Is Capital Investment Indeed Not Affected by the Market Cost of Capital in the Regulated Energy and Utility Industry? A Reexamination of the Averch-Johnson Model

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Abstract

The Averch-Johnson model provides a classic depiction of the behavior of a regulated monopoly firm. It has become one of important models and has found wide applications especially in energy and utility industry. The traditional A-J model assumes that regulated or fair rate of return is exogenous to but not affected by the market cost of capital, therefore, demand for capital (hence output) is not responsive to the change in the cost of capital, a result that contradicts well-established phenomenon in business world. In this paper, we show that the capital investment could indeed respond to a change in the cost of capital if such a change affects the fair rate of return. Consequently, the traditional Averch-Johnson model is only a special case of a more general outcome.

Keywords: Averch-Johnson effect, rate-of-return regulation, regulated monopoly

1. Introduction

The Averch-Johnson model (Averch and Johnson, 1962; Bailey and Malone, 1970; Yang and Fox, 1994) or A-J provides a classic depiction of the behavior of a regulated monopoly firm. It has become one of important models in microeconomics text since and has found wide applications especially in energy and utility industry, among other regulated industries, across the world (Note 1). Even though some states in the US deregulated the utility industry, some have re-regulated the industry due to rapidly increasing oil price. This is particularly true in the developing countries that import oil from abroad. As such, the rate-of-return regulated monopoly or the A-J model still remains empirically relevant from both theoretical and practical aspects. In a typical A-J model in which a company uses two inputs, labor L and capital K to produce output in a monopoly market, the firm's output and price decision are affected by the regulatory agency's "fair rate of return", which may very well depend on its cost of capital.

The comparative static properties of the A-J model indicate that rate-of-return regulation creates an incentive for firms to utilize too much capital in the production process. That is, a regulated monopolist has the tendency to substitute capital for labor to increase the size of its rate base, the well-known A-J effect (Averch and Johnson, 1962; Hayashi and Trapani, 1976).

The literature regarding the empirical tests of the A-J hypothesis has mixed results. Some studies have supported the hypothesis (Courville, 1974; Petersen, 1975; Hayashi and Trapani, 1976; Hsu and Chen, 1990), while others have rejected the hypothesis (Moore, 1970; Barron and Taggert, 1977; Kanemoto and Kiyono, 1995; Kidokoro, 1998; Vitaliano and Stella, 2009; Cambini and Rondi, 2010; Buranabunyut, and Peoples, 2012).

One of the paradoxical results in the literature is that *demand for capital (hence output) is not responsive to the change in the cost of capital.* This result contradicts that of an unregulated firm in which demand for capital is clearly a function of cost of capital. As a consequence, there exists a testable difference (Bailey, 1973, pp129) between two models in terms of firm's response. As will be demonstrated, this result is only a special case of a more general outcome. It can be shown that demand for capital does respond to some moderate changes in the market cost of capital.

The traditional A-J model assumes that *regulated or fair rate of return (s)* is exogenous and not to be affected by the market cost of capital. However, the fair rate of return *s* is the rate of return allowed by the regulatory agency on plant and equipment in order to compensate the firm for its market cost of capital *r*. Thus, the increase in *r* can be used to substantiate a proportionate increase in the *s* (Averch and Johnson, 1962; Hayashi and Trapani, 1976). In the empirical study, Joskow (1972) has concluded that capital costs are a significant basic component of the allowed rate of return. He has also found the rate of return is positively associated with the cost of debt, an important component of cost of capital. His result clearly indicates the close connection between cost of capital and fair rate of return.

Other factors can cause a change in fair rate of return as well. For example, the Texas Public Utility Commission voted to allow electric generators to charge up to 50% more on wholesale power to cover the financial cost emanated from increased demand for electricity in hot Texas summer recently (Smith, 2012). It is to be noted that the cap is only on wholesale power (generators), not on retail electricity suppliers who auction for the best prices from the power generators. The change in price that wholesale generators can charge is equivalent to a change in regulated rate of return *s* as a result of change in financial cost of capital *r* in the A-J model. The raised cap on *s* would provide incentives for energy and utility companies to build more generating plants.

