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International Graduate Student Conference Series

No. 7, 2004

An Empirical Analysis of the Averch-Johnson Effect in Electricity Generation Plants

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This paper was presented at the 3rd East-West Center International Graduate Student Conference, February 19-21, 2004 in Honolulu, Hawaii.

An Empirical Analysis of the Averch-Johnson Effect in Electricity Generation Plants

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Abstract

Ample presence of infrastructure has been identified as one of the key drivers of economic growth. Having experienced sluggish growth compared to its ASEAN neighbors, among the reforms introduced by the Philippines is deregulation of its key infrastructure sectors, particularly the energy sector. Despite the deregulation, however, energy prices remain to be one of the highest in the region. To be able to benefit from the restructuring, critical aspects of electricity regulation need to be examined critically particularly the appropriateness of the current method of pricing in the deregulated environment. This paper attempts to answer the question of whether the current pricing methodology, the Rate-of-Return (ROR) regulation, gives incentive for regulated firms to overcapitalize. According to the Averch-Johnson (A-J) Model, ROR regulation induces firms to have an inefficiency high capital/labor ratio because as more capital is used, the firm is allowed to earn higher absolute profit. By observing the input prices and the marginal products of a regulated firm in the generation sub-sector, the A-J hypothesis was tested. Since marginal products are not directly observable, it is approximated by estimating the firm's production function using capital, labor and fuel as three major inputs. The results confirm the existence of overcapitalization in all generation plants in the sample by approximately twenty to thirty percent. The results are consistent with previous studies done in the USA. The empirical results obtained are consistent with the hypothesis that the rate of return regulation induces firms to overcapitalize.

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[1] An earlier draft of this paper was presented at the Third East West Center International Graduate Student Conference, Hawaii, February 2004. This paper is a part of the author's master's thesis at Hitotsubashi University, titled "Essays on Electricity Regulation in the Philippines." The author acknowledges the help of her supervisor, Prof. Shigeki Kunieda. Thanks are also due to Mr. Hua Changchun for his valuable comments and contribution as well as to the moderators and participants of the International Conference.

1. Introduction

Traditional cost-of-service price regulation has the well-known problem that if the firm knows that higher costs are reimbursed in the form of higher prices, then inefficient modes of production may lead to higher profits. By choosing a non-minimum-cost mode of production, this firm may cause the regulator to set even higher prices and therefore earn higher profits than if it produced its output at minimum cost. This essay investigates whether this kind of problem is present in the regulation of the electricity generation sub-sector in the Philippines.

2. Review of Related Literature

Electricity production is classified as natural monopoly, a classic case of market failure. The fact that average cost falls as more electricity is produced shows existence of economies of scale due to large fixed costs. For instance, the first kilowatt-hour will not be produced without a generation plant. If production is confined to only one kilowatt-hour, the cost incurred is very high. However, when the plant produces more, its fixed costs are spread over more units, average cost then declines.

From a cost perspective, natural monopoly is the natural outcome of a competitive process and direct intervention has to be put in place. At least three potential situations may be identified. First, price could be set equal to marginal cost, as it is in a competitive market. In this case, however, losses would be made and lump sum transfers would be required to ensure breakeven. Public control will be seen as a sensible solution, with the necessary fund coming from general taxation. But since tax is an additional cost, this solution will lead distortion to the national economy. Second, the industry could be in the hands of private firm which would have its price regulated by the state in which its earnings approximate to a normal rate of return on capital. And third, the rights to supply will be auctioned off to bidders whose bids would be in the form of a contract to supply at a given price. Given sufficient bidders, price may be expected to approximate average cost.

In all these alternatives, a regulator is needed to induce the firm to produce the desired outcome. When there is perfect information, the regulator could simply mandate the optimal outcome—with firms producing at most efficient input combinations and prices set at marginal cost. In reality, however, the regulator does not have enough information to determine these levels. Instead the regulator has to devise incentive mechanisms to induce the firm to attain socially optimal outcomes while earning its desired profit.

Central to the normative analysis of regulation is the design of mechanisms that regulators can apply so that firms will be induced to achieve social optimal outcomes. Achieving optimal regulation involves two tasks: first, characterizing the optimal outcome through marginal cost pricing at the optimal output level, and second, finding alternatives to marginal cost pricing through establishing incentive schemes to make the firm's pursuit with profit maximization be consistent with social welfare maximization as well.

In theory marginal cost pricing leads to first-best allocation of resources: neither the firm nor the consumer will be made better off when the allocation involves the firm fully utilizing his capacity and the consumer paying for his margin equal to the cost of producing that unit. However, the problem with pricing utilities based on marginal cost will entail the firm incurring losses. In utilities exhibiting increasing returns to scale, marginal cost pricing will result in revenues failing to cover costs, unless there is a direct subsidy from the government to make-up for the losses. Thus, marginal cost pricing is not a solution for public utilities.

Most common in regulatory practice, pricing through rate-of-return and price cap constraints accept that there will be no welfare optimal outcome. The main question a regulatory agency faces is determining the appropriate level of price given that a monopoly's costs are determined both by input factors and the effort level of the firm, both of which cannot be observed accurately by the regulator. If price accurately reflects actual observed costs, which is one possible representation of rate-of-return regulation (ROR), then allocative efficiency is nearly attained and there are no excessive profits, but the firm has weak incentives to reduce costs. When the price is fixed at some predetermined level, a kind of pure price cap regulation, then the benefits and problems of ROR are reversed (Armstrong, et. al, 1994).

3. Theoretical Framework

This section expounds the Averch-Johnson effect discussed in the previous section. The A-J Model of Rate-of-Return Regulation is presented, followed by its implications on the behavior of the regulated firm. It then outlines the applicability of the A-J model in analyzing ROR regulation in the electricity sector.

3.1 The Averch-Johnson (A-J) Model of Rate-of-Return Regulation

The essence of rate-of-return regulation is average cost pricing in that the prices chosen are determined by equating total revenue and total cost. ROR regulation allow the utility to earn a fair rate of return on its investment in capital, but disallow the firm to make profits in excess of this fair rate of return. To quote Averch and Johnson (1962) on the fair rate of return criterion:

> "After the firm subtracts its operating expenses from gross revenues, the remaining net revenue should be just sufficient to compensate the firm for its investment in plant and equipment. If the ROR, computed as the ratio of net revenue to the value of the plant and equipment (the rate base), is judged to be excessive, pressure is brought to bear on the firm to reduce prices. If the rate is considered to be too low, the firm is permitted to increase prices."

The simplest example would be one in which the regulator announces his willingness to pay a fair rate of return*, f,* on any capital required by the utility. The utility then can freely set its input and output levels and its price as long as the chosen levels do not result in profits that exceed *f* (Train, 1991).

