REGULATION, OWNERSHIP FORM, AND THE ECONOMIC EFFICIENCY OF RURAL ELECTRIC DISTRIBUTION COOPERATIVES

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Abstract–This paper uses a translog profit function to analyze economic efficiency in rural electric distribution cooperatives for the period 1974-1982. Hypotheses dealing with absolute price efficiency, the effect of capital on profit and the effect of service area density on profit are tested. The paper uses a translog profit function analysis with both fixed and variable inputs to test the various hypotheses. Regulatory intensity variables are developed and used to examine the effect of regulation on technical efficiency. The results indicate that cooperatives are not profit maximizers, regulation has a negligible effect on technical efficiency, capital positively affects profit, and increasing service area density positively affects profit.

I. INTRODUCTION

The theory of the privately owned not-for-profit firm (the cooperative) has been extensively examined in the literature on agricultural cooperatives, credit unions, and various types of labor-managed cooperatives. Relatively little empirical work, however, has been performed to evaluate the distribution cooperative. In this country, rural electric distribution cooperatives (hereafter, RECs) have been studied by Mikesell and Mann (1976) and Neuberg (1977), and rural telephone cooperatives have been analyzed by Stansell (1980).

Studies by Dahlman (1979), DeAlessi (1974, 1975, 1983), Demsetz (1964, 1966, 1967), and Furbotn and Pejovich (1972) suggest that the different structures of property rights result in cost-reward distributions which systematically affect economic outcomes. The literature also suggests that the effects of regulation on economic efficiency depend on the structure of property rights.

It has been hypothesized that publicly owned firms differ substantially from privately owned firms in terms of economic efficiency. Jensen and Meckling (1976) developed a theory of agency in which the costs of monitoring and bonding play an essential role. They noted the importance of both the system of property rights and the firm's internal organization in a subsequent article (1979).

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The theory suggests that the owners of public firms have reduced incentives to enforce contracts and develop internal controls. Public firms differ from private firms in terms of economic behavior because of reduced opportunities to specialize in ownership and, hence, risk, and their inability to capitalize future events into the value of the firm. Property rights in publicly owned firms are in fact virtually nontransferable. Finally, no one has a right to claim the residual in a public firm. These same defects may exist in the cooperative.

The purpose of this study is to perform an empirical analysis of the economic efficiency of RECs. We analyzed a sample of over 900 RECs for the period 1974-1982. The productive efficiency of RECs affects a large number of consumers. As of the end of 1982, over eight million patron/owners were served by RECs. These cooperatives serviced 1,869,691 route miles of line in 46 states, Puerto Rico and the Virgin Islands. We used the literature on property rights and agency to examine the economic efficiency of RECs. The second section of the paper develops the methodology which employs a system of translog profit and input demand equations. The data and the construction of a measure of regulatory stringency are presented next. Finally, the results of the hypothesis tests are discussed.

II. DEVELOPMENT OF THE PROFIT FUNCTION

Economic, Price and Technical Efficiency

Numerous studies have examined the productivity of the firm using various specifications of the production function. The profit function employed in this study allows the same tests possible with a production function and, in addition, allows tests of price efficiency. The development of the profit function is due in part to the work of Shephard (1953, 1970), McFadden (1962), Uzawa (1964), and Diewert (1973) and early empirical studies by Lau and Yotopoulos (1971, 1972), and Yotopoulos and Lau (1973). More recent studies by Atkinson and Halvorsen (1980), Hollas and Stansell (1988 a, 1988 b) and Stansell and Hollas (1988, 1990) have employed the profit function to analyze economic efficiency. Through these types of studies we are able to analyze economic efficiency in a much broader sense.

Price efficiency can be categorized as relative price efficiency and absolute price efficiency. This study tests for absolute price efficiency, which occurs when the value of the marginal product of each factor is equated to its factor price. Absolute price efficiency implies profit maximization. Cost minimization is a necessary precondition for absolute price efficiency.

Given exogenously determined output prices, variable input prices, and fixed factors of production, one can obtain consistent estimates of the price and technical efficiency parameters by estimating the profit function. According to the duality theorems, an appropriate arbitrary functional form for the profit function corresponds to a concave production function. As Lau (1978) notes, the arbitrary profit function must be decreasing and convex in input prices and increasing in output prices.

For convenience, let E^1 denote the economic efficiency of regulated firms and E^2 denote the economic efficiency of nonregulated firms. Conceptually, we test whether $E^1 = E^2$. Note that E is a function of both price efficiency k and technical efficiency T. If $T^1 = T^2$ and $k^1 = k^2$, then $E^1 = E^2$.

Differences in either technical or price efficiency may cause $E^1 \neq E^2$. We assume the $k^1 = k^2 = k^1$ for all firms. If the technological level of regulated firms is denoted T^1 and unregulated firms is T^2 then we actually test whether:

$$H_o: T^1 = T^2$$

$$H_a: T^1 \neq T^2$$

In the following section we specify a model for the purpose of evaluating the economic efficiency of RECs.