Technically speaking, a rise in material costs such as fuel cost is expected to lead to increased price, which in turn gives rise to a change in rate of return of the utility company. A change in the company's rate of return will change the beta coefficient in the Capital Asset Pricing Model. As is well known, a change in beta is expected to cause change in cost of capital. In sum, a noticeable increase in material cost can increase cost of capital, which can in turn affect regulated rate of return.

The motivation of this paper is twofold. (1) In the empirical literature, it is shown that the rate of return is associated with the market cost of capital. In fact, it is standard practice in many countries to calculate the cost of capital each time regulated rate of return are reset. (2) None of the above theoretical papers deals with the effects of market cost of capital on the fair rate of return. For policy implementation, we need to expand or extend the traditional regulation model to explore the behavior of a regulated monopoly firm in reality. By relaxing the assumption that the fair rate of return is exogenous in the A-J model developed by Averch and Johnson (1962) and Bailey (1973), we consider that the rate could be affected by the market cost of capital to improve the usefulness of the model. To the best of our knowledge, the results presented in this paper have not been investigated yet and as such are expected to fill a void in the regulation literature. In the following section, we describe the theoretical framework and reevaluate the comparative statics of the A-J Model. Conclusions are presented in the Section 3.

2. Reevaluation of the Comparative Static of the A-J Model

Following Bailey (1973), the A-J model can be formulated as below:

$$\underset{L,K}{\text{Maximize}} \quad \pi = R(L,K) - wL - rcK \tag{1}$$

$$\text{Subject to} \quad R(L,K) - wL \le scK \tag{2}$$

$$L \ge 0$$
$$K \ge 0$$
$$s > r$$

The first-order condition, assuming $L \ge 0$, $K \ge 0$ and $s > r$, are

$$(1-\lambda)(R_L - w) = 0 \text{ or } R_L = w \text{ for } \lambda \ne 1 \tag{3}$$

$$(1-\lambda)R_K - rc + \lambda sc = 0 \text{ or } \lambda = (rc - R_K)/(sc - R_K) \tag{4}$$

$$scK - R(K,L) + wL = 0 \tag{5}$$

We follow the convention of Baumol and Kievorick (1970), Bailey (1973) to have $0 < \lambda < 1$.

Where

λ = Lagrange multiplier of the A-J model

R_L = marginal revenue product of labor L

R_K = marginal revenue product of capital K

$R(K,L) = pq$ = total revenue generated from the product

$p = p(q)$ = inverse demand function

$q = q(K,L)$ = production function

s = fair rate of return on investment

r = market cost of capital

c = acquisition cost per physical unit of capital

w= wage rate

To derive the comparative statics in a systematic way, we differentiate totally equations (3), (4) and (5) to obtain following equation system:

$$\begin{bmatrix} (1\text{-}\lambda)R_{LL} & (1\text{-}\lambda)R_{LK} & w-R_L=0 \\ (1\text{-}\lambda)R_{KL} & (1\text{-}\lambda)R_{KK} & sc-R_K \\ w-R_L=0 & sc-R_K & 0 \end{bmatrix} \begin{bmatrix} dL \\ dK \\ d\lambda \end{bmatrix} = \begin{bmatrix} (1\text{-}\lambda)dw \\ drc-\lambda dsc \\ -Ldw-Kdsc \end{bmatrix} \tag{6}$$

$$\text{or } A \cdot B = D$$

From Cramer's rule, we have

$$\frac{dK}{dr} = \frac{\begin{bmatrix} (1\text{-}\lambda)R_{LL} & (1-\lambda)dw/dr & w-R_L=0 \\ (1\text{-}\lambda)R_{KL} & c-c\lambda(ds/dr) & sc-R_K \\ w-R_L=0 & -L(dw/dr)-cK(ds/dr) & 0 \end{bmatrix}}{\det|A|}$$

