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A Note on Technical Progress in Regulated Firms

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Abstract

This paper deals with the question in which manner regulated firms do engage in technical progress and how the standard results stated by Averch and Johnson (1962) are affected. Compared to unregulated firms our results show (a) that regulated firms do engage in R&D allowing for higher profits by weakening the profit constraint, (b) that this is done in an inefficient manner whenever R&D is (at least) partly a capital good, and (c) that the specifity of the factor augmenting effect of R&D with respect to labor or capital is irrelevant for this outcome.

1. Introduction

A principal question in public sector production refers to the incentives for technical progress and the efficient use of R&D funds. For bureaucracies producing public goods this issue has been discussed in Cantner/Kuhn (1994). In this paper we consider regulated firms' R&D activities and ask how this may affect the standard results stated by Averch and Johnson (1962). Technical progress may be accomplished by investing R&D funds which are considered as an additional factor of production enhancing the productivity of the other inputs.

With respect to the traditional production factors, capital and labor, it is well known that in the presence of rate of return regulation (RoR-regulation), the firm employs more capital and produces more output than in the uncontrolled situation. With respect to this result some interesting points are explored in the paper:

First, usually R&D activities provide for a higher profit by increasing the productivity of inputs; is it possible to appropriate such profits under RoR-regulation? Secondly, is R&D accomplished in an efficient and optimal manner, or under what conditions could we expect inefficiencies? Finally, since profit regulation is tied to the factor capital, do the results depend on the factor specific augmenting effect of R&D?

In order to give an answer to theses questions we proceed as follows. In 2 we restate the standard model of RoR-regulation. In 3 we introduce technical progress and implement it into the model. A summarizing 4 concludes our note.

2. RoR-Regulation

We consider a firm which produces a private good (e.g. electrical power) under monopolistic conditions. The output q is produced with labor L and capital goods K:

$$q = q(L,K) \quad , \tag{1}$$

assuming the production function to be twice continuously differentiable and partially as well as globally concave. Every unit of labor is paid a wage w and each unit capital earns the interest rate r. On the supply side the firm is facing a demand function $p(q)$ with $p'(q)<0$. Without engaging in technical progress the firm attempts to maximize the following profit function with profit π:

$$\pi = p(q)q(L,K) - wL - rK \tag{2}$$

The firm under consideration underlies a public regulation allowing for a certain level of profit only (RoR-regulation). This level is determined by a rate of return on capital which may not exceed α and whose lower bound are the unit cost of capital, r. Thus, the profit constraint reads as follows:

$$\pi + rK \leq \alpha K \, , \quad \alpha > r \tag{3}$$

Now, the regulated firm's objective is to maximize the profit function (2) subject to the regulative constraint on profits (3). Developed by Averch and Johnson (1962) the well known result is that the firm under consideration employs more capital and produces more output than in an uncontrolled situation. This is the socalled Averch-Johnson effect (A-J effect).

3. Implementing technical progress

To give an answer to the questions raised in the introduction we implement technical progress into our model given by (1)-(3). To accomplish technical progress the firm may hire R&D-units R which could normally consist of labor input such as researchers and scientists as well as capital input like sophisticated machines (hard- and software). The share of R which belongs to capital is denoted by σ, the one which belongs to labor consequently $1-\sigma$. R&D labor and R&D capital are paid the wage rate w and the interest rate r respectively. The effect of any R&D engagement may be labor and/or capital augmenting (as measured in efficiency units) thus allowing for a higher output by using the same physical amount of labor and capital respectively. The modified model now reads:

$$q = q\big(a(R)L, b(R)K\big) \tag{4}$$

$$\pi = p(q)\,q - w\big[L+(1-\sigma)R\big] - r\big[K+\sigma R\big] \tag{5}$$

$$\pi \leq (\alpha - r)\,[K+\sigma R] \tag{6}$$

The functions $a(R)$ and $b(R)$ represent the factor augmenting effect of technical progress and both are assumed to be concave, i.e there are diminishing returns to R&D efforts. Moreover it has to be noted that the share of R&D which belongs to capital input softens the profit constraint in (6).

The unregulated firm maximizes (5) which leads to the well-known result that all inputs are used until the factor price to be paid equals the value marginal product of the respective factor. For the input factor R&D this condition reads:

$$[p_q q + p(q)](a_R + b_R) = w(1-\sigma) + r\sigma \tag{7}$$

This is to be interpreted as follows: the firm will engage in R&D until the marginal costs $w(1\text{-}\sigma)+r\sigma$ balances the value marginal product of R&D efforts. A statement equivalent hereto is found in Dasgupta/Stiglitz (1980).

