PRICE, QUALITY, AND REGULATION: AN ANALYSIS OF PRICE-CAPPING AND THE RELIABILITY OF ELECTRICITY SUPPLY

by

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ABSTRACT

This paper examines the relationship between price-cap regulation and the reliability of supply of a private monopoly. Two situations are considered: one in which reliability is excluded from the price-cap; and one in which it is included. If reliability is excluded, it is shown that there is a tendency for the firm to protect profits by lowering reliability when cost increases must be absorbed. Whereas if reliability is included then this tendency is eliminated. However, this inclusion creates an incentive for the firm to exploit the positive relationship between price and reliability when cost increases can be passed on. But this problem can be controlled by lowering the exogenous weight applied to reliability in the price-cap formula.

INTRODUCTION

It is clear that the main objective of price-cap regulation is to protect consumers from excessive price increases. But, as recognised by Vickers and Yarrow (1988), this focus on price should not be to the exclusion of the quality of supply "because a reduction in quality of service would be tantamount to an increase in price " (p.227). Particularly in the context of electricity supply, this issue of quality of supply has been formalised in the notion of reliability: the likelihood of capacity exceeding demand (Kleindorfer and Fernando, 1993). However, although the issue of reliability has been examined to some extent in the literature on the positive theory of public enterprise (Fraser 1993a), apart from a brief discussion by Vickers and Yarrow (1988, Ch9) it has not been considered in the context of electricity privatization and price-cap regulation.[1]

Recently, Braeutigam and Panzar (1993) suggested that price-cap regulation "is a classic case in which practice is far ahead of theory" (p.197), and in this context it is interesting to note from Abraham 91993) in relation to the regulation of Telecom Australia by AUSTEL that as of July 1992 the version of price-cap regulation used "includes a quality of service provision which allows AUSTEL to judge the price of a service to have increased if the quality decreases"(p.7).[2]

The aim of this paper is to contribute to the understanding of the role of quality in price-cap regulation by focusing explicitly on the issue of reliability. In particular, it is intended to examine how the privatized firm evaluates the trade-off between price and reliability for consumers in the face of price-cap regulation.

In this context two types of price-cap regulation will be examined: one where the regulator's price-cap constraint includes only the firm's price; the other where reliability of supply is also included in the price-cap constraint.

The structure of the paper is as follows: Section 1 sets out a simple model of a privatized monopoly firm setting price and capacity in the face of uncertain demand and price-cap regulation which features only the firm's price. This model is the subject of a numerical analysis in Section 2. It is shown that the exclusion of reliability from the regulator's price-cap formula is not necessarily detrimental to consumers. In particular, in the context of cost increases, if the firm is permitted to pass on to consumers a proportion of the cost increase sufficient at least to maintain expected profits, then the associated level of reliability will be increased. Therefore, in this situation consumers are to some extent compensated for the price increase by greater reliability. However, if the firm is forced to absorb the cost increase to the detriment of its level of expected profits, then the firm's response is to minimse the loss of expected profits, then the firm's response is to minimise the loss of expected profits by lowering capacity and hence, the associated level of reliability. Consequenty, in this situation the exclusion of reliability from the price-cap formula means that although consumers are largely protected from the cost increase, this protection is at the expense of lower reliability

Section 3 redevelops the model of Section 1 to include a modified price-cap constraint featuring both price and reliability of supply. In Section 4 this model is subjected a numerical analusis based on the optimal response of the firm to a cost increase in order to provide results which are comparable to those in Section 2. It is shown that including reliability of supply in the price-cap formula eliminates the problem of lower reliability in the situation where the firm is required to absorb the cost increase to the detriment of profits. However, the inclusion of reliability is also shown to create a new problem of over-pricing in the situation where the firm is not required to absorb the cost increase. The paper concludes with a brief summary.

SECTION ONE: THE MODEL - RELIABILITY EXCLUDED

The model is based on that contained in Fraser (1993a) and assumes that the monopoly firm produces a single output which is subject to uncertain demand. The firm's objective is to maximise expected profits by the optimal choice of capacity to satisfy demand which is itself determined by price chosen as a mark-up on the average variable cost of production, but subject to price-cap regulation.

