{10} \tilde{p}_{it}^p + \alpha_{12} k_{it}) \ln q_{it}^r + \alpha_{14} q_{it}^r - \beta_3 \tag{16}
$$

Results

For comparison, we start this section with the OLS regressions of the log of the cost function in (3) and the share equation in (6). We then proceed to discuss the results of the two step estimation.

Table 3 presents the results of the OLS regressions. The column (1) to (3) show the regression results of the residential electricity revenue share equation in (6) using different fixed effects specifications. The coefficient estimates are consistent across the specifications, except the one for the power purchases price. For example, in the column (3) where we employ state-year fixed effects, we find that member cooperatives have residential price-cost margin that is higher by 8% compared with non-member cooperatives. 1% increase in power purchases price decreases the share of residential revenue in total cost by 0.39%, while 1% increase in the transmission and distribution miles decreases the residential revenue share by 0.13% holding others constant. Kilowatt hours of residential output is positively associated with the residential revenue share with the elasticity of 0.54, while that of commercial output is negatively associated with the residential revenue share with the elasticity of 0.35.

In the column (4) to (6), we estimate the log of the cost function in (3) with different sets of fixed effects. If the fixed effects well controlled for the simultaneity of the unobserved productivity, the member cooperatives dummy in the cost function could be interpreted as difference in the fixed cost of operation between non-member and member cooperatives. For example, in the column (6) where we use state-year fixed effects, the coefficient for the member cooperatives dummy is statistically significant with the magnitude of -0.06. It means that the member cooperatives have lower fixed costs of operation by 6% which corresponds to about $ 2 million at the sample mean. The estimates for power purchases price and total miles show the elasticity of 0.63 and 0.19, respectively. Also, 1% increase in residential and commercial electricity increases the cost of operation by 0.39% and 0.34%, respectively. As discussed, however, we expect that the coefficients for residential and commercial output would be underestimated as far as the fixed effects do not control for the simultaneity between the outputs and the cost, in the way that the productivity is likely be positively correlated with the outputs but negatively correlated with the cost. In other words, the coefficients are underestimated if higher productivity firms produce more outputs given level of inputs, and incur lower cost of operation holding input prices and outputs constant, than lower productivity firms.

Table 4 presents the result of the first stage estimation, i.e., the residential share regression of (6) where the functional form is specified as translog in (11). We find the coefficient for the member cooperatives dummy (λ_{it}) is 0.06 and significant at 5%, implying that the residential price-cost margin is higher in member cooperatives by 6% compared with non-member cooperatives. The higher price-cost margin could arise from lower marginal cost of operation given level of the residential price, or from higher residential price given level of the marginal cost. Since we found the residential electricity prices were not statistically different across the groups in Table 2, we expect the marginal cost of operation would be lower in the member cooperatives than the non-member cooperatives. We investigate this

further below.

The parameter estimates in Table 4 are used to calculate the residential output elasticity of cost $G\left(\mathbf{P_{it}}, K_{it}, Q_{it}^C\right)$ in (11), and the marginal cost of residential distribution as $MC_{it}^R = G\left(\cdot\right) \frac{C_{it}}{Q_{it}^R}$, which are computed at the firm-level and presented in Table 5. The first column in Table 5 shows the estimates with the bootstrap standard error in the parentheses. The second and third column show the means of the estimates for non-member and member cooperatives, respectively, with the standard deviations in the parentheses. The last column tests the null that the mean of the estimates is equal across the non-member and member cooperatives with the standard error of the difference in the parentheses. We find the residential output elasticity of cost is 0.69, and is not different across the non-member and member cooperatives. The elasticity estimate is substantially greater than those in the OLS regression in Table 3. We also find that the marginal cost of residential electricity distribution is lower for member cooperatives by \$0.004/kwh at the mean, suggesting that there exist some extent of the marginal cost savings from the ownership of G&T by distribution cooperatives. This is consistent with Table 2, which shows that member cooperatives have lower average cost of operation, and have less amount of excess electricity purchased than sold. For the member cooperatives, the marginal cost savings could come from the cost complementarity between G&T and distribution, technological interdependence, or reduced transaction and information costs.