Formulation of the Translog Profit Function

The model developed in this section will allow a test of absolute price efficiency for cooperative electric distribution utilities. A two-equation system for normalized profit and labor demand is derived to perform the efficiency tests. Additional tests for regulatory effects upon profits will be presented later. Development of the theoretical model follows Lau and Yotopoulos (1971, 1972), and Yotopoulos and Lau (1973), while derivation of the translog model generally follows the contribution of Atkinson and Halvorsen (1980).

Actual normalized profit and actual input demand functions can be derived once an appropriate behavioral profit function is selected. We employ a modified translog functional form for the behavioral normalized profit function. Like Lau and Yotopoulos (1971, 1972), and Yotopoulos and Lau (1973), we treat capital as fixed in the short-run profit function. Behavioral profit is

$$\ln\Pi^{b} = \alpha_O + \alpha_L\, ln(k_L P_L) + \beta_k\, ln(K) + \beta_D\, ln(D) + \sum_i \beta_i\, ln(R_i) + \frac{1}{2}\gamma_{LL}\, ln(k_L P_L)^2 + \frac{1}{2}\beta_{kk}\, ln(K)^2 + \gamma_{LK}\, ln(k_L P_L)\, ln(K) + \sum_i \gamma_{Li}\, ln(k_L P_L)\, ln(R_i) + \sum_i \beta_{Ki}\, ln(K)\, ln(R_i) + \frac{1}{2}\sum_i \sum_g \beta_{ig}\, ln(R_i)\, ln(R_g), \quad [1]$$

where P_L is the price of labor, K is fixed capital, D is service area density, the R_i are regulatory variables, k_L represents a systematic rule of behavior for which profit maximization is one case (k_L=1) , $\beta_{ig} = \beta_{gi}$, and i,g = 1,2.

Actual profit is

$$\ln\Pi^{a} = ln[1 + \frac{(1-k_L)}{k_L}(\alpha_L + \gamma_{LL}\, ln(k_L P_L) + \gamma_{LK}\, ln(K) + \sum_i \gamma_{Li}\, ln(R_i))] + \alpha_O + \alpha_L\, ln(k_L P_L) + \beta_k\, ln(K) + \beta_D\, ln(D) + \sum_i \beta_i\, ln(R_i) + \frac{1}{2}\gamma_{LL}\, ln(k_L P_L)^2 + \frac{1}{2}\beta_{KK}\, ln(K)^2 + \gamma_{LK}\, ln(k_L P_L)\, ln(K) + \sum_i \gamma_{Li}\, ln(k_L P_L)\, ln(R_i) + \sum_i \beta_{Ki}\, ln(K)\, ln(R_i) + \frac{1}{2}\sum_i \sum_g \beta_{ig}\, ln(R_i)\, ln(R_g), \quad [2]$$

If $k_L = 1$, the actual and behavioral normalized profit functions are identical. This implies $VMP_L = k_L P'_L$, where VMP_L is the value of marginal product, and P'_L is the non-normalized dollar price of labor. If $k_L < 1$, input L is overutilized relative to the profit maximizing level.

Factor demand for labor is expressed as the ratio of normalized expenditure on the factor to actual normalized profit,

$$l_L = \frac{P_L X_L}{\Pi_a}$$

which is,

$$l_L = -k_L^{-1}\left[\alpha_L + \gamma_{LL}\, ln(k_L P_L) + \gamma_{LK}\, ln(K) + \sum_i \gamma_{Li}\, ln(R_i)\right]$$
$$[1 + \left(\frac{1-k_L}{K_L}\right)(\alpha_L + \gamma_{LL}\ln(k_L P_L) + \gamma_{LK}\ln(K) \qquad [3]$$
$$+ \sum_i \gamma_{Li}\ln(R_i))]^{-1}.$$

Equation (2) for normalized profit and the labor input demand equation (3) comprise the system to be estimated. Note that the system of two equations, actual normalized profit (2), and the input demand equation for labor (3), is derived for normalized profit.

A normalized profit function is assumed to be strictly decreasing and convex in the normalized prices. The second derivative of the normalized profit function with respect to the wage must be positive to meet the convexity assumption. The fitted values of the ratio of normalized expenditure on the factor to actual normalized profit must be positive for monotonicity. For a discussion, see Lau (1978).

III. THE DATA

Data on the financial and operating statistics of the RECs examined in this study were obtained from the Rural Electrification Administration (REA). The data set covers the time span from 1974 through 1982. Because all RECs are required to use a standardized accounting and reporting system by the REA, the data are believed to be highly comparable and internally consistent.

Profit (π) is calculated by subtracting maintenance and operating expenses (other than cost of purchased power) from operating revenue. Because the cost of purchased power is set under long-term contracts, it is a fixed expense and is not deducted. Therefore, our measure of profits is operating revenue minus variable costs. Output price is calculated by dividing operating revenues by KWH sold. The price of labor (P_L) is calculated by dividing total payroll by total hours worked. The amount of capital (K) is equal to the dollar value of net utility plant. Density (D) is measured by consumers per mile of distribution line. The profit function is normalized by the output price. Descriptive statistics for the data are available on request.