Rate of return on capital (*r*) is defined as revenues (*PQ*) minus costs for noncapital inputs, divided by the level of capital investment *(K).* Assuming that labor *(L)* is the only non-capital input, the rate of return is *(PQ-wL)/K.*

Following the definition of ROR regulation, this rate of return on capital must be no greater than *f*, which the regulator has previously announced. The utility can therefore choose any *K, L, Q* and *P* as long as it satisfies the constraint

$$f \geq \frac{(PQ - wL)}{K}$$

When r is subtracted from both sides, this inequality can be expressed in terms of economic profit,

$$f - r \geq \frac{(PQ - wL)}{K} - r$$
$$f - r \geq \frac{(PQ - wL - rK)}{K}$$

Since economic profit is defined as the difference between the firm's revenues and its costs for all inputs including capital: $\pi = PQ - wL - rK$, the equation then becomes

$$f - r \geq \frac{\pi}{K}$$
$$\pi \leq (f - r)K$$

Thus, the maximum economic profit that a regulated utility is allowed to earn is *(f-r)K.* To illustrate, if the fair rate of return is set at 15 percent and the price of capital is 10 percent, then the utility is allowed to earn not greater than 5 percent of its invested capital. For instance, if the utility invested 100 million pesos, then it is allowed to earn not more than 5 million pesos in profits.

The ROR regulation is the traditional approach to regulation of privately owned monopolies and an alternative to public owned utilities. The method is generally identified with the regulation of investor-owned utilities in the US. As shown, the ROR regulation allows the utility to cover its operating and capital costs as well as a return on capital.

Averch and Johnson (1962) proposed a method for examining the effects of regulation on the behavior of firms. They showed that rate-of-return regulation, the type of regulation used in the Philippines, induces firms to use inputs inefficiently.

Averch and Johnson (1962) treated a regulated monopoly as a profit maximization problem with two-inputs and a rate of return constraint. Expanding the exposition of ROR regulation mentioned above, let

$p(q)$ = inverse demand function of a monopoly firm

$q(K,L)$ = production function of a monopoly firm

K = units of capital employed by the firm

L = units of labor employed by the firm

r = unit cost of capital, K

w = unit cost of labor, L

Without ROR regulation, the firm will choose K and L to maximize its profits given as

$$\pi(K, L) = p(q(K, L))q(K, L) - rK - wL. \tag{1}$$

The first order conditions for profit maximization are:

$$\frac{\delta\pi}{\delta K} = \frac{dp}{dq}\frac{\delta q}{\delta K}q(K,L) + p(q(K,L))\frac{\delta q}{\delta K} - r = 0$$

$$p'(q)q_K q + p(q)q_K - r = 0$$

$$(p'(q)q + p(q))q_K = r$$

since $MR = p'(q)q + p(q)$

$$MRq_K = r$$

$$\therefore \quad \frac{\delta\pi}{\delta K} = MRq_K - r = 0$$

(2)

$$\frac{\delta\pi}{\delta L} = \frac{dp}{dq}\frac{\delta q}{\delta L}q(K,L) + p(q(K,L))\frac{\delta q}{\delta L} - w = 0$$

$$p'(q)q_L q + p(q)q_L - w = 0$$

$$(p'(q)q + p(q))q_L = w$$

$$MRq_L = w$$

$$\therefore \quad \frac{\delta\pi}{\delta L} = MRq_L - w = 0$$

(3)

where MR is the marginal revenue, and q_K and q_L are the marginal productivities of K and L.

The cost function is defined as:

$$C = wL + rK\ .$$

By cost minimization, the rate of technical substitution is

$$\begin{aligned} 0 &= wdL + rdK \\ -wdL &= rdK \\ -\frac{dL}{dK} &= \frac{r}{w} \end{aligned}$$

(4)

From (2) and (3)

$$MRq_K = r \qquad \Rightarrow q_K = \frac{r}{MR}$$

$$MRq_L = w \qquad \Rightarrow q_L = \frac{w}{MR}$$

By (2), (3) and (4) the cost-minimization condition is:

$$\frac{-dL}{dK} = \frac{r}{w} = \frac{q_K}{q_L} \qquad or \qquad \frac{q_K}{r} = \frac{q_L}{w}$$

(5)

Equation (4) shows the rate of technical substitution (defined as $\frac{-dL}{dK}$) equal to the price ratio $\frac{r}{w}$, while equation (5) shows that the marginal productivities per dollar (q_K, q_L) are equalized between capital and labor.

In the case of a regulated monopoly firm, the rate of return on capital is defined as the ratio $\frac{pq-wL}{K}$ and the rate of return constraint is given by

$$\frac{pq-wL}{K} \leq f \text{ ,}$$

(6)

where *f* is the allowed rate of return or the ceiling imposed by regulators.

When *r* is subtracted from both sides, equation (6) can be expressed in terms of economic profit (equation 1)

$$f-r \geq \frac{(PQ-wL)}{K} - r$$
$$f-r \geq \frac{(PQ-wL-rK)}{K}$$
$$f-r \geq \frac{\pi}{K}$$
$$\pi \leq (f-r)K$$

(3.7)

Thus, the maximum economic profit that a regulated utility is allowed to earn is *(f - r)K*.

The regulated monopoly can therefore choose any *(K, L)* to maximize its profits as long as it satisfies this constraint plane. Mathematically, it solves the following constrained maximization problem:

Let *fm* be the unregulated monopoly's rate of return, as implied by (2) and (3). For regulation to be effective, the rate *f* must be set between *r* and *fm*. Equation (7) can be changed to

$$\begin{aligned} pq - rK - wL &\leq (f-r)K \\ pq - fK - wL &\leq 0 \end{aligned} \qquad (8)$$

The constrained maximization problem is therefore expressed as

$$\underset{K,L}{Max} \qquad \pi(K,L) = pq - rK - wL$$
$$s.t. \qquad pq - fK - wL \leq 0$$

Assuming that $\lambda \geq 0$, the Lagrangian expression for this problem is

$$\mathrm{L} = \pi(K,L) - \lambda(pq - fK - wL) \tag{9}$$

Differentiating equation (9) to get first order conditions:

$$\frac{\delta \mathrm{L}}{\delta K} = p' qq_K + pq_K - r - \lambda(p' qq_K + pq_K - f) = 0$$

Since p’q+p=MR,

$$\begin{aligned} &= MRq_K - r - \lambda(MRq_K - f) = 0 \\ &= MRq_K(1-\lambda) - r + \lambda f = 0 \\ &\Rightarrow MRq_K(1-\lambda) = r - \lambda f \end{aligned}$$

(10)

$$\begin{aligned} \frac{\delta \mathrm{L}}{\delta L} &= p' qq_L + pq_L - w - \lambda(p' qq_L + pq_L - w) = 0 \\ &= MRq_L(1-\lambda) - w + \lambda w = 0 \\ &\Rightarrow MRq_L(1-\lambda) = w - \lambda w \end{aligned}$$

(11)

Combining equations (10) and (11) will yield

$$\frac{MRq_K(1-\lambda)}{MRq_L(1-\lambda)} = \frac{r-\lambda f}{w-\lambda w}$$

$$\frac{q_K}{q_L} = \frac{r-\lambda f}{w-\lambda w}$$

when *f=r,*

$$\frac{r-\lambda f}{w-\lambda w} = \frac{r-\lambda r}{w-\lambda w} = \frac{r}{w}$$

However, given the constraint that *f>r* and assuming that $\lambda > 0$,

$$\frac{r-\lambda f}{w-\lambda w} < \frac{r}{w}$$

$$\therefore \quad \frac{q_K}{q_L} < \frac{r}{w}$$

(12)