Table 6 provides the result of the second stage estimation, i.e., the estimates for the constant of integration in (13), and Table 7 presents the elasticity estimates for the rest of the cost function variables in (14) to (16). Table 7 also provides the productivity estimates in (8). The results show that the elasticities of cost are 0.38, 0.80, and 0.70 with respect to power purchases price, transmission and distribution miles, and commercial output, respectively. As with the residential output elasticity of cost estimates, the estimates for the commercial output elasticity of cost also significantly increases compared with those in the OLS regression. We find the productivity difference at the mean between non-members and members is 0.04 and statistically significant at 10%, implying that holding other variables constant, member cooperatives have the cost of operation that is lower by 4%, which corresponds to about \$1.4 million at the sample mean.

Finally, in Table 8 we regress the marginal cost estimates (MC_{it}^R) on the member cooperatives dummy (λ_{it}), the productivity estimates (ω_{it}), and other cost function variables. For the robustness, Column (1) to (3) provide the results using different sets of fixed effects. Controlling for the unobserved productivity, we find that the member cooperatives have the marginal cost of residential electricity operation that is lower by \$0.007 to \$0.003/kwh, while one unit increase in the productivity reduces the marginal cost by \$0.004 to \$0.002/kwh.

Conclusion

This paper investigates price-cost margin and productivity of electric distribution cooperatives, and estimate marginal cost savings from ownership of G&T by distribution coopera-

tives. We develop a model of cost minimization where the model allows us to recover the estimates for price-cost margin and unobserved productivity of electric distribution cooperatives. We compare the estimates across the member and non-member cooperatives.

Using the data of electric distribution cooperatives provided by USDA's Rural Utilities Services from 2006 to 2011, we estimate the cost function in the two step. The results show that the residential price-cost margin for the member cooperatives is higher by 6% than that for the non-member cooperatives. While we do not find differences in the residential electricity price across the groups, we find the higher margin for the member cooperatives are gained from the marginal cost savings of residential electricity operation, suggesting that there exist some extent of cost savings from the ownership of G&T by distribution cooperatives. The results also support that the member cooperatives have productivity that is higher by 4%, which corresponds to the cost of operation lowered by $1.4 million at the sample mean, holding other variables constant.

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Table 1: Financial statistics of electric distribution cooperatives

	Non-member	Member	Integrated	t-test
Total assets and other debits (mil)	91	84	68	6.87*
	(109)	(90)	(95)	(3.73)
Patronage capital (mil)	22	28	12	-6.12**
	(46)	(31)	(14)	(1.40)
Total margins and equities (mil)	39	33	17	6.44**
	(56)	(34)	(18)	(1.60)
Total long-term debt (mil)	36	39	39	-3.55*
	(46)	(46)	(67)	(1.82)
Capital credits retirements (mil)	0.61	0.67	0.43	-0.06
	(2.50)	(1.16)	(0.81)	(0.06)
Interest on long-term debt (mil)	1.82	1.98	1.73	-0.16*
	(2.32)	(2.39)	(3.20)	(0.009)
Patronage capital or margins - this year (mil)	2.85	2.54	1.83	0.31*
	(5.77)	(3.21)	(3.18)	(0.16)
Share of long-term debt in total assets	0.40	0.45	0.43	-0.05**
	(0.17)	(0.12)	(0.17)	(0.005)
Share of equities in total assets	0.45	0.42	0.35	0.03**
	(0.16)	(0.12)	(0.16)	(0.005)
Ratio of retirements to equities	0.014	0.020	0.012	-0.005**
	(0.01)	(0.02)	(0.02)	(0.0007)
Ratio of interests to long-term debts	0.056	0.050	0.045	0.005**
	(0.13)	(0.02)	(0.01)	(0.002)
Ratio of annual margins to total assets	0.030	0.032	0.024	-0.002**
	(0.022)	(0.020)	(0.023)	(0.0008)
Weighted average of retirements and interests	0.026	0.031	0.024	-0.004**
	(0.012)	(0.010)	(0.011)	(0.0004)
Number of Firms	167	448	8	
Number of Observations	867	2568	44	

Notes: The first three columns show the mean with the standard deviations in the parentheses. The last column shows the difference of the non-member and member cooperatives in the mean with the standard error of the difference.
** Significant at 5 percent or stricter
* Significant at 10 percent