The regulated firm, however, maximizes (5) subject to the constraint (6) taken as equality. We obtain the following conditions for an optimal solution where λ is the non-negative Lagrange-multiplier ($0<\lambda<1$):

$$\frac{\partial \mathcal{L}}{\partial L} = (1-\lambda)\Big[\big(p_q q + p(q)\big)q_L - w\Big] = 0 \tag{8}$$

$$\frac{\partial \mathcal{L}}{\partial K} = (1-\lambda)\big(p_q q + p(q)\big)q_K + \lambda\alpha - r = 0 \tag{9}$$

$$\frac{\partial \mathcal{L}}{\partial R} = (1-\lambda)\Big[\big(p_q q + p(q)\big)\big(a_R + b_R\big) - w(1-\sigma) - r\sigma\Big] + \lambda\sigma(\alpha - r) = 0 \tag{10}$$

From (8) and (9) we obtain the condition for the optimal combination of labor L and capital K. For the unregulated firm the condition must hold that relative factor prices equal relative productivities. In the regulated case we obtain:

$$\frac{q_L}{q_K} = \frac{w(1-\lambda)}{r-\lambda\alpha} > \frac{w}{r} \tag{11}$$

The inequality in (11) holds whenever $\alpha > r$ ($r/\alpha > \lambda > 0$) which is satisfied by assumption (see (3)). Thus, this condition repeats the standard result of the A-J-effect that capital is used in excess.

The condition for the use of R&D is more interesting. For the efficient use of R&D relative to labor as accomplished by the unregulated firm we obtain the following:

$$\frac{a_R + b_R}{q_L} = \frac{w(1-\sigma) + r\sigma}{w} \tag{12}$$

For the regulated firm, however, the comparable optimality condition reads:

$$\frac{a_R + b_R}{q_L} = \frac{w(1-\sigma)(1-\lambda) + \sigma(r-\lambda\alpha)}{w(1-\lambda)} \tag{13}$$

To interpret the R&D activities of regulated firms on this basis two main effects of the invested R&D funds have to be taken into account. First, like in the unregulated case the factor augmenting effect of R&D activities provides for a higher profit per unit of output (see first term in (10)). Although regulation is tied to capital input this result holds independently of which factor is affected by R&D; it is only relevant that total profits rise.

Secondly, R&D funds add to capital K by the share σ. Higher profits are thus allowed for (see second term in (10)). Investigating equation (13) gives an account of the efficiency of R&D-activities. An inefficient use of R&D is observed whenever R&D adds to the capital stock. The relevant condition to be analyzed is deduced by comparing (12) with (13):

$$(r-\lambda\alpha)\sigma \leq (1-\lambda)r\sigma \tag{14}$$

Whenever $\alpha > r$, $1 > \lambda > 0$ and $\sigma > 0$, R&D will be accomplished at a level which is above the one of the unregulated monopoly case. These conditions imply:

(i) The regulation constraint has to be binding, i.e. $\lambda > 0$. Otherwise the firm acts like the unregulated monopolist.

(ii) The share of R considered as capital input is larger than zero, $\sigma > 0$. Otherwise R&D efforts do not add to total capital and consequently do not increase total profit other than by enhancing factor productivity.

(iii) The regulation rule states $\alpha > r$. Otherwise there would be no profits allowed in both cases with and without R&D activities. Since the profit motive does not exist in this case, it is not clear what other incentives for technical progress could be found.

However, if only one of these conditions is not satisfied, R&D will be accomplished efficiently although the firm is profit regulated. For (i) and (iii) this is obvious. However, (ii) might need some more interpretation. In the case of $\sigma = 0$, R&D consists only of labour input. Thus, R&D workers will be hired until their value marginal product is equal to their marginal labor costs. Since there is no additional effect of further R&D input to weaken the capital constraint and to allow for higher profits, technical progress is accomplished efficiently. However, in our view this is a unrealistic case and we usually expect $\sigma > 0$.

4. Conclusion

In this paper we have shown that under fairly realistic conditions firms facing a rate of return regulation will have an incentive to engage in technical progress. On the one side, (as in the unregulated case) those activities improve the productivity of the other input factors; on the other side, the regulatory constraint on capital may be relaxed by the share of R&D capital thus allowing for higher profits. Compared to the unregulated case, R&D input might be undertaken inefficiently by the effect of relaxing the regulatory constraint. This result does depend on the nature of R&D to be of the labor or the capital type. Inefficiencies occur only in the latter case. The effect of R&D on the productivities of the traditional production factors, however, has no influence on this outcome. Profits only have to increase, no matter whether this is accomplished by labor and/or capital augmentation.

Finally, for the interpretation of our results it is to be considered that in our model the regulatory mechanism is given exogenously as usually done in the Averch-Johnson case. To apply this analysis to models with endogenous regulatory schemes would be an interesting task for future research.

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