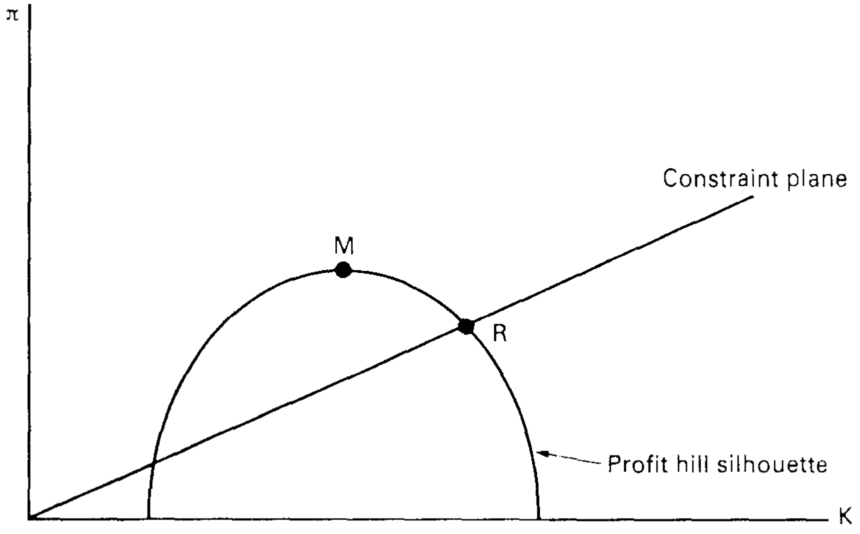
Therefore, for any $f \in (r, f_m)$, Averch and Johnson (1962) showed that the solution for the monopolist firm's constrained profit maximization function satisfies equation (12) leading to the A-J effects as summarized below.

Implication 1**: The regulated firm uses more capital than the unregulated firm.**

Under ROR regulation, a regulated firm uses more capital than an unregulated monopoly. Regulator's choice of capital, point R, can be seen clearly in a two-dimensional presentation of the constraint plane and profit hill in Figure 1. It is seen that as capital increases, the firm is allowed to make greater absolute profit even though the ROR is the same. The regulated firm therefore chooses point *R*, the point in the intersection of the plane and the profit hill in which capital is highest. The impact of regulation on the firm's use of labor, however, is indefinite. Depending on the profit function, the regulated monopoly can use either more, less or the same amount of labor as the unregulated monopoly.

Figure 1 Constraint Plane and Profit Hill

Figure 1. Constraint Plane and Profit Hill



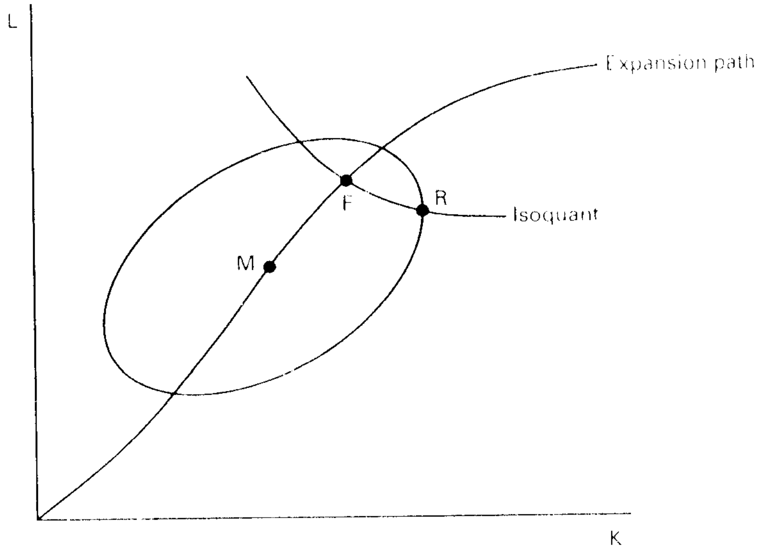
Sources: Train, 1991 based on Zajac, 1970.

***Implication 2*: The capital/labor ratio of the regulated monopoly is inefficiently high for its level of output.**

ROR regulation results in misallocation of economic resources, that is, the output of the regulated monopoly can be produced more cheaply with less capital and more labor than what the current input choice is.

The firm has an incentive to substitute between factors in an inefficient way which might be difficult for the regulatory agency to detect. Figure 2 shows the position of the firm's chosen input combination relative to the expansion path. The regulated firm chooses capital and labor combination in point *R*. The isoquant gives possible input combinations that will produce the same level of output at any point in the curve. This isoquant intersects at the expansion path at point *F*, which, by definition, will give the lowest cost compared to any other point in the isoquant including point *R*. At point *F*, there will be lesser use of capital and greater use of labor compared to point *R*, thus, the cost of producing output can be reduced by using more labor and less capital (Train, 1991).

Figure 2 Regulated firm's K/L ratio is inefficiently high



Sources: Train, 1991 based on Zajac, 1970.

Baumol and Klevorick (1970), Bailey (1973), Das (1980) and numerous others clarified and extended A-J analysis proving that regulated firms always choose input combinations below the expansion path, and that a point above or below will never be chosen.

These results point out the flaws of ROR regulation. ROR regulation puts forth a mechanism inducing firms to earn profit on capital even if the regulator's intention was not to increase the use of capital. The solution, however, does not lie merely in restricting the profits that the firm will earn, when *f=r*, the result is also not according to society's goals. Thus, a probable solution would be to design another mechanism that will induce the firm to be efficient, yet at the same time, viable.

3.2 Extension of the A-J Theory to Model A-J Effects in Electricity Sector[2]

Production of electricity requires three distinct activities: generation, transmission, and distribution.[3] In order to evaluate the A-J effects in the electricity industry, an electric utility can be taken as an entity or each activity can be evaluated separately. The first approach is viewed to present serious analytical problems and is therefore less desirable (Spann, 1974, Courville, 1974 and Petersen, 1975). First, the planning horizon for transmission and distribution activities is different from generation. Second, a study at the firm-level will have to take into account differences between technological structure. Since electric utility companies in the Philippines are widely diverse (from a big private conglomerate to small electric cooperatives), technological advancement will be very difficult to model.

In adopting the second approach, since capital and labor inputs for transmission/distribution are different from those of generation, it can be argued that the generation and the transmission/distribution activities are separable in the production of delivered activity. Given this argument, the production structure of an electric utility can be modeled as

$$Q = \min[G(K, F, L), T(K_T, L_T) D(K_D, L_D)]$$

where

$G(K,F,L)$=production function of generation sub-sector with K as capital, F fuel, and L labor

$T(K_T,L_T)$=production function of transmission sub-sector with K_T as capital and L_T as labor used in transmission activity

$D(K_D,L_D)$= production function of distribution sub-sector with K_D as capital and L_D as labor used in distribution activity

This implies that each sub-sector can be tested separately for possible evidence of A-J

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[2] Most of the analyses are based on Courville's (1974) study

[3] for the purposes of simplification, supply sourcing is lumped with generation while retail supply is lumped with distribution.

effect. Since the transmission sector in the Philippines is owned by the government, this sub-sector is excluded in the investigation. Courville (1974) pointed out that distribution and transmission sub-sectors are characterized by fixed proportions, thus, if A-J effect exists, it will occur only in the generation sub-sector.