Specifically, demand (d) is a function of price (p) subject to a multiplicative disturbance (θ):

$$d = A\theta g(p) \tag{1}$$

where: $E(\theta) = 1$

$g'(p) < 0$

A = scaling constant.

Sales (s) will be the lesser of actual demand and capacity (k). Consequently, expected sales (E(s)) are given by:

$$E(s) = \int_{0}^{k} A\theta g(p) f(\theta) d\theta + \int_{k}^{\infty} k f(\theta) d\theta \tag{2}$$

Price is given by the mark-up (λ) on (constant) average variable cost (c):

$$p = (1 + \lambda)c. \tag{3}$$

Therefore, expected profits ($E(\pi)$) are given by:

$$E(\pi) = pE(s) - cE(s) - rk \tag{4}$$

where: r = per unit cost of capacity.

Substituting (3) into (4) and simplifying gives:

$$E(\pi) = \lambda cE(s) - rk\,. \tag{5}$$

The price-cap constraint can be written as:

$$(1+\lambda)c/p_0 = b+x \tag{6}$$

where: p_0 = historical price

b,x = regulatory parameters.

Note that b relates to general inflationary conditions (ie RPI) while x relates to firm-specific cost changes. In what follows, general inflation will be assumed to be zero so that the value of b will be set equal to unity. Moreover, the value of x will determine the extent to which the firm is permitted to pass on to consumers specific cost increases (ie x > 0) in the form of higher prices or not pass on specific cost reductions (ie x < 0).

On this basis, the firm's constrained objective is given by:

$$\max_{\lambda,k} \quad \lambda c E(s) - rk - \gamma\{(1+\lambda)c/p_0 - (1+x)\} \qquad (7)$$

which implies the following first order conditions:

$$\frac{\partial E(\pi)}{\partial \lambda} = cE(s) + \lambda c \frac{\partial E(s)}{\partial \lambda} - \gamma c / p_0 = 0 \qquad (8)$$

$$\frac{\partial E(\pi)}{\partial k} = \lambda c(1 - F(k)) - r = 0 \qquad (9)$$

$$\frac{\partial E(\pi)}{\partial \gamma} = (1+\lambda)c / p_0 - (1+x) = 0 \qquad (10)$$

where F(k) = cumulative probability of capacity exceeding demand (ie. reliability).

Since:

$$\frac{\partial F(s)}{\partial x} = \frac{\partial E(s)}{\partial p} c \qquad (11)$$

(8) may be rearranged to give:

$$c\left(E(s)(1-\varepsilon_S) - \frac{c\,\partial E(s)}{\partial p} \right) - \gamma c / p_0 = 0 \qquad (12)$$

where: ε_S = elasticity of expected sales with respect to price.

The first term in (12) represents marginal expected profit from increasing the mark-up. On the assumption maintained in what follows that the price elasticity of expected sales is less than or equal to one, this term will always be positive, so that the price-cap constraint will always be binding. In this situation, the firm's mark-up can be determined from the constraint (10), with (8) yielding the shadow price of the constraint (γ) and (9) yielding optimal capacity and its associated level of reliability.

Consider now a situation where the firm experiences an increase in the average variable cost of production, say due to the imposition of a carbon tax.[3] If the firm is permitted to pass on to consumers all of this cost increase then:

$$\%\Delta c = x \tag{13}$$

and on the basis of (10) the firm's mark-up would remain unchanged. Moreover, with an increase in c and λ unchanged, (9) requires capacity to be adjusted so that reliability is increased (F(k)). Note, however, that with expected sales reduced by the price increase, its impact via (9) on optimal capacity is ambiguous as the increase in reliability could be achievable with less capacity. Nevertheless, it is clear that in the situation where the firm can pass on to consumers all of its cost increase, the undesirable (for consumers) impact on price is to some extent compensated for by an increase in reliability of supply.

In contrast, if the firm is required to absorb all of the cost increase then x is zero and so the mark-up must be reduced such that:

$$\%\Delta(1+\lambda)+\%\Delta c = 0 \tag{14}$$

Moreover, since.

$$|\%\Delta(1+\lambda)| < |\%\Delta\lambda| \tag{15}$$

it follows that:

$$\%\Delta\lambda c < 0 \qquad (16)$$

and on the basis of (9), optimal capacity is reduced with an associated decrease in reliability. Consequently, although the consumer does not experience any price increase following the increase in cost, the associated loss of reliability means that the consumer is not protected entirely from the cost increase.

