Quality Regulation without Regulating Quality

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Abstract

Against the background that a combination of price-cap and minimum quality regulation is social optimal but hard to implement the aim of this paper is to develop an alternative optimal regulatory mechanism that involves lower administrative costs. In a modelling framework which adequately describes the behaviour of market participants in network industries we found that return-on-cost regulation has (approximately) the same effects on price, quality and welfare than minimum quality regulation. If it is the aim of the regulator to achieve the welfare maximum under the zero profit constraint, we show that a combination of price-cap and return-on-cost regulation leads arbitrarily close to this point and can thus be applied instead of the price-cap plus minimum quality regulation.

JEL classification: L51, L98

1 Introduction

Since the 1980s, many countries have introduced economic reforms and competition laws that have involved privatisation, demonopolisation and regulatory reform in major network industries, such as electricity, gas, railroads and telecommunications. These initiatives have created a business environment conducive to competition. It must, however, be recognised that some parts of network industries still have natural monopoly properties. In particular the provision of the network itself involves high fixed sunk costs and is best left to a single firm subjected to regulation.

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To regulate a natural monopoly, many regulators have applied price-cap regulation as proposed by Littlechild (1983). It allows the regulated firm to increase its overall level of prices by the previous year’s rate of inflation in the economy, as measured by the Retail Price Index, moderated by a percentage that reflects the real cost reduction which the regulator expects. The firm can retain any further cost savings in form of extra profit. Without any doubt, price-cap regulation has a number of desired properties including that it can easily be implemented – at least compared to other regulatory regimes such as rate-of-return regulation –, and that the regulated firm minimises costs.

However, a major drawback of price-cap regulation is its possible adverse effect on infrastructure quality. Booz Allen & Hamilton (1999), for example, state that quality deterioration is a major concern in price-cap regulation for Railtrack, which is the monopolistic provider of the railway network in the UK. In a situation where the unregulated monopolist sets quality below the social optimal level, quality deterioration under price-cap regulation implies that the maximum welfare is not obtainable. The problem is well known in the theory of monopoly regulation. White (1972), Spence (1975), and Sheshinski (1976) show that a price regulation can reduce the quality and can even result in a welfare loss. Recently, Kidokoro (2002) concludes that price-cap regulation increases investment related quality, but decreases effort related quality.

As both price and quality enter the decision of the monopolist, the obvious solution to the problem of quality deterioration is to combine price-cap with minimum quality regulation. It can easily be shown that under this regime the monopolist still minimises costs and that any price-quality combination including those which maximise welfare is achievable. But measuring quality is a difficult task, so that the successful implementation of minimum quality regulation involves high administrative costs.

The object of this paper is to develop an alternative regulatory mechanism which has (approximately) the same effects of price, quality and welfare than the combination of price-cap and quality regulation but involves less administrative costs. For this purpose we introduce a modelling framework which includes the following major characteristics of a network industry. First, total costs consist of substantial fixed costs but almost negligible variable costs; to simplify, we assume that variable costs are equal to zero. Second, the monopolist can choose among various quality levels, but the possibility of quality discrimination is excluded. A quality level refers to certain physical properties of the network, and it is plausible to assume that they are uniform for all network users. Third, fixed costs are endogenous; they
increase with quality and thus shape the profit maximising behaviour of the monopolist.

Within this framework we find that minimum quality regulation can be replaced by an average cost pricing rule. If the monopolist is regulated such that he is allowed to earn a strictly positive profit, we show that a price regulation which allows the regulated firm a proportional mark up on the average costs – this regulation is also known as return-on-cost regulation – has the same effects on price, quality and welfare as a minimum quality regulation. Return-on-cost regulation further leads arbitrarily close to the solution under minimum quality standards when the profit is restricted to zero. If it is the aim of the regulator to achieve the second-best social optimum in which welfare is maximised under the restriction that the profit is nonnegative, the use of the second-best price as price cap, together with a maximum allowable return on cost set slightly above zero leads arbitrarily close to the second-best outcome. That means, quality can be regulated without restricting the level of quality and minimum quality regulation can be replaced by return-on-cost regulation to achieve approximately the social optimal outcome. Under both regimes the monopolist has no incentive to use an inefficient input combination or to waste inputs. The cost advantage of the return-on-cost regulation is obvious: the implementation requires only information on reported total costs and profit.