The regulatory data used in this study were obtained from the *Annual Report on Utility and Carrier Regulation*, 1974-1982, published by the National Association of Regulatory Utility Commissioners. The primary regulatory data set consists of 46 state-level variables covering an extensive range of regulatory information.

Construction of the Regulatory Variables

In order to reduce the number of variables and yet capture as much of the regulatory information as possible, a cross-sectional principal components analysis was conducted using the natural log of profits as the dependent variable,

$$\ln(\Pi) = a_1 X_1 + ... a_{46} X_{46}$$

where Π = profit and X_i = the 46 regulatory variables. This technique was employed by Hollas and Stansell (1988).[1] The variables include data on rates and rate changes, fuel adjustment clauses, rate base valuation, number of commissioners and compensation, the Duff-Phelps rating, commissioner selection method and term, and depreciation method. Detailed information is available on request.

The first two principal components from each of the separate principal components analyses are then used to construct two regulatory variables which are then used in the profit function analysis for each of the nine years. Approximately 30 percent to 40 percent of the total variation in profits is explained each year by the first two principal components. This procedure allows the model to capture an extensive amount of regulatory climate information in the form of two variables. Since RECs are regulated in some states but not in others, we constructed a "zero-one" dummy variable which has a value of one if regulation exists in that state and zero if it does not, and multiplied it by the first and second principal components. If RECs are not regulated in a given state, the two principal components are multiplied by zero and have a product of zero for that state for that year. If RECs are regulated, the two principal components are multiplied by one. The products are two separate variables, referred to hereafter as *Zl* and *Z2*, which reflect whether or not RECs are regulated in a given state and, if regulated, reflect in a continuous fashion much of the information in the full 46 variable regulatory data set. Because the regulatory variables *Zl* and *Z2* can be positive, zero, or negative, we enter these variables into the profit function equation (2) as $R_1 = e^{Z1}$ and $R_2 = e^{Z2}$, respectively.

Regional Aspects of REC Operations

The regional impact of RECs varies widely. Several states (Connecticut, Hawaii, Massachusetts, and Rhode Island) have none. In states such as Georgia, Tennessee, and Texas, the number of customers served is quite large. As indicated in Table 1, from 1974 to 1982 the number of customers served in the United States increased by 30.4 percent, from 7,431,432 to 9,687,382. Since miles of line energized increased by 13.4 percent from 1,760,842 to 1,997,068, we may conclude that the increase is attributable to increasing population density rather than increasing service area. From Table 1, the number of RECs increased 5 percent from 981 in 1974 to 986 in 1982. While RECs provide service nationwide, they primarily serve the Southeast, Southwest, and some states in the Midwest and Rocky Mountain regions. Given the rural nature of their service areas, this distribution is to be expected.

The analysis conducted in this study is performed on a cross-sectional national sample for each year from 1974 through 1982. There is no way to infer from the results anything on a regional or state basis other than that if RECs serve a large number of customers in a given area, anything that affects RECs will affect that area.

In Table 2, descriptive data on the number of utilities by state (segregated into public, private, and cooperatives and the regulatory status) are presented for the years 1974 and 1982. In 1982, approximately half of the states did not regulate or control rates on cooperatives.

IV. RESULTS OF THE EMPIRICAL TESTS

The unconstrained model as specified in Equations (2) and (3) was estimated using cross-sectional data for the years 1974 through 1982. Estimates of the coefficients for the unconstrained model are reported in Table 3.

Virtually every fitted observation met convexity and monotonicity requirements between 1975 and 1982. In 1974, when the industry apparently was in disequilibrium–possibly due to the oil embargo–very few observations passed the convexity requirements. Also, the fitted values of the labor demand function were evaluated using the monotonicity test. Again, except for 1974, virtually every value passed the monotonicity requirement.

Constraints were imposed on the model to allow tests for absolute price efficiency, regulatory effects, the effect of service area density, and the effect of fixed capital on profits. The hypotheses and model restrictions are specified below.