Considered together, these results imply that for a given percentage increase in c there must be a smaller value of x which, although reducing the mark-up, means that the value of λc is unchanged so that on the basis of (9) reliability is unchanged. This value of x represents the minimum contribution consumers can make via the payment of a higher price to maintaining the firm's expected profits in the face of the cost increase without negatively affecting the reliability of service. However, whether this contribution is sufficient to maintain expected profits at or above their initial level is unclear. In particular, (5) shows that although net operating revenue per unit of expected sales is unchanged with this contribution, because of the higher price not only expected sales but also the associated optimal capacity (consistent with constant reliability) are lower. Consequently, these changes overall have an analytically ambiguous impact on expected profits. Nevertheless, it is clear from (2) that the relationship between the value of x which maintains reliability and the value which maintains expected profits will depend both on the responsiveness of demand to price and on the uncertainty of demand.

Motivated by this analytical ambiguity (and the ambiguity regarding the adjustment to the optimal capacity in the case of $\%\Delta\lambda c = x$), the next section will undertake a numerical analysis of the model of this section. Such an analysis will not only clarify the role of the value of x in determining the relationship between reliability and expected profits, but it will also reveal the sensitivity of this role to key parameter values.

SECTION TWO: NUMERICAL ANALYSIS - RELIABILITY EXCLUDED

To subject the model of Section 1 to a numerical analysis, functional forms for the responsiveness of demand to price and for the uncertainty of demand are required. In what follows it is assumed that demand features a constant elasticity relationship with price:

$$d = A\theta p^{-\varepsilon} \qquad (17)$$

where: ε = elasticity of expected demand with respect to price.

In addition, it is assumed that the distribution of θ is normal. This assumption means that expected sales are given by (see Fraser (1993a):

$$E(s) = F(k)(\bar{d} - \sigma_d Z(k)/F(k)) + (1 - F(k))k \qquad (18)$$

where: $\bar{d} = Ap^{-\varepsilon}$ = expected demand

$\sigma_d = \bar{d}\sigma_\theta$ = standard deviation of demand

σ_θ = standard deviation of θ

$$Z(k) = (1/\sqrt{2\pi})\exp\left[-0.5((1 - k/\bar{d})/\sigma_\theta)^2\right]$$

Finally, the following parameter values have been chosen to represent a "Base Case":

$$A = 1000$$
$$\varepsilon = 0.50$$
$$c_0 = 5$$
$$p_0 = 15 \qquad (\lambda = 2)$$
$$\sigma_\theta = 0.30$$
$$r = 5.$$

Note that these values imply:

$$k_0 = 258.20$$
$$F(k_0) = 0.50$$
$$E(\pi_0) = 982.01.$$

Next, consider a situation where the firm experiences a specific increase in the average variable cost of production (c) of 20% Table 1 gives details of the impact of this change on the key variables for four different values of x.

The results in Table 1 confirm that: if the firm is not permitted to pass on to consumers any of the cost increase (ie. x = 0), then the reliability of supply is reduced by a reduction in optimal capacity (and in expected profits); but if the firm is permitted to pass on all of the 20% increase then reliability is increased. Moreover, the results indicate that a value of x of 6.67% is required for reliability for be maintained at its initial level (ie. 0.50) However, the results also suggest that a higher value of x (ie. 7.76%) is required for expected profits to be maintained at their initial level (ie, 982.01). Nevertheless, in this situation consumers are to some extent compensated for the higher associated price with an increase in reliability from 0.50 to 0.51.[4] Finally, the results suggest that, in the situation where all the cost increase can be passed on, the negative impact of the reduction in demand following the price increase clearly dominates the positive impact of the increase in reliability in determining the adjustment in optimal capacity.