4. Empirical Framework

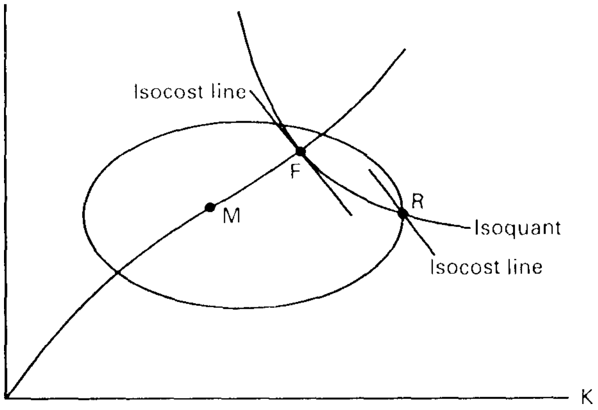
This section discusses the econometric methods employed to test the presence of A-J effect in the generation subsector of the electricity industry.

4.1 Empirical Estimation of the A-J Effect

The main proposition of the A-J model is that given an output level, the regulated firm employs too much capital relative to labor. This theoretical proposition can be stated in terms of a hypothesis that can be tested empirically.

The proposition is expressed graphically in Figure 3, where the regulated firm chooses point *R* while the cost-minimizing input for this level of output is at point *F*. As required for cost minimization, the isocost line, $-\frac{r}{w}$, is tangent to the isoquant, which is seen at point *F*. However, at *R*, the isocost is not tangent to the isoquant. By definition, the slope of the isoquant is the negative of the marginal rate of technical substitution at that point, and *MRTS* is the ratio of the marginal products of capital and labor, that is, $MRTS = \frac{MPK}{MPL}$. Since marginal products change at any combination of *K* and *L*, there is a different MRTS at different points on the isoquant. At the cost-minimizing point F, $MRTS = \frac{MPK}{MPL} = \frac{r}{w}$, since the isoquant and the isocost lines are tangent. However, at point *R*, where there is more capital and less labor used, *MRTS* is lower than at point *F* and thus, is less than the ratio of prices. Thus, $\frac{r}{w} > \frac{MPK}{MPL}$.

Figure 3 Observable Consequence of the AJ Effect



Source: Train, 1991.

The A-J model states that a regulated firm will choose point *R*. By observing the input prices and the marginal products of a regulated firm, the A-J hypothesis can be tested. Stated succinctly,

Null Hypothesis:

$$\frac{r}{w} = MRTS = \frac{MPK}{MPL} \tag{13}$$

Alternative Hypothesis

$$\frac{r}{w} > MRTS = \frac{MPK}{MPL}$$

where:

r=input price of capital

w=input price of labor

$MRTS$ = marginal rate[4] of technical su

MPK=marginal product of capital[5]

MPL=marginal product of labor[6]

The problem with empirical testing is that marginal products are not directly observable. The marginal products, therefore, are approximated by estimating the firm's production function, then deriving marginal products. The estimated $\frac{MPK}{MPL}$ is compared to $\frac{r}{w}$ and statistical tests are performed to determine the significance of the results.

In testing the hypothesis on electric generation plants, three inputs will be considered, capital, labor and fuel. Under ROR regulation, fuel costs are treated similar to labor costs, thus it is implied that $\frac{r}{v} > \frac{MPK}{MPF}$, where v is the input price of fuel and MPF is the marginal product of fuel input. The hypotheses are then restated as follows:

Null Hypotheses:

$$\frac{r}{w} = \frac{MPK}{MPL} \qquad and \qquad \frac{r}{v} = \frac{MPK}{MPF}$$

(14)

Alternative Hypotheses:

$$\frac{r}{w} > \frac{MPK}{MPL} \qquad and \qquad \frac{r}{v} > \frac{MPK}{MPF}$$

To derive marginal products, a production function for electricity generation is estimated. Following Courville (1974), a Cobb-Douglas production function is estimated:

$$Q_i = AK_i^{\alpha} F_i^{\beta} L_i^{\lambda} e^{\varepsilon_i}$$

where

Q_i=output of plant i

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[4] Defined in the theoretical framework as $-\frac{dL}{dK}$

[5] Defined in the theoretical framework as q_K

[6] Defined in the theoretical framework as q_L

K_i=capital of plant *i*
F_i=fuel consumption of plant *i*
L_i=labor consumption of plant *i*, and
$\varepsilon_i =$ random variable with mean=0 and var=σ^2

The empirical model is specified as

$$\log Q_i = \log A + \alpha \log K_i + \beta \log F_i + \lambda \log L_i + \varepsilon_i \,. \tag{15}$$

Under this specification, marginal products are defined as

$$MPK = \frac{\Delta Q}{\Delta K} = \frac{\Delta \log Q}{\Delta \log K}\left(\frac{Q}{K}\right) = \alpha \frac{Q}{K},$$
$$MPF = \frac{\Delta Q}{\Delta K} = \frac{\Delta \log Q}{\Delta \log F}\left(\frac{Q}{F}\right) = \beta \frac{Q}{F} \text{ and}$$
$$MPL = \frac{\Delta Q}{\Delta L} = \frac{\Delta \log Q}{\Delta \log L}\left(\frac{Q}{L}\right) = \lambda \frac{Q}{L}.$$

(16)

By estimating parameters α, β and λ, and by observing a firm's levels of *Q, K, F,* and *L*, the marginal products are calculated.

3.4.2 Empirical Issues

The literature on electricity generation indicates that there are significant differences in production technologies among plants. Different-sized plants generally use different technologies, ergo, different levels of efficiency. To capture technological differences, capacity of the plant has to be included as an explanatory variable in the production function. There are also perceived problems in output *Q* being measured as total kilowatt-hours produced during the year, since each plant's output varies at any point in time depending on the day and season. This variation affects production function estimation because the efficiency of plant operation depends on the degree of variability in its output. To be able to capture this effect, capacity utilization has to be added as another explanatory variable.

Given these issues, the production function is rewritten as

$$Q_i = AK_i^{\alpha} F_i^{\beta} L_i^{\lambda} e^{\delta U_i} e^{\xi C_i} e^{\varepsilon_i}$$

(17)

where Q_i, F_i, L_i, ε_i are as defined earlier

U_i=the capacity utilization of plant i

C_i=the capacity of plant i

The empirical model estimated is therefore

$$\log Q_i = \log A + \alpha \log K_i + \beta \log F_i + \lambda \log L_i + \delta U_i + \xi C_i + \varepsilon_i . \quad (18)$$

4.3 Definition of Variables

In the empirical estimation of the production function and costs of inputs, the following variables are used:

Output, Q_i=total kilowatt-hour produced by a plant

Capital, K_i=book value of the plant, equipment, and land

Labor, L_i=the plant's labor usage defined to be the total number of employees (Spann, 1974)

Fuel, F_i=total British Thermal Units (*BTUs*) of fuel consumed by the plant

Wage rate, w=defined as payments of labor divided by total employees

Price of fuel, v=total fuel cost divided by BTUs of fuel burned

Rental rate of capital, r=capital recovery rate reported by IPPs

Capacity utilization, U_i=defined as annual output of the plant expressed as a percentage of the plant's capacity

Capacity, C_i=the maximum output the plant is capable of producing

4.4 Data

The data for this study are from the company profiles of the National Power Corporation plants and financial reports of IPPs from the Securities and Exchange Commission (SEC). Data for years 2001 to 2002 were obtained but due to incomplete financial statements in 2002, only the year 2001 was estimated. There are 26 companies during the period specified. Output is defined as total electricity generated for the year expressed in megawatt-hour. Book value of capital is based from the appraised book values of plants computed by NPC. Rental rate of capital is also obtained from NPC and ERC.[7] Fuel is obtained from NPC originally expressed in diesel and bunker liters. To make diesel and bunker comparable, both were expressed in British Thermal Units (BTUs).[8] The number of employees is obtained from both NPC and ERC. Payments to labor and total fuel cost used in the computation for the price of fuel and capital, respectively, were obtained from financial reports of IPPs from SEC while government-owned plants were obtained from NPC.

