A list of Working Papers on the last pages

No. 71

Technology, Pricing and Investment in Telecommunications*

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* I am grateful to Bo Axell for helpful comments.

I. Introduction

The demand for telecommunication services shows seasonal, weekly and hourly fluctuations. To some extent the variations are predicted but the demand also has a stochastic component. Tariffs of telecommunication services are often fixed during long periods partly because of the cost of changing prices, partly because of institutional restrictions. Investments to increase the capacity takes time to plan and effect. The problem which teleadministrations has to solve is thus to determine prices and capacity before the actual stochastic demand is known.

Technological change is fast in the area of telecommunications. For transmissions satellites and optical fibres are used and electronic switches replace electromechanical. Subscribers terminal equipment increase in complexity and many new facilities like viewdata are introduced. Some of this technological development, particularly the introduction of electronic switches, alters drastically the possibility to incorporate the stochastic fluctuations in demand in the pricing decisions. This tendency was stressed already ten years ago by Vickery [6] and has since then been reinforced.

Nowadays, instantaneous adjustments of the prices to variations in demand is most probably technically possible. Why is this technology not introduced by teleadministrations? One common argument against momentary pricing is that it would be too costly. In this paper we show that this argument is dubious and moreover that it neglects the benefits of instantaneous pricing. We analyse the conditions under which investments in this technology increase welfare. We also study the effects on optimal prices, capacity and net revenue.

In section II the model is presented. Section III presents the results when the new technology is introduced. Section IV gives a numerical example of the costs of introducing the new technology. Section V contains a summary and conclusions.

II. **The Model**

The problem of determining welfare-maximizing prices and capacity with stochastic demand was first studied by Brown and Johnson [2]. They assumed that demand was a function of price and a continuous random variable. We will use a special kind of model in which the demand for a non-storable good like telecommunication services takes on two different levels. This kind of model was used by Andersen [1] and Sherman and Visscher [4, 5]. A single price p and the capacity $\bar{Q}$ has to be determined before the actual demand Q is known. We assume that the demand functions are linear and have the same slope.

(1) $Q_i = A_i - Bp \qquad \text{for } i = 1,2$

where subscript i = 1,2 denotes high and low demand, respectively.

The known probabilities of high and low demand are s and 1-s, respectively. The marginal operating cost is b per unit of output and the marginal capacity cost is β per unit of capacity. We assume that there are no problems of indivisibilities.

The objective function is taken to be the expected value of total benefits minus total costs, E(W)[1]. Since demand may exceed supply at the preset price we need some assumption about the nonprice rationing scheme. For telecommunication services there are generally no queuing system when there is congestion. However, the subscribers have the possibility to repeat the attempt until connection is established. If this were incorporated in the model we would have to consider the cost of the waiting time. Instead we make the reasonable assumption that rationing is random, i.e. all subscribers, irrespective of their willingness to pay, face the same probability to be served first.

The objective function is:

$$(2)\quad E(W) = s[\bar{Q}(A_1-Bp)\ /2B + (p-b)\bar{Q}]$$

$$+ (1-s)[(A_2-Bp)^2/2B + (p-b)(A_2-Bp)] - \beta\bar{Q}$$

When rationing is random we know from Sherman and Visscher [4] that the optimal price is either equal to $(A_1-\bar{Q})/B$ or $(A_2-\bar{Q})/B$, but never in between. We insert the price solutions in (2) and maximize with respect to $\bar{Q}$.

$$(3)\quad p^* = (A_1-\bar{Q}^*)/B \qquad \bar{Q}^* = A_1-B(b+\beta)$$

$$(4)\quad p^* = (A_2-\bar{Q}^*)/B \qquad \bar{Q}^* = (s/2)(A_1-A_2) + A_2 - B(b+\beta)$$

where asterisks denote optimal values.

Solution (3) is optimal for high values of s while (4) is optimal for low values of s. In (3) the price equals $b+\beta$ while in (4) the price is $b+\beta-s(A_1-A_2)/2B$. The expression $(A_1-A_2)/B$ is the vertical distance between the demand functions. When the probability of high demand increases the price decreases and the capacity increases. When s is high enough it becomes optimal to set the price equal to $b+\beta$ and choose the capacity as if there were high demand with certainty.

III **The New Technology**

We now introduce the technology by which prices at once can adjust to the fluctuations in demand. Let p_1 and p_2 denote the price at high and low demand, respectively. The capacity is still assumed to be determined before the actual demand is known.