The paper is organised as follows. In section 2 we present the modelling framework and compare the second-best optimum with the monopoly solution. The monopolist’s profit maximising decision always deviates from the second-best optimum, which provides the justification for regulation. In section 3 we study the effects of price-cap, minimum quality, and return-on-cost regulation. We use the results to compare the effects of a combined price-cap and quality regulation with those of a combination of price-cap and return-on-cost pricing in section 4. We conclude in section 5.

2 Second-Best Optimum and Monopoly Equilibrium

Cost and Demand Conditions

Two decision variables enter our model: price \( p \), and quality \( q \). Quality is treated as a scale index, with larger values corresponding to higher quality. Total costs are given by \( C(q) \) with

\[
C' > 0 \text{ and } C'' > 0. \tag{1}
\]
The monopolist chooses $p$ and $q$ such that the profit

$$\Pi(p, q) = R(p, q) - C(q).$$ \hspace{1cm} (2)

is maximised, where $R(p, q) = pD(p, q)$ defines the revenue function, with demand $D(p, q)$.

We assume that each consumer buys zero or one units of the good, and has a maximum willingness to pay for one unit given by

$$V(\theta, q) = \theta g(q) \text{ with } g(0) = 0, \quad g' > 0, \quad g'' \leq 0.$$ \hspace{1cm} (3)

The parameter $\theta > 0$ measures the intensity of a network user’s taste for quality and is distributed with a density function $f(\theta) > 0$ over the interval $[\theta, \overline{\theta}]$. The distribution function $F(\theta)$ is assumed to be twice continuously differentiable and strictly increasing. Let $N$ be the total number of potential network users.

An individual buys one unit if the price is below or equal to his willingness to pay, that is if $p \leq V(\theta, q)$ or, equivalently, $p/g(q) \leq \theta$. For any $p \geq 0$ and $q > 0$, total demand can then be written as

$$D(p, q) = N \left(1 - F(\overline{\theta})\right),$$ \hspace{1cm} (4)

where $\overline{\theta} = p/g(q)$ denotes the taste parameter of the individuals who are just willing to buy one unit. Partial derivation of (4) leads to $D_p < 0$ and $D_q > 0$.\footnote{Describing the demand in this way is common in the field of product differentiation (see e.g. Mussa and Rosen (1978), and Besanko and Donnenfeld (1988)) and has been used in network economics as well (see e.g. Economides (1999), and Lamberti and Orsini (2000)).}

A network user’s benefit is given by the difference of willingness to pay and price, and consumer surplus is defined as the sum of the individual benefits,

$$CS(p, q) = N \int_0^{\overline{\theta}} (\theta g(q) - p) f(\theta) d\theta,$$ \hspace{1cm} (5)

with $CS_p < 0$ and $CS_q > 0$. Social welfare $W$ is defined as the sum of consumer surplus and profit.

**Second-Best Optimum**

Social welfare is given by

$$W(p, q) = CS(p, q) + \Pi(p, q)$$

$$= Ng(q) \int_0^{\overline{\theta}} \theta f(\theta) d\theta - C(q),$$ \hspace{1cm} (6)
Maximisation of $W$ with respect to $p$ and $q$ yields a price equal to marginal costs, which means $p = 0$. Thus, in the first-best solution, the monopolist makes losses equal to total costs. If the aim of regulation is to achieve the first-best solution, it follows that the network provider has to be subsidised. But in practice, regulators are usually restricted to subsidy free regulatory mechanisms. Therefore the second-best optimum, defined as the solution of

$$\max_{p,q} W(p, q) \text{ s.t. } \Pi(p, q) \geq 0,$$

is often used as reference point in the theory of optimal regulation.

Let $(p^*, q^*)$ be the solution to problem (7). From the first-order conditions we obtain $\Pi^* = 0$. We also have

$$\Pi_p^* > 0 \text{ and } \Pi_q^* < 0.$$  \hfill (8)

Starting from the second-best point the monopolist could increase profit by increasing the price and lowering the quality. We follow Sheshinski (1976: 129) and assume that the second-order conditions hold. It can be shown that it is sufficient to assume $W_{pp} < 0$, which implies strict concavity of $W$ as well as strict concavity of $\Pi$.