TABLE 1
REC Data By State, 1974, 1982

State	Number of Active Borrowers		Number of Full-Time Employees		Miles of Line Energized		Consumers Served	
	1974	1982	1974	1982	1974	1982	1974	1982
UNITED STATES	981	986	42,908	55,258	1,760,842	1,997,068	7,431,432	9,687,382
Alabama	24	24	1,440	1,656	47,112	52,557	292,160	352,036
Alaska	13	15	594	835	5,559	7,829	65,449	117,072
Arizona	10	11	387	924	8,319	13,721	49,787	97,598
Arkansas	20	20	1,270	1,404	50,175	56,483	220,001	274,631
California	5	5	58	100	3,343	3,664	43,698	32,850
Colorado	24	24	1,195	2,733	44,733	55,687	152,095	249,876
Connecticut	0	0	0	0	0	0	0	0
Delaware	1	1	102	91	2,788	3,225	23,769	31,671
Florida	15	16	1,698	2,295	36,618	43,974	268,219	423,089
Georgia	42	44	2,413	3,354	2,525	101,590	502,902	720,030
Hawaii	0	0	0	0	0	0	0	0
Idaho	9	9	195	245	9,175	10,843	29,294	40,913
Illinois	29	29	1,134	1,210	50,251	52,925	174,259	204,417
Indiana	42	43	1,236	1,540	44,497	49,060	258,672	331,472
Iowa	53	52	1,326	1,246	61,151	64,168	156,192	172,089
Kansas	37	36	824	1,237	60,753	68,864	118,458	165,724
Kentucky	28	28	2,198	3,041	63,628	70,123	354,657	443,368
Louisiana	15	15	979	1,826	35,545	40,595	203,421	291,604
Maine	3	4	42	54	1,374	1,682	8,891	12,185
Maryland	2	2	493	426	8,326	9,958	67,480	90,079
Massachusetts	0	0	0	0	0	0		0
Michigan	15	15	600	598	25,874	28,809	152,453	181,043
Minnesota	52	50	1,983	2,625	93,704	104,569	332,832	421,867
Mississippi	25	24	2,060	2,192	62,540	67,879	344,189	408,670
Missouri	47	47	2,275	2,909	98,073	105,801	355,679	422,074
Montana	24	25	398	523	36,849	42,166	65,876	88,558
Nebraska	35	35	793	855	62,787	68,825	123,292	50,567
Nevada	7	8	107	128	3,803	4,543	9,703	15,501
New Hampshire	1	1	178	179	3,575	4,007	36,503	45,917
New Jersey	1	1	20	40	362	420	5,683	7,908
New Mexico	17	17	626	858	30,696	35,979	88,922	119,355
New York	4	4	62	63	2,167	2,461	8,688	10,607
North Carolina	28	28	1,489	1,708	53,879	61,904	357,781	455,160
North Dakota	25	26	968	2,308	58,028	64,856	77,172	94,153
Ohio	28	28	853	899	34,677	37,958	191,023	229,602
Oklahoma	28	28	1,560	1,821	78,255	8,875	226,613	314,479
Oregon	14	15	437	506	16,957	20,554	65,601	97,086
Pennsylvania	12	13	613	624	21,257	23,472	126,734	153,735
Rhode Island	0	0	0	0	0	0	0	0
South Carolina	22	21	1,130	1,335	42,428	48,882	244,991	325,919
South Dakota	34	34	731	802	56,182	62,093	89,879	103,679
Tennessee	24	24	1,851	1,956	54,641	61,078	464,347	565,129
Texas	80	80	3,494	4,478	196,077	28,006	628,668	866,567
Utah	5	5	141	221	4,156	5,010	12,820	20,116
Vermont	2	2	109	90	2,440	2,598	12,995	16,279
Virginia	15	14	1,024	1,047	31,201	34,906	183,901	232,438
Washington	16	16	350	416	15,849	17,838	55,554	77,399
West Virginia	1	1	20	15	655	704	3,418	4,224
Wisconsin	30	30	1,203	1,369	36,000	40,029	134,369	162,463
Wyoming	15	14	321	440	21,723	25,898	42,342	66,183

Source: Annual Statistical Report, Rural Electric Borrowers, 1974-1982, Rural Electrification Administration.

TABLE 2
Regulation of Rates and Electric Utilities, 1974, 1982

	1982 Private		1982 Public		1982 Cooperative		1974 Private		1974 Public		1974 Cooperative	
	No.	Regulatory Status	No.	Regulatory Status	No.	Regulatory Status	No.	Regulatory Status	No.	Regulatory Status	No.	Regulatory Status
Alabama PS	1	X	36		23		1	X	0		0	
Alaska PUC	25	X	12	X	15	X	22	X	14	X	11	X
Arizona CC	8	X	19		9	X	7	X	10		10	X
Arkansas PSC	4	X	3	X	19	X	7	X	NA		19	X
California PUC	8	X	34		4		9	X	31		4	X
Colorado PUC	3	X	30	X	30	X	4	X	32	X	31	X
Connecticut DPUC	4	X	6		0	X	4	X	6		0	
Delaware PSC	1	X	1		1	X	2	X	9		1	X
District of Columbia PSC	1	X	0		0		1	X	0		0	
Florida PSC	6	X	34	X	16	X	5	X	34		17	
Georgia PSC	2	X	53		43		2	X	50		39	
Hawaii PUC	5	X	0		0		5	X	0		0	
Idaho PUC	5	X	11		21		5	X	5		19	
Illinois CC	13	X	41		30		13	X	43		33	
Indiana PSC	9	X	73	X	46	X	9	X	75	X	45	X
Iowa SCC	10	X	141		61	X	10	X	145		68	X
Kansas SCC	7	X	132		37	X	8	X	139		84	X
Kentucky PSC	9	X	29		29	X	10	X	0		29	X
Louisiana PSC	5	X	25		16		5	X	NA		15	X
Maine PUC	6	X	6	X	5	X	14	X	5	X	4	X
Maryland PSC	5	X	5	X	4	X	10	X	7	X	4	X
Massachusetts DPU	14	X	40		0		15	X	40		0	
Michigan PSC	12	X	41		14	X	13	X	42		14	X
Minnesota PUC	7	X	121		48		8	X	124		57	X
Mississippi PSC	2	X	21		28		2	X	20	X	29	
Missouri PSC	11	X	87		47		12	X	NA		NA	
Montana PSC	6	X	0	X	26		6	X	0	X	NA	
Nebraska PSC			405		NA		0		NA		NA	
Nevada PSC		X	8		11		7	X	1		8	X
New Hampshire PUC	5	X	3	X	1	X	5	X	6	X	1	X