Consider next the sensitivity of the results to the level of demand elasticity. Table 2 contains details of the results for situations of more and less elastic demand. A comparison of the results in Tables 1 and 2 suggests that the requirement for x to be larger to maintain expected profits than to maintain reliability is robust with respect to the level of demand elasticity. Nevertheless, the results in Table 2 suggest that the less elastic is demand the closer are the two values of x in question. However, the results in Table 2 also suggest that the direction of adjustment of optimal capacity in the case of $x = 20\%$ is not robust with respect to the elasticity of demand. In particular, in the case of $\varepsilon = 0.1$ optimal capacity with $x = 20\%$ must exceed initial optimal capacity in order to achieve the level of reliability which satisfies (9), whereas in the other two cases ($\varepsilon = 0.5, 0.9$) the reverse is true.

Finally, consider the sensitivity of the results in Table 1 to the level of demand uncertainty. Table 3 contains details of the results for a situation of more uncertain demand ($\sigma_\theta = 0.50$ instead of 0.30). A comparison of the results in Tables 1 and 3 shows that the requirement for x to be larger to maintain expected profits than to maintain reliability is also robust with respect to the level of demand uncertainty. In particular, there is only a very slight decrease in the value of x required to maintain expected profits (from 7.76% to 7.60%), despite the relatively large increase in the level of demand uncertainty. In addition, the results in Table 3 suggest that the direction of adjustment of optimal capacity in the case of x = 20% is also not robust with respect to the level of demand uncertainty, with optimal capacity smaller in the case of $\sigma_\theta = 0.30$ and larger in the case of $\sigma_\theta = 0.50$.

SECTION THREE. THE MODEL - RELIABILITY INCLUDED

If reliability is not included in the price-cap constraint then this was written in Section 1 as:

$$(1+\lambda)c/p_0 \leq b+x \tag{19}$$

where: p_0 = historical price

b,x = regulatory parameters

However, if reliability is to be included in the price-cap constraint then the constraint needs to be rewritten as:

$$w_1(1+\lambda)c/p_0 + w_2F(k_0)/F(k) \leq b+x \tag{20}$$

where: w_1,w_2 = exogenous weights

$F(k_0)$ = historical level of reliability

As in Section 1, b relates to the general level of inflation (ie RPI)which is assumed to be zero so that b is set equal to unity. Moreover, the value of x relates to firm-specific cost changes and it will determine the extent to which the firm is permitted to pass on to consumers specific cost increases (ie $x > 0$) in the form of higher prices or not pass on specific cost reductions (ie $x < 0$). For example, if the firm experiences a cost increase but x is set equal to zero, then (20) shows that unless the mark-up is reduced to absorb fully the effect of the cost increase on price, the firm is required to increase reliability to an extent consistent with the exogenous weights (w_1, w_2).

On this basis, the firm's constrained objective is given by:

$$\max_{\lambda, k} \quad \lambda c E(s) - rk - \gamma\{w_1(1+\lambda)c/p_0 + w_2 F(k_0)/F(k) - (1+x)\} \qquad (21)$$

which implies the following first order conditions:

$$\frac{\partial E(\pi)}{\partial \lambda} = cE(s) + \lambda c \frac{\partial E(s)}{\partial \lambda} \; \gamma w_1 c / p_0 = 0 \qquad (22)$$

$$\frac{\partial E(s)}{\partial k} = \lambda c(1 - F(k)) - r + \gamma w_2 f(k) F(k_0)/(F(k))^2 = 0 \qquad (23)$$

$$\frac{\partial E(\pi)}{\partial \gamma} = w_1(1+\lambda)c/p_0 + w_2 F(k) - (1+x) = 0 \qquad (24)$$

where $\quad f(k) = \partial F(k)/\partial k$.

Combining equations (22) and (23) and rearranging gives

$$\left\{cE(s)+\lambda c\frac{\partial E(s)}{\partial \lambda}\right\}/\left(\lambda c(1-F(k))-r\right)=-\frac{w_1 c(F(k))^2}{w_2 p_0 f(k)F(k_0)} \qquad (25)$$