4.5 Methodology

Following the empirical method of Courville (1974), the researcher will use ordinary least squares to estimate the production function. To test the presence of A-J Effect, the marginal productivities of capital and fuel based on the estimated production function will be then compared with their ration of prices. The hypothesis will be tested by constructing values of T^* for each firm.

To extend the analysis, an estimate of frontier efficiency is also presented per firm using Data Envelopment Analysis and Stochastic Frontier Analysis.

5. Empirical Results

This section presents the results of running the OLS regression was ran to obtain estimates for the marginal productivities for the 26 generation plants in 2001. A description of the method for testing the significance of comparisons, the T-test, is presented. Estimates of the the departure from minimum cost combinations using First Order Conditions is then calculated. Benchmarking methods, such as SFA and DEA,

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[7] In their computation, expected life of a plant varies from 29 to 20 years with an average of 8% depreciation rate in 2001. NPC also said that generating plants are tax-.exempt.

[8] Per liter of diesel fuel has 36,042 BTUs while per liter of bunker has 38,823.

are then utilized to determine technical inefficiencies among the plants.

5.1 Production Function Estimation

In the preliminary estimation, a Cobb-Douglas production function following Courville's specification (outlined in the previous section) was ran. The estimation results are:

Table 1 Results of Preliminary Estimation

	MODEL	Regression Results	R^2
1	Courville specification	LOG(Q) = 5.6148 – 0.1486 LOG(K) + 0.4766 LOG(L) + 0.3788 LOG(F) + 0.0000003386 C + 0.0555 U	0.91
	(t-values)	(2.2356)** (-1.5464) (2.1455)** (4.5524)* (3.7399)* (7.5856)*	
2	Courville specification (with all regressors in logs)	LOG(Q) = -4.9947 - 0.0259 LOG(K) + 0.0502 LOG(L) + 0.0264 LOG(F) + 1.0119 LOG(C) + 1.0483 LOG(U)	0.99
	(t-values)	(-14.6938)* (-1.9328)** (2.1261)* (2.1364)* (61.4606)* (44.8176)*	

Note: *, ** and *** significant at 0.01, 0.5, and 0.1 level of significance.

The variable for capital consistently entered with the wrong sign and was statistically insignificant in the first specification. The transcendental logarithmic (translog) production function was then estimated taking the form of:

$$\begin{aligned} \log Q_i &= \log A + \alpha \log K_i - \alpha_1 \log^2 K_i + \beta \log F_i - \beta_1 \log^2 F_i \\ &\quad + \lambda \log L_i - \lambda_1 \log^2 L_i + \delta U_i + \xi C_i + \varepsilon_i \end{aligned} \tag{19}$$

The estimation result is as follows:

$$\begin{aligned} \log Q_i &= -19.8834 + 0.6498 \log K_i - 0.0162 \log^2 K_i + 0.8855 \log F_i \\ &\quad - 0.0323 \log^2 F_i + 0.3119 \log L_i - 0.0389 \log^2 L_i + 1.1544 U_i + 1.0222 C_i \end{aligned}$$

(t values) (-4.0006)* (1.7676)*** (-1.8487)*** (4.3701)*
(-4.3057)* (1.6917)*** (-1.7093)*** (26.0223)* (87.0549)*
R^2=0.9993

The translog production function proved to be the appropriate specification for Philippine generation plants. All the coefficients have the correct signs and are significant at the 0.1 level of significance. The translog specification of the production function implies the presence of second order effects.

The very high R^2 obtained led to doubts as to whether multicollinearity is present in the model. Based on pair-wise correlation coefficients, regressors are not highly correlated with each other.[9] The R^2s obtained in auxiliary regressors are also very low. The possibility of multicollinearity was therefore rejected. Heteroscedasticity, however, was detected. It is corrected by using White Heteroscedasticity Consistent Covariance in running the OLS.

5.2 Averch-Johnson Hypothesis Testing

After conducting diagnostic tests for the production function, the ratio of marginal products is then calculated for each plant. The estimates of α, β and λ indicate that:

$$\frac{MPK_i}{MPF_i} = \left(\frac{0.6498}{0.8855}\right)\left(\frac{F_i}{K_i}\right) = 0.7338\left(\frac{F_i}{K_i}\right)$$
$$\frac{MPK_i}{MPL_i} = \left(\frac{0.6498}{0.3119}\right)\left(\frac{L_i}{K_i}\right) = 2.0834\left(\frac{L_i}{K_i}\right) \qquad (20)$$

The ratio of marginal products is derived by substituting the levels of *K, F* and *L* for each plant. To be able to test the A-J hypothesis, the obtained ratios of marginal products have to be compared with the ratio of input prices. Following the definitions and procedure outlined in the previous section, the ratio of input prices, $\frac{r_i}{v_i}$ and $\frac{r_i}{w_i}$ are calculated for each plant.

Given that the null hypothesis is stated as:

$$\frac{r_i}{v_i} = \frac{MPK_i}{MPF_i} \qquad and \qquad \frac{r_i}{w_i} = \frac{MPK_i}{MPL_i}$$

(21)

which can be restated,

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[9] The highest correlation coefficient obtained is 0.77 for capital and capacity. This level, however, is still not high enough to indicate presence of multicollinearity.

$$\frac{\alpha}{\beta}\frac{F_i}{K_i}-\frac{r_i}{v_i}=0 \qquad \text{and} \qquad \frac{\alpha}{\lambda}\frac{L_i}{K_i}-\frac{r_i}{w_i}=0$$

(22)

$$\frac{\alpha F_i}{K_i}-\frac{\beta r_i}{v_i}=0 \qquad \text{and} \qquad \frac{\alpha L_i}{K_i}-\frac{\lambda r_i}{w_i}=0.$$

To test the significance of the ratios statistically, the following was constructed. Let,

$$T_{iF}^{*}=\frac{\frac{\hat{\alpha}F_i}{K_i}-\frac{\hat{\beta}r_i}{v_i}}{\sqrt{\sigma^2}} \qquad \text{and} \qquad T_{iL}^{*}=\frac{\frac{\hat{\alpha}L_i}{K_i}-\frac{\hat{\lambda}r_i}{w_i}}{\sqrt{\sigma^2}}$$