Table 2: Electric operation statistics of electric distribution cooperatives

	Non-member	Member	Integrated	t-test
Commercial kwh (mil)	212	182	50	30*
	(322)	(491)	(95)	(17)
Commercial revenue ($ mil)	18	13	17	4.9**
	(27)	(23)	(33)	(0.9)
Residential kwh (mil)	322	248	30	73**
	(457)	(327)	(53)	(14)
Residential revenue ($ mil)	31	25	11	6.4**
	(47)	(33)	(19)	(1.4)
Total kwh sold (mil)	556	446	86	110**
	(760)	(686)	(148)	(27)
Total revenue ($ mil)	53	40	31	12**
	(75)	(52)	(53)	(2.3)
Total kwh purchased or generated (mil)	584	469	88.9	115**
	(796)	(704)	(154)	(28.5)
Cost of purchases or generation ($ mil)	36	27	19	9.1**
	(56)	(39)	(31)	(1.7)
Employee hours worked (mil)	0.16	0.13	0.09	0.028**
	(0.16)	(0.12)	(0.11)	(0.005)
Total payroll ($ mil)	4.54	3.70	4.48	0.8**
	(4.91)	(3.63)	(6.75)	(0.1)
Total cost ($ mil)	45	34	23	10**
	(66)	(46)	(38)	(2)
Total miles	3117	3125	310	-8.9
	(2541)	(2041)	(465)	(85)
Commercial price ($/kwh)	0.09	0.08	0.4	0.009**
	(0.03)	(0.02)	(0.08)	(0.001)
Residential price ($/kwh)	0.1	0.1	0.4	0.001
	(0.04)	(0.01)	(0.09)	(0.001)
Commercial share of Total kwh	0.33	0.34	0.52	-0.01**
	(0.15)	(0.18)	(0.15)	(0.006)
Residential share of Total kwh	0.58	0.59	0.35	-0.01*
	(0.19)	(0.20)	(0.08)	(0.007)
Ratio of total kwh generated or purchased to sold	1.07	1.06	1.09	0.008**
	(0.08)	(0.02)	(0.19)	(0.001)
Ratio of total revenue to cost	1.23	1.20	1.30	0.02**
	(0.11)	(0.08)	(0.22)	(0.003)
Hourly wage ($/hour)	27.93	27.22	36.04	0.70**
	(5.66)	(4.54)	(11.28)	(0.19)
Power purchases price ($/kwh)	0.059	0.056	0.22	0.002
	(0.08)	(0.01)	(0.07)	(0.001)
Average cost ($/kwh)	0.084	0.081	0.33	0.002**
	(0.03)	(0.01)	(0.08)	(0.0009)
Number of Firms	167	448	8	
Number of Observations	867	2568	44	

Notes: The first three columns show the mean with the standard deviations in the parentheses. The last column shows the difference of the non-member and member cooperatives in the mean with the standard error of the difference.

** Significant at 5 percent or stricter

* Significant at 10 percent

Table 3: OLS regression

Coefficient on	Residential share			Total cost		
	(1)	(2)	(3)	(4)	(5)	(6)
Member coop	0.07**	0.08**	0.08**	-0.08**	-0.06**	-0.06**
	(0.008)	(0.01)	(0.01)	(0.008)	(0.01)	(0.01)
Power purchases price	-0.10**	-0.34**	-0.39**	0.75**	0.61**	0.63**
	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)
Total miles	-0.12**	-0.13**	-0.13**	0.16**	0.19**	0.19**
	(0.008)	(0.009)	(0.009)	(0.008)	(0.008)	(0.008)
Residential kwh	0.49**	0.54**	0.54**	0.43**	0.39**	0.39**
	(0.005)	(0.007)	(0.007)	(0.005)	(0.005)	(0.006)
Commercial kwh	-0.37**	-0.35**	-0.35**	0.35**	0.34**	0.34**
	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)
Constant	-0.99**	1.65**	1.80**	2.70**	3.14**	3.10**
	(0.04)	(0.05)	(0.06)	(0.04)	(0.04)	(0.05)
Year Fixed Effects	No	Yes	No	No	Yes	No
State Fixed Effects	No	Yes	No	No	Yes	No
State-Year Fixed Effects	No	No	Yes	No	No	Yes
Adjusted R^2	0.78	0.82	0.82	0.96	0.97	0.97
Number of observations	3419	3419	3419	3419	3419	3419

Notes: Standard errors are in parentheses.