Equation (25) shows that the firm maximises expected profits by balancing the marginal contributions to these profits of a higher mark-up or increased capacity with the marginal impact of these changes on the firm's price-cap constraint. In particular, the numerator of the left hand side of (25) can be rearranged to give:

$$c\left(E(s)(1-\varepsilon_s)-c\frac{\partial E(s)}{\partial p}\right) \qquad (26)$$

where ε_s = elasticity of expected sales with respect to price,

so that on the assumption, made in Section 1 of this paper, that:

$$\varepsilon_s < 1$$

it follows that marginal expected profit from increasing the mark-up (ie. (26)) is always positive. Given that the right-hand side of (25) is always negative, it follows that the firm's optimal choices are characterised by:

$$\lambda c(1-F(k)) < r \qquad (27)$$

Reference to Section 1 shows that, in the situation where reliability is not included in the firm's price-cap constraint, the optimal situation is characterised by:

$$\lambda c(1 - F(k)) = r \quad (28)$$

Consequently, although nothing can be inferred from a comparison of (27) and (28) about the input of including reliability in the price-cap constraint on the firm's optimal mark-up, what can be seen is that, *ceteris paribus*, the firm with reliability included in its price-cap constraint will, as a consequence, feature a higher level of reliability.

Moreover, it is this difficulty in determining analytically the implications for the firm's optimal choices of including reliability in the price-cap constraint which motivates the numerical analysis of the next section.

SECTION FOUR: NUMERICAL ANALYSIS - RELIABIITY INCLUDED

Recalling the Base Case results of Section 2, it was shown that for a firm which is subject to a price-cap constraint which excludes reliability the Base Case parameter values imply the firm is constrained to choosing a mark-up equal to two ($\lambda = 2$) and its optimal capacity and associated reliability are as follows:

$$k = 258.20$$
$$F(k) = 0.50$$

which gives:

$$E(\pi) = 982.01.$$

As outlined in Section 3, the introduction of reliability into the firm's price-cap constraint modifies its first order conditions for maximizing expected profit, subject to this constraint, to those given by (24) and (25). Solving these equations numerically with the addition of:

$$F(k_0) = 0.50$$

to the base case parameter values and setting:

$$x = 0$$
$$w_1 = 0.7$$
$$w_2 = 0.3$$

gives the results contained in Table 4. It can be seen from Table 4 that, with the introduction of reliability into its price-cap constraint, the firm takes the opportunity to increase its mark-up and consequently its expected profits. Moreover, the higher price is justified in the context of the price-cap constraint because reliability is increased not only by the reduction in expected demand associated with the higher price, but also by an increase in the level of capacity. In other words, because reliability is positively related to price for a given capacity level, its inclusion in the price-cap constraint means the firm can exploit this relationship to increase expected profit consistent with its new constraint.

Next consider the results in Table 5 which show the main factors influencing the extent to which the firm can exploit the positive relationship between price and reliability to increase expected profits. A comparison of the results in Tables 4 and 5 shows that the firm's response to the inclusion of reliability in its price-cap constraint in terms of exploiting the positive relationship between price and reliability is weakened if: demand is more elastic, the value of the exogenous weight on reliability in the constraint is smaller; and if demand is more uncertain.[5] Although the elasticity and uncertainty of demand are beyond the control of the regulator, the results in Table 5 clearly suggest that the regulator can limit the extent of this exploitation by reducing the exogenous weight applied to reliability in the firm's price-cap constraint.

Finally, consider the issue of a firm-specific increase in the average variable cost of production (c). As shown in Section 2, if reliability is excluded from the price-cap constraint then, in the situation where the firm is forced to absorb this cost increase (ie $x = 0$) consumers will experience a reduction in reliability even though they are insulated from any price increase. This outcome appears as the first row of results in Table 6. However, the second table row of results in Table 6 shows that if reliability is included in the price-cap constraint then this problem is largely eliminated. Although, the firm makes some minor adjustments to its price and reliability levels in order to minimise the negative impact of the cost increase on expected profits (compare the results in rows two and three of Table 6), the inclusion of reliability in the price-cap constraint means the firm has no opportunity to protect profits at the expense of consumers.

By contrast, consider the situation where the firm is permitted to pass on in full the cost increase as represented by the results in the bottom half of Table 6 (x = 20%). If reliability is excluded from the firm's price-cap constraint then as shown by the fourth row of results in Table 6, the consumer experiences the full 20% increase in price but is compensated to some extent by an associated increase in reliability. However, if reliability is included in the firm's price-cap constraint then, as shown by the results in row five of Table 6, the firm takes advantage of this situation to increase price by more than 20% (ie 24.86%), with the price-cap constraint being satisfied by an associated increase in reliability (ie 1.20%). In so doing, the firm achieves an additional 10% increase in expected profits over the situation where price was simply increased by 20% and reliability maintained (compare the results in rows five and six of Table 6).