(23)

in which,

$$\sigma_F^2=\sigma_{\hat{\alpha}}^2\left(\frac{F_i}{K_i}\right)^2+\sigma_{\hat{\beta}}^2\left(\frac{r_i}{v_i}\right)^2-2\sigma_{\hat{\alpha}\hat{\beta}}\frac{F_i}{K_i}\Diamond\frac{r_i}{v_i} \qquad \text{and}$$

$$\sigma_L^2=\sigma_{\hat{\alpha}}^2\left(\frac{L_i}{K_i}\right)^2+\sigma_{\hat{\lambda}}^2\left(\frac{r_i}{w_i}\right)^2-2\sigma_{\hat{\alpha}\hat{\lambda}}\frac{L_i}{K_i}\Diamond\frac{r_i}{w_i}$$

(24)

where

$\sigma_{\hat{\alpha}}^2=$ estimated variance of $\hat{\alpha}$

$\sigma_{\hat{\beta}}^2=$ estimated variance of $\hat{\beta}$

$\sigma_{\hat{\lambda}}^2=$ estimated variance of $\hat{\lambda}$

$\sigma_{\hat{\alpha}\hat{\beta}}=$ estimated covariance between $\hat{\alpha}$ and $\hat{\beta}$,

where $\hat{\alpha}$ and $\hat{\beta}$ are the linear regression estimates of α and β

$\sigma_{\hat{\alpha}\hat{\lambda}}$ = estimated covariance between $\hat{\alpha}$ and $\hat{\lambda}$, where $\hat{\alpha}$ and $\hat{\lambda}$ are the linear regression estimates of α and λ.

If F_i, L_i and K_i are considered nonstochastic, under the null hypothesis, T^*_{iF} and T^*_{iL} has a Student *t*-distribution with *n*-*k* degrees of freedom with *n* as the number of observations and *k* as the number of parameters in the regression. The region of rejection consists of negative and low values of T^* (Courville, 1974).

Rejection of the null hypotheses confirms overcapitalization since rejection of H_0 due to low values of T^* also leads to the rejection of

$$\frac{\alpha F_i}{K_i} - \frac{\beta r_i}{v_i} > 0 \qquad \text{and} \qquad \frac{\alpha L_i}{K_i} - \frac{\lambda r_i}{w_i} > 0 \tag{25}$$

and thus the alternative hypotheses

$$\frac{r_i}{v_i} > \frac{MPK_i}{MPF_i} \qquad and \qquad \frac{r_i}{w_i} > \frac{MPK_i}{MPL_i}$$

(26)

are not rejected.

The values of T^*_{iF} and T^*_{iL} are presented in Tables 2 and 3. The results confirm the existence of overcapitalization in all generation plants in the sample. Consistent with the Averch-Johnson analysis, firms under rate-of-return regulation tend to have higher values of $\frac{K}{F}$ and $\frac{K}{L}$ than is optimal. These results are consistent with previous studies done in the USA such as those of Courville (1974) and Spann (1974).

Table 2 T^*_{iF} Values of Generation Plants

PLANTS	$\frac{MPK_i}{MPF_i}\left(\frac{F_i}{K_i}\right)$	$\frac{r_i}{v_i}$	T^*_{iF}
ENRON - SUBIC (108 MW)	0.000906076	0.004546828	-3.624658401
EDISON	0.000427709	0.003250886	-3.998919831
BAUANG FPPC	0.000720892	0.003045238	-3.380868191
MASINLOC COAL FIRED 1 & 2	0.000003271	0.002571583	-4.368668090
SUAL COAL-FIRED PP 1 & 2	0.001666066	0.003456936	-1.752990847
SUCAT 2 & 3	0.016936142	0.000364031	1.733954358
MALAYA 1 & 2	0.002822026	0.001051932	1.150813893
HOPEWELL G T (UNIT #1-3)	0.004338739	0.002031093	0.981739876
HOPEWELL TILEMAN (FT)	0.000632944	0.001948692	-2.765633502
CALACA COAL-FIRED 1	0.000007998	0.001697303	-4.365093883
CALACA COAL-FIRED 2	0.000120575	0.002918360	-4.307288325
BATAAN S C BLK. A & B	0.001067364	0.002535258	-2.118340314
ENRON – PINAMUCAN	0.002472786	0.002553548	-0.060766856
MAGELLAN D P P	0.000231464	0.002788537	-4.194563268
PAGBILAO COAL FIRED U#1	0.000097963	0.003067634	-4.325654533
PAGBILAO COAL FIRED U#2	0.000093202	0.003027193	-4.327726361
CEBU DIESEL 1	0.001050343	0.000354438	1.212408005
CEBU THERMAL 1	0.000679247	0.001860825	-2.486812105
CEBU THERMAL 2	0.000563898	0.002412743	-3.401135044
GT - LAND BASED 1	0.000010151	0.001963867	-4.364596298
GT - LAND BASED 2	0.000010151	0.002070706	-4.364887521
A C M D C	0.001221280	0.003566090	-2.642135678
POWER BARGE 117	0.000335187	0.003045243	-4.093871617
POWER BARGE 118	0.000577571	0.002990101	-3.662437761
S P P C - GEN. SANTOS	0.000356371	0.001665362	-3.531224032

W M P C – ZAMBOANGA	0.000024353	0.002400372	-4.358819869

Table 3 T_{iL}^* Values of Generation Plants

PLANTS	$\frac{MPK_i}{MPL_i}\left(\frac{L_i}{K_i}\right)$	$\frac{r_i}{w_i}$	T_{iL}^*
ENRON - SUBIC (108 MW)	0.0000000785	0.0000014127	-0.0004365820
EDISON	0.0000001293	0.0000015787	-0.0007102607
BAUANG FPPC	0.0000001479	0.0000010355	-0.0004147079
MASINLOC COAL FIRED 1 & 2	0.0000000260	0.0000024257	-0.0015788349
SUAL COAL-FIRED PP 1 & 2	0.0000040627	0.0000019196	0.0006365154
SUCAT 2 & 3	0.0000000460	0.0000002559	-0.0000077151
MALAYA 1 & 2	0.0000000934	0.0000012267	-0.0002477002
HOPEWELL G T (UNIT #1-3)	0.0000073157	0.0000012063	0.0008639279
HOPEWELL TILEMAN (FT)	0.0000005045	0.0000054707	-0.0032326512
CALACA COAL-FIRED 1	0.0000000456	0.0000034089	-0.0033523725
CALACA COAL-FIRED 2	0.0000000329	0.0000028017	-0.0015952034
BATAAN S C BLK. A & B	0.0000000183	0.0000010412	-0.0004492192
ENRON - PINAMUCAN	0.0000002232	0.0000007454	-0.0001229101
MAGELLAN D P P	0.0000001521	0.0000013572	-0.0007132507
PAGBILAO COAL FIRED U#1	0.0000005797	0.0000059116	-0.0029297165
PAGBILAO COAL FIRED U#2	0.0000006847	0.0000059265	-0.0029194523
CEBU DIESEL 1	0.0000004400	0.0000002060	0.0001376685
CEBU THERMAL 1	0.0000002071	0.0000010537	-0.0005465205
CEBU THERMAL 2	0.0000000601	0.0000013330	-0.0007534709
GT - LAND BASED 1	0.0000000216	0.0000012241	-0.0010358167
GT - LAND BASED 2	0.0000000199	0.0000011245	-0.0009024451
A C M D C	0.0000001504	0.0000054594	-0.0018438081
POWER BARGE 117	0.0000000590	0.0000013367	-0.0006800835
POWER BARGE 118	0.0000000966	0.0000013289	-0.0006173697

S P P C - GEN. SANTOS	0.0000000432	0.0000023134	-0.0019937759
W M P C - ZAMBOANGA	0.0000000281	0.0000032587	-0.0022762679

5.5 Implications of the Averch-Johnson Effect

An important aspect that still needs to be explored is by how much $\frac{K}{F}$ and $\frac{K}{L}$ depart from the minimum cost combination. While the results of the analysis presented earlier confirm overcapitalization among Philippine generating plants, the economic impact of this finding is not yet quantified. The annual cost deviation imposed by the inefficient production of electricity is then estimated.