We assume that the cost function remains linear with the new technology but that both marginal operating and capacity costs are changed to d and δ, respectively. We further make the reasonable assumption that $d>b$ and $\delta>\beta$.

When the price can adjust instantaneously to the variations in demand there is never any nonprice rationing. The objective function is:

$$(5)\quad E(W) = s\left[\bar{Q}(A_1/B-(A_1-\bar{Q})/B)/2 + \left((A_1-\bar{Q})/B-d\right)\bar{Q}\right]$$

$$+ (1-s)\left[(A_2/B-p_2)(A_2-Bp_2)/2 + (p_2-d)(A_2-Bp_2)\right] - \delta\bar{Q}$$

At high demand the price is equal to $(A_1-\bar{Q})/B$ while at low demand the price is either equal to

$(A_2-\bar{Q})/B$ or equal to the marginal operating cost. Inserting the price solutions in (5) and maximizing with respect to $\bar{Q}$ we get:

$$(6) \quad p_1^* = (A_1-\bar{Q}^*)/B \quad p_2^* = d \quad \bar{Q}^* = A_1 - B(d + \delta/s)$$

$$(7) \quad p_1^* = (A_1-\bar{Q}^*)/B \quad p_2^* = (A_2-\bar{Q}^*)/B$$

$$\bar{Q}^* = sA_1 + (1-s)A_2 - B(d+\delta)$$

The expected price, i.e. $sp_1 + (1-s)p_2$, is equal to $d + \delta$. This means that the price will increase when the new technology is introduced. We also see that the expected net revenue will be zero. Before the introduction of the new technology net revenue was negative when solution (4) was optimal. These results agree with Littlechild [3] who analysed the problem of public utility pricing and investment under risk using a state preference approach. He also assumed that price was set after demand is observed.

The capacity will decrease with the new technology if solution (3) is optimal. This is what one would expect since the increased flexibility in prices should allow the capacity to be reduced. However, if solution (4) is optimal we get the interesting result that the capacity may either decrease or increase. It is usually assumed that labor productivity is higher in the manufacturing of electronic switches than in the production of electromechanical switches. We see that even under this plausible assumption the demand for labor in the production on switches may increase if the increase in capacity is large enough.

We further note that the expected welfare with the new technology is the same as if the teleadministration had to preset one price with a perfect nonprice rationing scheme where those who receive the largest consumer surplus were served first. The distribution of the welfare between consumer surplus and net revenue is, however, different.

To test wether the new technology increases welfare we compare (2) and (5) in which the respectively optimal prices and capacity are inserted. To shorten the presentation we give an example and assume that solutions (3) and (6) are optimal.[2] The change in expected welfare from the introduction of the new technology is:

$$(8)\quad \Delta E(W) = B(d^2-b^2)/2 + B(d\delta-b\beta) + B(\delta^2/s-\beta^2)/2$$
$$- \left(sA_1 + (1-s)A_2\right)(d-b) - A_1(\delta-\beta)$$

The possibility to adjust prices increases welfare while the higher marginal operating and capacity costs decreases welfare. Depending on the parameters in the problem (8) may be positive or negative. From (8) we get the following comparative static results:

$$(9)\quad \partial\left(E(W)\right)/\partial B = (d^2-b^2)/2 + (d\delta-b\beta) + (\delta^2/s-\beta^2)/2 > 0$$

$$(10)\quad \partial\left(\Delta E(W)\right)/\partial A_1 = - s(d-b) - (\delta-\beta) < 0$$

$$(11)\quad \partial\left(\Delta E(W)\right)/\partial A_2 = -(1-s)(d-b) \leqslant 0$$

$$(12)\quad \partial\left(\Delta E(W)\right)/\partial s = -B\delta^2/2s^2 - (A_1-A_2)(d-b) < 0$$

where the signs hold under the maintained assumption that $d>b$ and $\delta>\beta$.

In this example we see that the less steep the demand functions and the lower the intercepts, the more likely it is that the new technology is introduced. The higher the probability of high demand, the less probable it is that the new technology is adopted.

As observed previously the introduction of the new technology means that net revenue will be zero, while before it could be negative. If the tele-administration has to cover its costs we would have to add a break-even constraint to (2). To test wether the new technology increases welfare the new formulation of (2) should be used in the comparison above.