$$= \frac{L(dw/dr)-cK(ds/dr)}{sc-R_K} \tag{7}$$

Where $dK/dr = -cK(ds/dr)/(sc-R_K)$ due to $dw/dr=0$. Since it can be proved easily (Baumol-Klevorick, 1970, and Bailey 1973) that $R_K < sc$, the sign of dK/dr is dependent upon that ds/dr. As a result, the well-known result is clearly a special case of $ds/dr=0$ in equation (7). Indeed, for small increase in the cost of capital r, the fair rate of return s may not be affected. However, as mentioned before, for a moderate or large increase in the cost of capital, the fair rate of return could very likely increase to compensate for the loss in profit (Hayashi and Trapani, 1976; Averch and Johnson, 1962). In light of this result, the sign of dK/dr must be determined empirically. The validity of $dK/dr=0$ is hinged upon the assumption that the change in cost of capital is very small.

To verify the propositions of this paper, we simulate the A-J model based on a CES production function and a linear demand function and report the results in Table 1. As was proved in this paper, amount of capital does not respond to changes in financial cost of capital for the range from r=0.1 through 0.19. That is, within this range, p=0.5336, q=466.27, L=648.27, K=1163.34 but profit keeps decreasing as r increases from 0.1 to 0.19. Note that within the range, s remains at 0.2. As we increase s from 0.2 to 0.21, however, it is found that K changes from 1163.336 to 1103.746 when r changes from 0.18 to 0.19 and s (9th and 11th rows of Table 1). That is to say, when $ds/dr=1$ ($[0.21-0.20]/[0.19-0.18]$), $dK/dr=-5959$ ($[1103.746-1163.336]/[0.19-0.18]$). The fact that dK/dr does not equal zero as asserted in our paper is numerically verified in our simulation.

Table 1. Simulations of the A-J Model[a].

r	s	P	Q	L	K	profit
0.10	0.20	0.5335568	466.4432	648.2695	1163.336	116.3336
0.11	0.20	0.5335568	466.4432	648.2695	1163.336	104.7002
0.12	0.20	0.5335568	466.4432	648.2695	1163.336	93.06688
0.13	0.20	0.5335568	466.4432	648.2695	1163.336	81.43352
0.14	0.20	0.5335568	466.4432	648.2695	1163.336	69.80016
0.15	0.20	0.5335568	466.4432	648.2695	1163.336	58.16680
0.16	0.20	0.5335568	466.4432	648.2695	1163.336	46.53344
0.17	0.20	0.5335568	466.4432	648.2695	1163.336	34.90008
0.18	0.20	0.5335568	466.4432	648.2695	1163.336	23.26672
0.19	0.20	0.5335568	466.4432	648.2695	1163.336	11.63336
0.19	0.21	0.5382017	461.7983	670.1568	1103.746	22.07493

[a]The simulation is based on the following parameters: $q = 0.5\left[0.25(l^{-2}) + 0.75(k^{-2})\right]^{-0.5}$, $p = 1 - 0.001q$, $c = 1$, $w = 0.025$, $r = 0.15$. The simulation is performed using GINO (Liebman *et. al.*, 1986).

3. Concluding Remarks

Half of a century has elapsed since Averch and Johnson published their seminal paper on the behavior of regulated monopoly model. In this paper, we have shown that the capital investment K could very well respond to the change in the cost of capital if such a change will affect the fair rate of return. An increase in oil price will change the rate of return of the utility company. The same can be said if the supply condition is at bottleneck. Consequently, $dK/dr = 0$ is a moot point and as such cannot be used as a testable difference between the constrained and unconstrained profit-maximizing firms. This is because in both cases, capital normally responds to changes in cost of capital. In the realm of practitioners, the concept that a change in cost of capital does not affect the use of capital (hence output) is unthinkable. Thus, its potential usefulness in empirical studies is rather limited. We have shown in this paper that the riddle can be solved if we discard the assumption that cost of capital does not affect fair rate of return in the regulated monopoly model.

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Note

Note 1. As of 2005, more than half of all U.S. use fair rate of return to regulate the electricity industry (Vitaliano and Stella, 2009).