Deviations Based on First Order Conditions

Following Courville's study, the percentage deviations of actual cost from minimum cost is computed. To obtain the value of the percentage deviation from minimum cost, optimal values for fuel, labor and capital are computed using the first-order condition and the empirical production function.[10]

The following system of equations are solved for F_i, L_i and K_i:

$$F_i = \frac{\hat{\beta}}{\hat{\alpha}} K_i \frac{r_i}{v_i},$$

$$L_i = \frac{\hat{\lambda}}{\hat{\alpha}} K_i \frac{r_i}{w_i}$$

(27)

$$\log Q_i = \log \hat{A} + \hat{\alpha} \log K_i - \hat{\alpha}_1 \log^2 K_i + \hat{\beta} \log F_i - \hat{\beta}_1 \log^2 F_i + \hat{\lambda} \log L_i - \hat{\lambda}_1 \log^2 L_i + \hat{\delta} U_i + \hat{\xi} C_i + \varepsilon_i$$

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[10] Computations are from a cost-minimizing point of view.

Let F_i^* , L_i^* and K_i^* be the solutions to these equations. The percentage deviation from the minimum cost levels is then expressed as

$$\Delta_i = \frac{\left(v_i F_i^A + r_i K_i^A + w_i L_i^A\right) - \left(v_i F_i^* + r_i K_i^* + w_i L_i^*\right)}{\left(v_i F_i^A + r_i K_i^A + w_i L_i^A\right)}$$

(28)

wherein $v_i F_i^A + r_i K_i^A + w_i L_i^A$ represents actual cost and $v_i F_i^* + r_i K_i^* + w_i L_i^*$ represents minimum cost.

On average, the percentage of deviation of actual cost from minimum cost is 72 percent. If indeed this is true, this entails very huge costs incurred from overcapitalization. In all but one of the cases covered, capital needs to be decreased in all plants. On average, capital should be decreased by 77 percent. However, 16 out of 26 plants need to reduce their capital by more than 90 percent. Both fuel and labor, on the other hand, need to be increased. There are five plants that need to increase their fuel inputs by an average of 30 percent. Removing these outlier plants, the remaining plants should reduce their fuel inputs by 67 percent. Labor employed needs to be increased in 9 out of 26 plants by an average of 81 percent. For the rest of the plants, labor should be decreased by 21 percent to attain minimum costs.

It should be noted, however, that first order conditions of the empirical production function is a conceptual framework that abstracts from the conditions of plant operations. Courville (1974) himself noted that "a completely satisfactory answer to the computation of the percentage deviation from minimum cost is difficult to obtain." It should also be mentioned that a negative value of Δ_i occurred in one of the samples.[11] The results presented here are thus for the purposes of theoretical exposition only and cannot be used in actual benchmarking by the regulator.

To curtail the deficiencies of the FOC estimates, newer methods are employed to estimate efficient input and output combinations. As Coelli (1998) put it, "the production function of the fully efficient firm is not known in practice and thus, must be estimated

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[11] This problem was also present in Courville's study in which 6 out of 105 plants in the USA have negative Δ_i values.

from observations on a sample of firms in the industry." The advent of incentive regulation led to rapid developments in benchmarking methodologies such as Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA). A study of international regulation practices concluded that frontier methods are suitable at initial stages of regulatory reform when a priority objective is to reduce the performance gap among the utilities through firm-specific efficiency requirements (Jamasb and Politt, 2000). Frontier methods that estimate the efficient performance frontier based on the best practice in a sample of firms is also more useful (as opposed to average benchmarking methods) for the case of the Philippines. Most of the plants are IPPs that are bound by contracts, and the most reasonable way of inducing these firms to produce more efficiently is to benchmark them within their own cohort.

Stochastic Frontier Analysis

The translog and the Cobb-Douglas production functions are the two most common functional forms that have been used in empirical studies on frontier analyses. Although a Cobb-Douglas function has also been estimated,[12] the analysis will focus on the translog production function specified as:

$$\begin{aligned}\log Q_i &= \log A + \alpha \log K_i + \alpha_1 \log^2 K_i + \beta \log F_i + \beta_1 \log^2 F_i \\ &\quad + \lambda \log L_i + \lambda_1 \log^2 L_i + \chi K_i F_i + \tau K_i L_i + \rho F_i L_i + v_i - u_i\end{aligned}$$

(29)

The SFA is estimated using the FRONTIER 4.1 program of Tim Coelli. The estimation assumed a half-normal distribution of the inefficiency term and the firm specific inefficiency term u_i is assumed to be constant over time.

The measures of technical efficiency relative to the production frontier are presented in Table 4 taking a value between zero and one. If a plant has an efficiency index of 0.7, this means that it can produce the same level of output using only 70 percent of its current inputs.

The estimated results show that the most efficient electricity generating plants are

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[12] The results of the Cobb-Douglas estimation are not robust, with most coefficients having the wrong signs or being statistically insignificant.

ACMDC and Malaya 1 & 2 which are using almost 100 percent of their current inputs to produce output, while Hopewell Tileman FT could have used only 9 percent of its inputs for its current level of outputs. Even when benchmarked among them, the plants have a mean efficiency of only 60 percent, implying that to produce the current level of electricity, 40 percent of the inputs could have been freed.