** Significant at 5 percent or stricter

* Significant at 10 percent

Table 4: The first stage regression results

Member coop	0.06**
	(0.007)
Power purchase price ($\tilde{p}_{it}^{p}$)	0.10*
	(0.06)
Total miles (k_{it})	-0.33**
	(0.04)
Residential kwh (q_{it}^{r})	0.09**
	(0.02)
Commercial kwh (q_{it}^{c})	0.05**
	(0.01)
$\tilde{p}_{it}^{p2}$	0.02**
	(0.006)
k_{it}^{2}	-0.02**
	(0.003)
q_{it}^{r2}	0.02**
	(0.001)
q_{it}^{c2}	0.01**
	(0.0007)
$\tilde{p}_{it}^{p}k_{it}$	-0.01**
	(0.006)
$\tilde{p}_{it}^{p}q_{it}^{r}$	-0.02**
	(0.004)
$\tilde{p}_{it}^{p}q_{it}^{c}$	0.01**
	(0.003)
$k_{it}q_{it}^{r}$	0.04**
	(0.005)
$k_{it}q_{it}^{c}$	0.01**
	(0.001)
$q_{it}^{r}q_{it}^{c}$	-0.05**
	(0.001)
Constant	0.93**
	(0.18)
Adjusted R^2	0.91
Number of observations	3419

Notes: Standard errors are in parentheses.
** Significant at 5 percent or stricter
* Significant at 10 percent

Table 5: The residential output elasticity of cost and marginal cost estimates

	All	Non-member	Member	t-test
Elasticity	0.69**	0.70	0.69	0.006
	(0.003)	(0.21)	(0.21)	(0.008)
Marginal cost ($/kWh)	0.09**	0.10	0.09	0.004**
	(0.0004)	(0.3)	(0.02)	(0.001)
Residential price-cost margin	1.07**	1.03	1.09	-0.05**
	(0.003)	(0.20)	(0.15)	(0.006)
Number of observations	3419	857	2562	

Notes: The first column shows the estimate for the cost elasticity of residential output with the bootstrap standard error in the parentheses. The second and third columns show the mean of the elasticity in each group with the standard deviations in the parentheses. The last column shows the difference of the non-member and member cooperatives in the mean with the standard error of the difference in the parentheses.

** Significant at 5 percent or stricter

* Significant at 10 percent

Table 6: The second stage regression results

Power purchases price	-0.10 (0.21)
Total miles	-1.69 (1.23)
Commercial kwh	-0.26 (0.167)
Number of observations	2826

Notes: Standard errors are in parentheses. The number of observations decreases to 2826 because we needed lagged values of Q_{it}^C as the instrument in estimation. This rules out some observations that are not in two consecutive years.
** Significant at 5 percent or stricter
* Significant at 10 percent

Table 7: The elasticities for the rest of the variables and the productivity estimates

	All	Non-member	Member	t-test
Power purchases price elasticity	0.38**	0.37	0.38	-0.006**
	(0.001)	(0.08)	(0.05)	(0.002)
Total miles elasticity	0.80**	0.81	0.80	0.01**
	(0.001)	(0.06)	(0.05)	(0.002)
Commercial kwh elasticity	0.70**	0.70	0.70	-0.004
	(0.001)	(0.10)	(0.07)	(0.003)
Productivity	1.14**	1.10	1.15	-0.04*
	(0.01)	(0.87)	(0.57)	(0.02)
Number of observations	3419	857	2562	

Notes: The first column shows the estimate for the productivity with the bootstrap standard error in the parentheses. The second and third columns show the mean of the productivity estimates in each group with the standard deviations in the parentheses. The last column shows the difference of the non-member and member cooperatives in the mean with the standard error of the difference in the parentheses.

** Significant at 5 percent or stricter

* Significant at 10 percent

Table 8: The marginal cost regression

Coefficient on	Dependent variable: MC_{it}^R		
	(1)	(2)	(3)
Member coop	-0.007**	-0.003**	-0.003**
	(0.0009)	(0.001)	(0.001)
Productivity	-0.004**	-0.003**	-0.002**
	(0.0008)	(0.0007)	(0.0008)
Power purchases price	0.03**	0.01**	0.009**
	(0.001)	(0.001)	(0.001)
Total miles	0.006**	0.01**	0.01**
	(0.001)	(0.0009)	(0.0009)
Residential kwh	-0.009**	-0.01**	-0.01**
	(0.0007)	(0.0007)	(0.0008)
Commercial kwh	-0.001**	-0.002**	-0.002**
	(0.0004)	(0.0004)	(0.0004)
Constant	0.16**	0.16**	0.18**
	(0.005)	(0.005)	(0.005)
Year Fixed Effects	No	Yes	No
State Fixed Effects	No	Yes	No
State-Year Fixed Effects	No	No	Yes
Number of observations	3419	3419	3419
Adjusted R^2	0.22	0.51	0.49

Note: Standard errors are in parentheses.
** Significant at 5 percent or stricter
* Significant at 10 percent