IV A Numerical Illustration

To get an estimate of the magnitude of the costs of the type of technology discussed we use Sweden as an example.[3] In 1982 the total number of telephone exchanges in Sweden was 6 755. The number of electronic exchanges increases but there were only 6 running in mid-1981. Of the total number of telephone exchanges about 800 had a function in the tariff-system. The total number of telephones in 1982 was 6.9 million.

Firstly, we estimate the investment costs. In mid-1981 the Swedish Telecommunications Administration (Televerket) estimated the value of the fixed assets to about 67 billion Swedish crowns (SEK) at replacement costs. In 1976 the corresponding figure was about 22 billion SEK, of which telephones made up 3 percent, subscriber lines 32 percent, telephone exchanges (excluding buildings) 26 percent, local circuits 9 percent, trunk circuits 18 percent and buildings 12 percent. These percentages were about the same in 1972 when a similar division of replacement costs was made. Although the cost trends differ somewhat between the items, we use these figures in the example.

We assume that the investments in the new technology only affects switching equipment (excluding buildings) which has a function in the tariff system. Thus the present telephones are used to convey information about the tariffs to the subscribers. Since these 800 telephone exchanges generally are larger than average size and have extra equipment we estimate their share of the total replacement costs of exchanges to 80 percent. This means that about 21 percent of the fixed assets are affected by the investements. We further assume that the new technology raises the replacement costs by 10 - 20 percent because of higher hardware and software costs. Thus, the additional costs of introducing the new technology in electronic telephone exchanges are about 1.4 - 2.8 billion SEK.This can be compared with the investments in the telephone branch made by Televerket in 1980/81 which were 2.8 billion SEK. In this example we ignored the effect of changes in capacity by the introduction of the new technology. The investment costs would naturally be higher if telephones were also affected by the change of technology.

If we assume that the new technology was introduced on top of the present yearly investments and that the investments were proportional to the replacement costs of the items previously separated, then the investment costs in 1980/81 would have increased by some 57 - 115 million SEK, i.e. by 2.1 - 4.2 percent.

Secondly, we estimate the operating costs. In 1975/76 Televerket estimated the total operating costs to 1.1 billion skr, of which telephone exchanges made up 0.3 billion SEK. We assume that the increase in operating costs follows the increase in replacement costs which was about 50 percent from 1975/76 to 1980/81. We further assume that the new technology raises the operating costs by 5-10 percent, which means 18-36 million SEK in 1980/81. If we assume that this cost difference is constant over time then the discounted present value of the increase in operating costs (25 years and 5 %) is 0.3-0.5 billion SEK. Thus, the large costs of introducing the new technology are the investment costs.

This admittedly crude estimation shows that the resistance among teleadministrations against instantaneous pricing is hardly based on cost considerations. Other frequent arguments against momentary pricing are difficulties in forecasting demand and revenues, possible adverse subscriber reactions and increasing problems in dimensioning the telesystem. These arguments should also be carefully scrutinized to assess their proper importance.

V Summary and Conclusion

The telecommunications sector plays a crucial role in any developed economy. As the share of the information sector in the economy increases this importance is enhanced. Telecommunications are also of great interest since the large investments in the sector has a considerable impact on the national economies. This attention is usually reinforced during periods of slow economic growth. It is therefore important that the pricing and investment decisions in this sector are carefully examined.

This paper focuses on the introduction of new technology in the telecommunication sector. In a model with stochastic demand we analysed the effects of introducing a technology which enabled the prices to adjust to the fluctuations in demand. Under the plausible assumption that the new technology raises marginal operating and capacity costs we saw that the optimal prices increased while the capacity could increase as well as decrease. The effect on net revenue was non-negative.
We also gave an example of the conditions under which the technology increased welfare. The less steep the demand functions, the lower the intercepts and the lower the probability of high demand, the more likely was the introduction of the new technology.

The increase in the yearly investment costs of the Swedish Telecommunications Administration by gradually introducing instantaneous pricing was roughly estimated to 2-4 percent. The additional operating costs were estimated to about 1-2 percent of total operating costs. Thus, the resistance among teleadministrations against the new technology is hardly based on cost considerations.

Notes

[1] The usual assumptions for the applicability of partial welfare analysis are made.

[2] Since there are two solutions for each objective function the total number of comparisons are four. The other comparisons are made analogously.

[3] The numerical example is based on interviews with experts at the Swedish Telecommunications Administration (Televerket) and on published and unpublished statistics from Televerket.

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