Table 4 Technical Efficiency Estimates based on SFA

PLANT	**EFF**
A C M D C	0.9996
MALAYA 1 & 2	0.9996
GT - LAND BASED 2	0.9985
CEBU THERMAL 2	0.9778
PAGBILAO COAL FIREDU#2	0.9655
CALACA COAL-FIRED1	0.9435
PAGBILAO COAL FIRED U#1	0.9415
SUCAT 2 & 3	0.8968
CALACA COAL-FIRED 2	0.8252
S P P C - GEN. SANTOS	0.7747
GT - LAND BASED 1	0.7158
ENRON - PINAMUCAN	0.6483
HOPEWELL G T (UNIT #1-3)	0.6221
BAUANG FPPC	0.6133
SUAL COAL-FIRED PP 1 & 2	0.5809
CEBU DIESEL 1	0.4570
ENRON - SUBIC (108 MW)	0.4372
W M P C - ZAMBOANGA	0.3924
POWER BARGE 117	0.3858
POWER BARGE 118	0.3722
MASINLOC COAL FIRED 1 & 2	0.3191
CEBU THERMAL 1	0.2920
EDISON	0.2383
MAGELLAN D P P	0.2050
BATAAN S C BLK. A & B	0.1476
HOPEWELL TILEMAN (FT)	0.0954
Mean Efficiency	**0.6094**

Data Envelopment Analysis

In order to compare the results obtained in SFA, a nonparametric DEA method was ran. An input oriented DEA model with only one output (electricity generated in MWh), three inputs (labor, fuel and capital) and two environmental variables (capacity and capacity utilization) was used. The two environmental variables entered as an output since both capacity and capacity utilization represent activity levels or performance measures.[13]

Of the two alternative assumptions about the returns to scale, the variable returns to scale (DEA-VRS) was chosen instead of the constant returns to scale (DEA-CRS). The assumption of the latter, that plants are operating at an efficient scale, does not hold true in the case of Philippine generation plants. Comparisons against the VRS frontier ensure that plants with similar levels of outputs and inputs are compared against each other. Sole CRS frontier estimation can lead to the danger of larger plants being compared to smaller plants, and vice versa. Nevertheless, DEA-CRS was still computed to allow for the derivation of scale efficiencies. Efficiency estimates at DEA-VRS and DEA-CRS, as well as scale efficiencies and returns to scale are reported in Table 5.

Table 5 DEA-VRS and DEA-CRS Efficiency Estimation

PLANTS	VRS-TE	CRS-TE	SCALE	RTS
MASINLOC COAL FIRED 1 & 2	1	1	1	-
SUAL COAL-FIRED PP 1 & 2	1	1	1	-
SUCAT 2 & 3	1	1	1	-
CALACA COAL-FIRED 1	1	1	1	-
PAGBILAO COAL FIRED U#1	1	1	1	-
PAGBILAO COAL FIRED U#2	1	1	1	-
A C M D C	1	1	1	-
BATAAN S C BLK. A & B	1	0.857	0.857	drs
CEBU THERMAL 2	1	0.836	0.836	irs
MALAYA 1 & 2	1	0.816	0.816	drs
CEBU DIESEL 1	1	0.572	0.572	irs
GT - LAND BASED 2	1	0.267	0.267	irs
GT - LAND BASED 1	1	0.253	0.253	irs
W M P C - ZAMBOANGA	0.939	0.618	0.658	irs
S P P C - GEN. SANTOS	0.902	0.686	0.76	irs
HOPEWELL TILEMAN (FT)	0.796	0.626	0.786	irs
CALACA COAL-FIRED 2	0.762	0.747	0.981	irs
HOPEWELL G T (UNIT #1-3)	0.685	0.411	0.6	irs
ENRON – PINAMUCAN	0.639	0.574	0.899	irs
POWER BARGE 117	0.625	0.505	0.808	irs

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[13] According to www.deazone.com, “a key aspect of DEA is incorporating environmental factors into the model as either inputs or outputs.” Environmental variable enters as input when the variable represents resources available to units, while when it represents activity levels or performance measures, the variable enters as output.

ENRON – SUBIC (108 MW)	0.6	0.55	0.916	irs
MAGELLAN D P P	0.527	0.332	0.63	irs
POWER BARGE 118	0.469	0.41	0.875	irs
EDISON	0.468	0.343	0.733	irs
BAUANG FPPC	0.432	0.401	0.927	irs
CEBU THERMAL 1	0.358	0.303	0.845	irs
Mean Efficiency	**0.658**	**0.816**	**0.808**	

There are seven plants in the frontier in DEA-CRS, while ten firms are in the DEA-VRS model. The frontier provides a yardstick against which to judge the comparative performance of all other plants that do not lie on the frontier. Generating plants that form the efficient frontier use the minimum quantity of inputs to produce the same quantity of outputs as other similar plants, such that they have the highest ratios of output to input. These plants on the frontier “envelope” the others in the sample, and thus define the best practice frontier of the sample.

Based on the VRS-Technical Efficiency (VRS-TE) estimates, on average, firms that are not on the frontier should be able to reduce their inputs by 34.2 percent without having to reduce their output. For example, the technical efficiency score of Power Barge 117 is 0.685. This score indicates that the plant could produce the same level of output with only 68.5 percent of the inputs it currently uses. Similarly, one minus this score represents the proportionate reduction in all inputs required to reach the frontier.

It is important to note that this best practice level of performance for this plant is based on the observed performance of its peers or the plants in the sample that use broadly similar input to input and output to output mixes, and not upon a pre-conceived or externally imposed notion of what best practice performance is or should be. In the case of Power Barge 117, its peers are identified to be Sucat 2 and 3, Pagbilao Coal Fired U#1, ACMDC, Sual Coal Fired PP 1 & 2, and Cebu Diesel 1.

DEA-VRS also reports scale efficiencies. A scale efficient plant is one that is able to produce a similar proportionate increase in output for a proportionate increase in input. That is, if inputs are increased by 20 per cent, a scale efficient plant would be able to produce 20 per cent more outputs. Generation plants in this position are known to have constant returns to scale, and are scale efficient. Among the 26 firms, there are currently seven plants that are operating on constant returns to scale. A plant that had an increase in inputs of 20 percent, and an increase in outputs of greater than 20 per cent, is considered to have increasing returns to scale. For a similar increase in inputs, a distributor that produced less than a 20 per cent increase in output is said to have decreasing returns to scale. Thus, based on the DEA-VRS results, 17 plants need to increase production while two plants need to reduce production until they reach the more efficient point of production at constant returns to scale.

It would appear that there are inconsistencies between the rankings of SFA and DEA. It should be noted that since the DEA technique allows the data to determine the shape of the frontier, plants that use different combinations of inputs to produce different combinations of outputs can be frontier efficient. The inconsistent ranking of some plants are found to be due to the absence of a peer group for these five plants. When Masinloc Coal Fired, Malaya 1& 2, Bataan S-Block A&B, Pagbilao Coal Fired U#2, and GT-Land Based are removed from the sample, the results of DEA efficiency estimates are much closer to that of SFA estimates.

Estimation Issues

When compared to the results of DEA and SFA, the FOC results appear to be too high. One possible explanation is that prices might have been distorted leading to very different marginal productivities and price ratios. Another might be that rate of return is very low when risk is factored in. The WB study gave the Philippines very high risk rating compared to other countries in ASEAN. Despite this fact, however, results of SFA and DEA, both of which do not incorporate prices, show huge inefficiencies even when the plants are benchmarked among themselves and not on the minimum cost.

6. Concluding Remarks

This essay aims to empirically investigate whether the Averch-Johnson effect of ROR regulation applies to the generating subsector of the electricity industry in the Philippines. The empirical results obtained are consistent with the hypothesis that the rate of return regulation induces firms to overcapitalize. Even when plants are benchmarked against each other, it is found that overcapitalization still persists.

The differences in the cost deviation calculated through FOC, SFA and DEA shows that there might be some deficiencies in the estimation of the A-J Model. Given this, it is thus suggested that the model be recalculated using a rental rate of capital adjusted for risk through the use of models incorporating CAPM, among others. The reason for the price distortion, if any, should also be traced. Should the problem be the estimation of marginal productivities, the reasons for its existence should be looked up for each company.

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