Consequently, the results in Table 6 suggest overall that although including reliability in the price-cap constraint is to the consumer's benefit in a situation where the firm is required to absorb a cost increase, in a situation where the firm is permitted to pass on a cost increase, then the firm will take this opportunity to further exploit the positive relationship between price and reliability and extract a higher level of expected profits from consumers. Nevertheless, it follows from the result in Table 5 that the regulator may limit this opportunity by assigning reliability a low exogenous weight in the price-cap constraint.

CONCLUSION

The aim of this paper has been to contribute to the understanding of the role of quality in price-cap regulation, with a particular focus on the issue of reliability of supply. A model was developed in Section 1 which showed that there is a positive relationship between the level of reliability and the extent to which the firm is permitted to pass on specific cost increases, with reliability lowered in the case of full absorption of a cost increase, and increased from this level in the case of full passing on of the cost increase. Consequently, it was demonstrated that there is some minimum level of price adjustment which is required to maintain reliability.

However, it was unclear from this analysis whether this minimum level of price adjustment was also sufficient to maintain expected profits following a cost increase. Therefore, in Section 2 a numerical analysis of the model was undertaken which suggested that a higher level of price adjustment is required to maintain expected profits than to maintain reliability following a cost increase (although there is an associated higher level of reliability which to some extent compensates the consumer). Moreover, this finding was shown to be robust with respect to the level of demand elasticity and the level of demand uncertainty. Finally, the numerical analysis showed that the unambiguouly positive relationship between expected profits and reliability does not carry across to the case of the relationship between expected profits and optimal capacity: optimal capacity may increase or decrease following the full adjustment of price to a cost increase depending both on the level of demand elasticity and on the level of demand uncertainty.

In Section 3 the model of Section 1 was redeveloped to include reliability in the firm's price-cap constraint. This model was subjected to a numerical analysis in Section 4 where it was shown that the inclusion of reliability in the price-cap constraint creates a tendency for the firm to exploit the positive relationship between price and reliability (ie that increases in price are associated with increased reliability at constant capacity because of the responsiveness of demand to price) to increase expected profits, but in a manner which satisfied the price-cap constraint. For example, in the case of a cost increase, it was shown that if the firm is permitted to pass on this cost increase, it was shown that if the firm is permitted to pass on this cost increase which is proportionately larger than the cost increase but with an associated increase in reliability. Nevertheless, it was shown that this tendency could be limited by the regulator applying a low exogenous weight to reliability in the price-cap constraint. In addition, the inclusion of reliability in the price-cap constraint was shown to benefit the consumer in a situation where the firm is required to absorb a cost increase because the firm can no longer protect profits by reducing reliability

FOOTNOTES

1. For example, Bös (1991, Ch.7) is an analysis of price-cap regulation in the absence of uncertainty of demand and therefore the issue of reliability does not arise.

2. Although there is no indication as to "how AUSTEL might value the reduction in quality or determine the change in quality which might be deemed to have met the price-cap given the variations to the prices of other services" (p 8)

3. The impact of a carbon tax on the pricing behaviour of a price-cap regulated multi-product monopoly is considered in Fraser (1993b)

4. Crew and Kleindorfer (1980) find a positive relationship between expected profits and reliability in their numerical analysis of a rate of return regulated monopoly

5. Although in the latter case the firm is still able to achieve a larger increase in expected profits by the increase in its capacity.

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Table 1

Impact of a 20% increase in c on key variables [a].

	Base Case	x = 0	x = 6.67%	x = 7.76%	x = 20's
p	15	15	16.00	16.16	18
k	258.20	247.37	250.00	250.24	250.57
F(k)	0.50	0.44	0.50	0.51	0.58
E(π)	982.01	757.41	950.81	982.01	1318.84

Note: a All other Base Case values apply

Table 2

Sensitivity of the Results to the Level of Demand Elasticity: 20% increase in c [a].