TABLE 2 (Continued)
Regulation of Rates and Electric Utilities, 1974, 1982

	1982						1974					
	Private		Public		Cooperative		Private		Public		Cooperative	
	No.	Regulatory Status	No.	Regulatory Status	No.	Regulatory Status	No.	Regulatory Status	No.	Regulatory Status	No. Status	Regulatory
New Jersey BPU	4	X	9		1	X	6	X	9		1	X
New Mexico PSC	5	X	9		21	X	5	X	6		22	X
New York PSC	11	X	46	X	5		13	X	45	X	5	
North Carolina UC	7	X	71		34		11	X	75		33	
North Dakota PSC	3	X	11		25		3	X	10		21	
Ohio PUC	9	X	80		28		8	X	NA		NA	
Oklahoma CC	4	X	70		33	X	4	X	0		36	X
Oregon PUC	4	X	15		16		4	X	15		16	
Pennsylvania PUC	13	X	4	X	0		19	X	2	X	0	
Rhode Island PUC	4	X	1	X	0	X	4	X	1	X	0	X
South Carolina PSC	6	X	22		23		6	X	22		21	
South Dakota PUC	6	X	34		35		NA		NA		NA	
Tennessee PSC	3	X	58		22		3	X	NA		25	
Texas PUC	15	X	72	X	89	X	NA		NA		NA	
Utah PSC	3	X	37		11	X	2	X	0		13	X
Vermont PSB	14	X	15	X	3	X	11	X	15	X	3	X
Virginia SCC	6	X	16		14	X	6	X	18		15	X
Washington UTC	3	X	45		16		4	X	46		17	
West Virginia PSC	17	X	2	X	2	X	16	X	2	X	3	X
Wisconsin PSC	17	X	85	X	30		19	X	85	X	30	
Wyoming PSC	6	X	14	X	19	X	8	X	8	X	24	X

Note: An "X" indicates that some type of state regulation exists. Regulation in some states is limited and is not described by this table.
The agency has authority to regulate or control rates on sales to ultimate consumers.
Source: Annual Report on Utility and Carrier Regulation, 1974 and 1982.

TABLE 3
Coefficients from Unconstrained Model

Variable	1982	1981	1980	1979	1978	1977	1976	1975	1974
k_L	.00000400	.00025079	.00265780	.00149600	.00126120	.00134263	.00148800	.00048536	1.68440000
a_L	-.00000300	-.00033204	-.00294380	-.00147840	-.00166820	-.00176430	-.00146550	-.00070725	-.5172600
γ_{LL}	-.00000003	-.00002793	-.00032687	-.00015062	-.00016888	-.00179800	-.00014143	-.00005489	.13547000
γ_{LK}	.00000010	.00000491	.00004974	.00002351	.00002823	.00003002	.00002491	.00001469	.03205100
γ_{L1}	-.00000003	-.00000209	-.00001929	-.00001201	-.0000150	9.00001606	-.00000140	-.00000373	.32528000
γ_{L2}	.00000001	.00000001	-.00003890	-.00001045	-.00002008	-.00002138	-.00000176	-.00000246	-.01415100
a_O	.85676000	2.67273000	1.15760000	.03141000	-1.29830000	-1.29500000	.1512100	.17928000	-.54961000
β_K	.56321000	.32184000	.51674000	.67441000	.86211000	.86177000	.72013000	.66642000	.63801000
β_1	.27308000	.40270000	.32272000	.28121000	.07950800	.07957700	-.10459000	.06855500	.68043000
β_2	.66220000	-.22258000	.74507000	.63197000	.57105000	.57095000	.33059000	.01461600	1.42000000
β_D	.16731000	.21930000	.2407600	0.23968000	.19525000	.19525000	.16180000	.19919000	.24501000
β_{KK}	.02291800	.03702600	.02383100	.01360900	.00293750	.00295220	.01124700	.01622200	.01849000
β_{11}	.02616500	-.01239000	-.03648000	.00180110	-.02165200	-.02162400	-.04214600	-.0438622	-.05028700
β_{22}	.31722000	.00731930	.14067000	.03861800	-.06634800	-.06634800	-.02256600	.01763900	.06891600
β_{K1}	-.02262900	-.02504600	-.01630200	-.02072700	-.00577830	-.00578750	.00857920	-.00241850	-.05238700
β_{K2}	-.0536500	.01156300	-.04290500	-.04510700	-.02647300	-.02647300	-.01553500	.00228720	-.07890300
β_{12}	.64270000	.01887000	-.0752500	.95842000	-.10689000	-.10689000	-.06401600	-.06359000	-.05664000

A Test for Absolute Price Efficiency

In our model the only variable input is labor. We therefore are able to test only for absolute price efficiency.