**Monopoly Equilibrium**

Without regulation, the monopolist maximises profit as given by (2). The first-order conditions are

$$\Pi_p^M = 0 \text{ and } \Pi_q^M = 0,$$

where $(p^M, q^M)$ denotes the solution to this problem. (9) is necessary and sufficient, given $W_{pp} < 0$ since this implies strict concavity of the profit function (see above).

The comparison of (8) and (9) leads to the conclusion that the monopoly solution deviates from the second-best optimum,

$$W^*(p^*, q^*) > W^M(p^M, q^M),$$

which is analysed more detailed in the following subsection.

**Comparison of second-best optimum and monopoly equilibrium**

The second-best optimum and the monopoly equilibrium can be depicted in a $(p, q)$-diagram. The slope of an iso-$W$-curve is

$$\left. \frac{dq}{dp} \right|_{W=\text{const}} = -\frac{W_p}{W_q},$$

(11)
and the slope of the zero-profit curve is
\[ \frac{dq}{dp} \bigg|_{\Pi=0} = -\frac{\Pi_p}{\Pi_q}. \] (12)

By (12), it can be seen that the curve \( \Pi = 0 \) is vertical in points with \( \Pi_q = 0 \), and horizontal where \( \Pi_p = 0 \) holds.

The slope of the curve \( \Pi_p = 0 \) is
\[ \frac{dq}{dp} \bigg|_{\Pi_p=0} = -\frac{\Pi_{pp}}{\Pi_{pq}}, \] (13)

and the slope of the curve \( \Pi_q = 0 \) is
\[ \frac{dq}{dp} \bigg|_{\Pi_q=0} = -\frac{\Pi_{pq}}{\Pi_{qq}}. \] (14)

From \( W_{pp} > 0 \) it can be derived that \( \Pi_{pp} < 0 \), \( \Pi_{qq} < 0 \), \( \Pi_{pq} > 0 \), and \( \Pi_{pp}\Pi_{qq} - \Pi_{pq}^2 > 0 \). Hence, both expressions are positive and the curve \( \Pi_p = 0 \) is steeper than the curve \( \Pi_q = 0 \).

It can also be shown that the curve \( \Pi_p = 0 \) and the iso-demand curve \( D = D^M \) are identical (see Kriehn (2004)). Consequently, for any point left to the curve \( \Pi_p = 0 \), demand is higher than in the monopoly solution. The profit is maximised where both curves intersect.

In the second-best optimum, the iso-\( W^* \) curve is tangent to the curve \( \Pi = 0 \) and thus we have
\[ -\frac{\Pi^*_p}{\Pi^*_q} = -\frac{W^*_p}{W^*_q} = -\frac{CS^*_p}{CS^*_q} > 0. \] (15)

The slope of both curves is positive, so that the point \((p^*, q^*)\) must be in the increasing and concave section of the curve \( \Pi = 0 \). Therefore \((p^*, q^*)\) lies on a higher iso-demand curve than the monopoly solution, or equivalently,
\[ D(p^*, q^*) > D(p^M, q^M). \] (16)

Comparing both points in figure 1, we see that \( q^M \) may be larger or smaller than \( q^* \), and \( p^M \) may be larger or smaller than \( p^* \). From Result 1 it follows that we have either
\[ p^* < p^M \text{ and } q^* \leq q^M, \] (17)

or
\[ p^* \geq p^M \text{ and } q^* > q^M. \] (18)

Figure 1 shows a situation in which the monopoly price is higher and the monopoly quality is lower compared to the second-best values.\(^2\)

\(^2\)W.l.o.g., we assume that the curves \( \Pi_p = 0 \), \( \Pi_q = 0 \), and the iso-demand curves are linear.


\[ p = 0, \quad D = D_M \]

\[ q = 0 \]

\[ p_M, q_M \]

\[ W_M, p_M \]

\[ D = D^* \]

Figure 1: Monopoly vs. Second-Best Solution

3 Price-Cap, Minimum Quality, and Return-on-Cost Regulation

*Price-Cap Regulation (PCR)*

The PCR constraint is given by

\[ p \leq \bar{p} \text{ with } \bar{p} < p^M. \quad (19) \]

As it is well known, under this regime the monopolist minimises costs and chooses \( p = \bar{p} \) (see e.g. Kriehn (2004)). Therefore, the first-order conditions for the constrained profit maximum can be written as

\[ \Pi_{PC}^p > 0 \text{ and } \Pi_{PC}^q = 0, \quad (20) \]

where \((p^{PC}, q^{PC})\) denotes the solution.