ε = 0.1	Base Case	x = 0%	x = 6.67%	x = 6.86%	x = 20%
p	15	15	16.00	16.03	18
k	762.77	730.79	757.86	758.50	796.23
F(k)	0.50	0.44	0.50	0.50	0.58
E(π)	2901.03	2237.51	2882.30	2901.03	4190.83

ε = 0.9	Base Case	x = 0%	x = 6.67%	x = 9.98%	x = 20%
p	15	15	16	16.35	18
k	87.40	83.74	82.47	81.92	78.85
F(k)	0.50	0.44	0.50	0.52	0.58
E(π)	332.41	256.39	313.65	332.41	415.03

Note: a All other Base Case values apply

TABLE 3

Sensitivity of the Results to the Level of Demand Uncertainty: 20% increase in c [a].

$\sigma_\theta = 0.5$	Base Case	x = 0%	x = 6.67%	x = 7.60%	x = 20%
p	15	15	16	16.14	18
k	258.20	240.16	250.00	251.09	260.48
F(k)	0.50	0.44	0.50	0.51	0.58
E(π)	776.02	573.82	751.36	776.02	1098.12

Note: a All other Base Case values apply

TABLE 4

Impact of the introduction of reliability into the price-cap constraint: Base Case values

		λ	p	k	F(k)	E(π)
(1)	**Reliability Excluded**	2	15	258.20	0.50	982.01
(2)	**Reliability Included** [a]	2.51	17.54	306.19	0.83	1379.81
		(+25.5%)	(+16.93%)	(+18.59%)	(+66%)	(+40.51%)

Note a: Percentage changes from results in row one.

TABLE 5

Factors influencing the response of the firm to including reliability in the price-cap constraint [a]

		λ	p	k	F(k)	E(π)
	$\varepsilon = 0.8$					
(1)	Reliability Excluded	2	15	114.58	0.5	435.80
(2)	Reliability Included [b]	2.49	17.43	127.67	0.80	583.33
		(+24.5%)	(+16.2%)	(+11.42%)	(+60%)	(+33.85%)
	$w_1 = 0.9$; $w_2 = 0.1$					
(3)	Reliability Excluded	2	15	258.20	0.50	982.01
(4)	Reliability Included [c]	2.09	15.43	289.50	0.68	1040.24
		(+4.5%)	(+2.87%)	(+12.12%)	(+36%)	(+5.93%)
	$\theta = 0.5$					
(5)	Reliability Excluded	2	15	258.20	0.50	776.01
(6)	Reliability Included [d]	2.46	17.30	332.17	0.78	1105.97
		(+23.0%	(+15.33%)	(+28.65%)	(+56%)	(+42.52%)

Notes a. All other Base Case values apply

b. Percentage change from results in row one

c. Percentage change from results in row three

d. Percentage change from results in row five

TABLE 6

Impact of a Cost Increase: Base Case values
(% change from base case results in brackets)

		λ	p	k	F(k)	E(π)
	<u>x = 0%</u>					
(1)	Reliability Excluded	1.5	15	247.37	0.44	754.41
		(-25%)	(0%)	(-4.19%)	(-12%)	(-23.18%)
(2)	Reliability Included	1.92[a]	17.53	305.45	0.82	1148.49
		(-23.5%)	(-0.06%)	(-0.24%)	(-0.35%)	(-167.6%)
(3)	Constant price & reliability	1.92[b]	17.54	306.19	[illegible]	[illegible]47.71
		(-23.5%)	(0%)	(0%)	(0%)	(-16.82%)
	<u>x = 20%</u>					
(4)	Reliability Excluded	2	18	250.57	0.58	1318.84
		(0%)	(+20%)	(-2.96%)	(+16%)	(+34.30%)
(5)	Reliability Included	2.65	21.90	278.33	0.84	1923.12
		(+5.58%)	(+24.86%)	(-9.10%)	(+1.20%)	(+39.38%)
(6)	Constant mark-up & reliability	2.51	21.05	279.513	0.83	1791.01
		(0%)	(+20%)	(-8.71%)	(0%)	(+29.80%)

Notes a: Differences exist between the values at the third decimal point, hence the price difference.

b: Percentage change based on four decimal points.