Hypothesis 1. *RECs are absolute price efficient in the use of labor.*

H_o: $k_L = 1.0$

H_a: $k_L \neq 1.0$

If $k_L < 1.0$, this implies overutilization of labor, and vice versa.

From an inspection of Tables 3 and 4, we reject the null hypothesis of absolute price efficiency in each of the nine years examined. Since $k_L < 1.0$ in all years except 1974, we conclude that electric distribution cooperatives overutilize labor. This confirms the conventional view that cooperatives are not profit-maximizing firms. The evidence indicates that the industry was going through an adjustment period in 1974 due to the oil embargo.

Since in every year except 1974 the k_L are very close to zero in value, we conclude that the value of the marginal product of labor is virtually zero. This indicates that on average, RECs are very close to the boundary between stage two and stage three of the production function where the marginal physical product of labor equals zero. The industry, therefore, appears to be overutilizing labor to a significant degree, beyond a profit-maximizing level and certainly beyond the level at which the average variable cost curve is at a minimum. A rationally managed REC might either engage in profit-maximization behavior with dividend repatriation of profits or, more probably, operate at the output level which minimizes per unit costs. Since RECs appear to be price takers in the output market and must serve all customers, they can control neither prices nor membership. Thus, they have no control over output in the long run. The evidence indicates that the firm operates near the point at which total revenue is maximized. These results are consistent with those of Paroush and Kahana (1980), who found that cooperatives, even if risk averse, would produce more and demand more labor input under conditions of price uncertainty than their capitalist twin.

Although direct comparisons of the economic efficiency of REC and private electric distributors are not possible in this study, a previous study by Hollas and Stansell (1988) of private, municipal, and cooperative electric generating utilities concludes that none of the three ownership forms is absolute price efficient (a profit maximizer), nor is any of the three relative price efficient (a cost minimizer). For the four years examined (1977-1980), there is no evidence that any of

TABLE 4
χ^2 Statistics Log Likelihood Ratio Tests

HYPOTHESIS NO.	D.F.	χ^2 [a]	1982	1981	1980	1979	1978	1977	1976	1975	1974
1	1	6.64	12.84	19.80	22.80	18.32	12.34	12.34	80.12	43.64	58.68
2	9	21.67	920.30	25.64	32.44	39.52	91.94	1,036.92	25.64	860.84	280.08
3	4	13.27	15.14	30.28	42,159.98	39,80.46	23.34	4,234.10	26.12	4,484.66	3,741.74
4	1	6.64	313.10	96.44	110.24	105.04	842.88	76.02	53.86	73.32	91.58

a: χ^2 critical value, .01 significance level.

the forms consistently leads to absolute price efficiency in the use of labor. However, privates consistently (all four years) came closer to employing the profit-maximizing levels of labor and fuel than did cooperatives. Although no pure distribution utilities were included in the previous analysis, the results of that study possibly suggest that a rural private distributor might be more absolute price efficient in the use of labor than a rural cooperative distributor of electricity, especially given the tendency of the cooperatives sampled in this study to employ labor up to the boundary of the second and third stages of the short-run production function.

A Test for Regulatory Effects on Total Profit

If regulation affects total profit, the coefficients of one of the regulatory variables or interaction terms must be significantly different from zero.

Hypothesis 2. *Regulation affects the economic efficiency of RECs.*

$$H_o\colon \gamma_{L1} = \gamma_{L2} = \beta_1 = \beta_2 = \beta_{K1} = \beta_{K2} = \beta_{11} = \beta_{12} = \beta_{22} = 0$$

$$H_a\colon \gamma_{L1} \neq 0 \; or \; \gamma_{L2} \neq 0 \; or \; \beta_1 \neq 0 \; or \; \beta_2 \neq 0 \; or \; \beta_{K1} \neq 0 \; or \; \beta_{K2} \neq 0 \; or \; \beta_{11} \neq 0 \; or \; \beta_{12} \neq 0 \; or \; \beta_{22} \neq 0$$

If all of the coefficients of the regulatory variables and their interactions are equal to zero, regulation has no effect on profits. If the coefficients are negative in sign and significant, regulation has a negative effect on profits, and vice versa.