Since the slope of the curve \( \Pi_q = 0 \) is positive and the point \((p^{PC}, q^{PC})\) is on this curve, PCR always leads to a decrease of quality and an increase of output. The second-best outcome cannot be achieved, because this would require \( \Pi_{q}^{PC} < 0 \). The effects of PCR are illustrated in figure 2. The monopolist chooses \( p^{PC} = \bar{p} \) and sets \( q^{PC} \) such that an iso-profit curve is tangent to the vertical price restriction. We draw a situation in which PCR leads to a welfare increase, which is not always the case.\(^3\)

\(^3\)A counterexample is given in Kriehn (2003).
Minimum Quality Regulation (MQR)

Under MQR the constraint is given by

\[ q \geq q^0 \text{ with } q > q^M. \]  

(21)

Let \( (p^{MQ}, q^{MQ}) \) be the solution to the profit maximisation problem under MQS. Similar to PCR, it is easy to show that the monopolist does not waste resources, chooses \( q^{MQ} = q^0 \) and sets \( p \) such that

\[ \Pi_{p}^{MQ}(p^{MQ}, q^{MQ}) = 0. \]  

(22)

Since the slope of the curve \( \Pi_{p} = 0 \) is positive and the point \( (p^{MQ}, q^{MQ}) \) lies on this curve, MQR increases both price and quality such that demand is equal to \( D^M \). From \( \Pi_{p}^{MQ} = 0 \) we know, that the second-best optimum cannot be achieved.

In figure 3, we illustrate a MQR that increases welfare. The monopolist chooses the point \( (p^{MQ}, q^{MQ}) \) on the curve \( \Pi_{p} = 0 \) where an iso-profit-curve tangents the horizontal quality restriction.
Return-on-Cost Regulation (ROCR)

We consider a price regulation, that allows the monopolist to mark up price over average costs by the proportion $\delta$, that is

$$ p \leq (1 + \delta)C(q) \text{ with } \delta > 0. $$

(23) can be written as

$$ \frac{R(p, q)}{C(q)} \leq \delta \text{ with } \delta > 0, $$

which means that the proportional average cost pricing rule is equivalent to return-on-cost regulation (ROCR) which restricts the proportion of costs the firm is allowed to retain as profit.\footnote{The proportional average cost pricing rule is also formally equivalent to the return-on-sales regulation which allows the monopolist to earn a certain amount of profit on each unit of revenue, that is $\frac{R(p, q) - C(q)}{R(p, q)} \leq \zeta$. Setting $\delta = \frac{1}{1-\zeta} - 1$ in (24) leads to the return-on-sales restriction.}

From Train (1991, ch. 2) we know that it depends on the sign of the marginal revenue whether the monopolist has an incentive to waste ressources or not under ROCR. Our model can be seen as a special case of Train’s approach in which the marginal revenue is equal to zero in the monopoly solution and remains zero under regulation (see below). For this case it is known that the monopolist does not waste. Consequently, the monopolist minimises costs. This together with a binding restriction allows us to write the profit maximisation
problem as
\[
\max_{p,q} \Pi(p, q) \text{ s.t. } \Pi(p, q) = \delta C(q).
\] (25)

From the first-order conditions we obtain \( \Pi_{p}^{ROC} = 0 \), which means that ROCR has no effect on total demand. It also follows that the curve \( ROC = \delta \) tangents the curve \( \Pi_{p} = 0 \) in the solution point \((p^{ROC}, q^{ROC})\). Comparative statics yield
\[
\frac{dp^{ROC}}{d\delta} = -\frac{1}{|H|}\delta C^{ROC}C^{ROC'}\Pi_{pq}^{ROC} < 0
\] (26)
and
\[
\frac{dq^{ROC}}{d\delta} = \frac{1}{|H|}\delta C^{ROC}C^{ROC'}\Pi_{pp}^{ROC} < 0,
\] (27)
where \( H \) is the bordered Hessian matrix. A stronger regulation leads to an increase of both price and quality such that total demand remains constant. Again, with \( \Pi_{p} = 0 \) we can exclude that welfare is equal to \( W^* \).