The empirical results reported in Tables 3 and 4 indicate that regulation significantly affects total profit. Since it is difficult to directly interpret these results due to the mixed signs, in order to gain some insight into the effects we calculate elasticities of actual profit with respect to regulation:

$$E_{Ri} = \frac{\partial \ln \Pi^a}{\partial \ln R_i} = \beta_i = \gamma_{Li} \ln(k_L P_L) + \beta_{ki} \ln(K) + \beta_{ii} \ln(R_i) + \beta_{ig} \ln(R_g)$$

$$+ \left[\frac{(1-k_L)}{k_L} \gamma_{Li} \right] \left[1 + \frac{(1-k_L)}{k_L} (\alpha_L + \gamma_{LL} \ln(k_L P_L) + \gamma_{LK} \ln(K) + \sum_i \gamma_{Li} \ln(R_i)) \right]^{-1}$$

for $i,g = 1,2;\ i \neq g$.

[4]

The net effect of regulation is shown as the sum of E_{R1} and E_{R2} in Table 5.

We have calculated E_{R1} and E_{R2} under two different behavioral assumptions: first, assuming profit maximization behavior ($k_L = 1$) ; and second, assuming not-for-profit behavior ($k_L \neq 1$). If we assume profit maximization behavior, regulation has a negative effect in every year. Except for 1974, the coefficients are small in magnitude. If we assume that the firms are not profit maximizers (as our results indicate) the coefficients are very small in magnitude for most years and have mixed signs. We conclude that regulation has a negligible effect on profit in six of the nine years studied.

TABLE 5
Mean Elasticities of Actual Profit with Respect to Regulation

	Assuming Profit Maximization ($k_L = 1.0$)			Assuming Non-Profit Maximization ($k_L \neq 1.0$)		
	E_{R1}	E_{R2}	$E_{R1} + E_{R2}$	E_{R1}	E_{R2}	$E_{R1} + E_{R2}$
1982	-.009	.006	-.003	-.007	.088	.081
1981	-.017	.006	-.011	-.004	-.003	-.007
1980	-.019	-.067	-.086	.003	-.007	-.004
1979	-.021	-.023	-.044	.004	.226	.230
1978	-.036	-.050	-.086	-.014	.010	-.004
1977	-.047	-.041	-.088	.015	.018	.003
1976	-.037	-.021	-.058	-.007	.010	.003
1975	-.024	-.042	-.066	-.004	-.005	-.009
1974	-.132	.020	-.112	.383	.042	.425

A study by Arzac and Edwards (1979) suggests that conflicting forces are simultaneously operating on the regulated firm. If the firm engages in expense preference behavior and is regulated, it may employ too little capital. If the firm is rate-of-return regulated, it may employ too much capital. The two forces may offset each other.

A Test for the Effect of the Amount of Capital on Marginal Profit

We next examine the effect of capital on profit.[2]

Hypothesis 3. *Capital usage affects marginal profit.*

H_o: $\beta_{KK} = \gamma_{LK} = \beta_{K1} = \beta_{K2} = 0$

H_a: $\beta_{KK} \neq 0$ *or* $\gamma_{LK} \neq 0$ *or* $\beta_{k1} \neq 0$ *or* $\beta_{K2} \neq 0$

We reject the null hypothesis in every year. The overall effect of the amount of capital on marginal profit is positive. However, overutilization of capital may have occurred during the period examined. Capital subsidies were provided to the RECs by the REA. During the period examined in this study, loans were available for capital expansion at interest rates significantly below the prevailing open market rate. Further, rates on these loans did not reflect risk differentials between cooperatives. Such policies certainly encourage overutilization of capital. In other words, the effective price of capital is lower than the market price of capital due to subsidies, and thus is lowered relative to the market price of labor. This distortion creates an additional incentive to substitute capital for labor. The extent to which RECs are (relative price) inefficient in the long-run substitution of capital and labor could be significant. Since we consider capital a fixed input, we cannot directly test this proposition; we merely conclude that RECs are not absolute price efficient in the short-run use of labor.

We next calculate a measure of the responsiveness of output to a change in the fixed capital input. An appropriate measure of the responsiveness of profit (and, by duality, production) is the elasticity of profit with respect to capital:

$$E_K = \beta_k + \beta_{KK}\ln(K) + \gamma_{LK}\ln(k_L P_L) + \sum_i \beta_{ki}\ln(R_i)$$

$$+\left[\frac{(1-k_L)}{k_L}\gamma_{LK}\right]\left[1+\frac{(1-k_L)}{k_L}(\alpha_L + \gamma_{LL}\ln(k_L P_L) + \gamma_{LK}\ln(K) + \sum_i \gamma_{Li}\ln(R_i))\right]^{-1}. \quad [5]$$

TABLE 6
Mean Elasticity of Profit with Respect to Capital

	Assuming Profit Maximization ($k_L = 1.0$) E_K	Assuming Non-Profit Maximization ($k_L \neq 1.0$) E_K
1982	.935	.159
1981	.908	.177
1980	.888	.202
1979	.887	.228
1978	.929	.262
1977	.926	.281
1976	.930	.313
1975	.951	.355
1974	.914	.396

Mean elasticities of profit with respect to capital for each year are reported in Table 6. We again perform the calculation under both an assumption of profit maximization behavior and not-for-profit behavior. Our elasticity estimates of actual profit with respect to capital (E_K) reported in Table 6 indicate that $E_K < 1.0$ in every year; it appears that the average product of capital exceeds the marginal product of capital, indicating that cooperatives operate near the third stage of production.

Embodied technical change implies that technological improvements are embedded in capital. An examination of Table 6 indicates that, assuming not-for-profit behavior, all values of the elasticity of profit with respect to the amount of capital are positive in sign and between 0.159 and 0.396 in value. Our model does not allow us to examine the separate effects of embodied technology versus the amount of capital on profit. We may, however, examine the responsiveness of profit and, by duality, production to capital. From 1974 through 1982, the coefficients decrease in magnitude by 0.237, implying a small decrease in responsiveness. This may imply a slight downward trend in embodied technical change.

The elasticity of profit E_K reported in Table 6 is less than 1.0 in every case, which implies that there may be diseconomies of scale in the cooperative distribution of electricity. However, since only capital expansion is reflected in E_K and not expansion of all inputs (i.e., this change is not on the expansion path), no strong conclusions are warranted concerning production economies. Under both behavioral assumptions, the elasticities are positive. They are significantly smaller if not-for-profit behavior is assumed, and there is a significant downward trend in the elasticities, suggesting that profits are less responsive to the amount of capital in recent years. These results are consistent with the position that diseconomies of scale exist, although as noted earlier, this conclusion should be viewed with caution. Neuberg (1977) suggests that, while very large municipal distribution firms are probably greater than the optimal size, very small firms may be well under the optimal size.

A Test for the Effect of Service Area Density

If service area density affects total profit, the coefficient of the service area density variable β_D should be significantly different from zero. Our hypothesis may be formally stated:

Hypothesis 4. *Service area density affects economic efficiency.*

H_o: $\beta_D = 0$

H_a: $\beta_D \neq 0$

As the results reported in Table 4 indicate, the null hypothesis is rejected in every year. The coefficients of β_D reported in Table 3 indicate that service area density has a positive effect on firms' profits. However, Mikesell and Mann (1976) found that service area density did not affect REC pricing practices.

V. CONCLUSIONS

The property rights and agency theory literature suggests that cooperative firms, even though privately owned, should not be as economically efficient as profit-maximizing firms. The results of the tests conducted in this study indicate that cooperatives in fact do not maximize profits because absolute price efficiency is rejected. Cooperatives appear to overutilize labor inputs. Given that we reject profit maximization behavior and conclude that not-for-profit behavior exists, regulation's effects are negligible and mixed in sign. Service-area density has a positive effect on total profit. The elasticity of profit estimates suggest that the effect of the amount of capital on profits (i.e., economic efficiency) is positive.

Meade (1974) analyzes the labor-managed cooperative and concludes that it will add workers as long as the marginal revenue value of their marginal product is greater than the current income per worker available for distribution to labor. While the RECs analyzed in their study are not labor managed, the results obtained in this study are consistent with such behavior.

These results are not consistent with the conventional theory of natural monopoly. The industry may be experiencing diseconomies of scale. From a policy standpoint, our results indicate that capital subsidies to RECs are difficult to justify.

The REC may have a different objective function from that of a profit-maximizing firm. It is difficult to reconcile the results obtained from this study with any mode of behavior that is consistent with the maximization of the utility of the cooperative's patron/owners. Maximization of total revenue, which seems to be consistent with our results, is not consistent with either minimization of per-unit cost or profit maximization.

The regional implications of our results must be couched in terms of REC service intensity by state (shown in Table 3). In certain states (and, generally, certain geographic areas) RECs serve a significant number of rural customers. In particular, the Southeast, Southwest, and Rocky Mountain region would be significantly affected by any policy changes affecting RECs.

Regulation does not appear to have a strong impact on RECs. Many states do not even regulate them. Our empirical results indicate that regulatory effects are neither substantial nor consistent from period to period. The broad results of our study suggest that on average diseconomies of scale may exist, that capital subsidies could be reduced, and that the benefits from technological change are declining. In the regions where RECs serve significant customer bases, these results indicate that public policies that reduce REC size and capital subsidies, and encourage an examination of the type and level of capital employed, might improve the economic efficiency of RECs.

ENDNOTES

1. There are many facets of electric utility regulation, some more important than others. Since capital is treated as a fixed input, rate-of-return regulation should not distort the results of this study through an Averch-Johnson effect. However, other institutional aspects of regulation, such as how "close" public service commissioners are to their constituents, are not highlighted by a principal component analysis. See (Boyes and McDowell 1989) for a recent study on the role of institutional setting in the pricing of electricity by private utilities.

2. Although we do not report the statistical results, the null hypothesis $\beta_k = 0$ is rejected in each year at the .05 level of significance.

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