The effects of ROCR are illustrated in figure 4. The slope of an iso-ROC curve is given by
\[
\left. \frac{dq}{dp} \right|_{ROC=\text{const}} = -\frac{C\Pi_{p}}{C\Pi_{q} - \Pi C'},
\] (28)
and is thus equal to zero where the curve intersects the curve \( \Pi_{p} = 0 \). Consequently, in \((p^{ROC}, q^{ROC})\) the curve \( ROC = \delta \) tangents the curve \( \Pi = \Pi^{ROC} \).

![Figure 4: Effects of Return-on-Cost Regulation](image)

If we compare figures 3 and 4, it is obvious that the effects of MQR and ROCR are identical as long as the profit is strictly positive. Both regulations result in a point on the
curve $\Pi_p = 0$ in the northeast of the monopoly solution. Any point achieved by MQR can also be achieved by ROCR, except the intersection point of the curves $\Pi_p = 0$ and $\Pi = 0$. But by lowering $\delta$ toward zero the regulator can induce the monopolist to choose an outcome arbitrarily close to the intersection point. Thus we obtain

**Proposition 1** For all $q$ with $\Pi^{MQ}(q) > 0$ there exists an $\delta > 0$ such that

$$W^{ROC}(\delta) = W^{MQ}(q).$$

(29a)

If $q$ is given such that $\Pi^{MQ}(q) = 0$, we have

$$\lim_{\delta \to 0} W^{ROC}(\delta) = W^{MQ}(q).$$

(29b)

4 Combined Regulations

**Price-Cap plus Minimum Quality Regulation**

If the regulator restricts only one decision variable (price or quality), the second-best optimum cannot be achieved, as it was shown in the last section. It is intuitively clear that the simultaneous restriction of both price and quality by the second-best values leads to the second-best outcome, which is illustrated in the following figure. The monopolist is allowed to choose the second-best point or any point in the grey area including the borders. As the second-best point is the only point in which the profit is nonnegative, the monopolist sets the second-best price and quality.

![Figure 5: Effects of PC plus MQ Regulation](image-url)
Though the combination of PC and MQ regulation is optimal, its implementation might involve high administrative costs, because it requires the estimation of the current and optimal levels of quality which usually is a difficult task. Proposition 1 asserts that PCR could be combined with ROCR instead of MQR such that welfare is arbitrarily close to the second-best welfare. The effects of the PC-ROC regulation are analysed in the following.

**Price-Cap plus Return-on-Cost Regulation**

If PCR and ROCR are combined such that both regulations are binding, the profit maximising problem can be written as

\[
\max_q \Pi(p, q) \text{ s.t. } \delta C(q) - \Pi(p, q) = 0. \tag{30}
\]

Let \((p^{POC}, q^{POC})\) be the solution point to problem (30). From the first-order conditions to this problem it follows that the monopolist chooses one of the two intersection points of the vertical price restriction \(p = \overline{p}\) and the \(ROC = \delta\)-curve. As we have \(\Pi^{POC} = \delta C(q^{POC})\) in both points, the monopolist chooses the point with the higher quality. The problem is depicted in figure 6.

![Figure 6: Effects of PC plus ROC Regulation](image)

The points in the grey area including the border are allowed. From the first-order conditions we know that the monopolist chooses either point A or point B. As \(\Pi^A = \delta C(q^A) >\)

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5It is shown in Kriehn (2004), that the monopolist chooses the maximum allowable values of price and return on cost and does not waste resources.
\( \delta C(q^B) = \Pi^B \), the monopolist chooses point A in which we have \( \Pi^POC_p > 0 \) and \( \Pi^POC_q < 0 \) as in the second-best solution.

As the monopolist chooses a point such that the price equals the price cap and \( \Pi^POC_q < 0 \) holds, we suggest that a point arbitrarily close to the second-best point can be achieved by setting \( \overline{p} = p^* \) and lowering \( \delta \) toward zero. In fact, this can easily be shown. Comparative statics yield
\[
\frac{dq^POC}{d\delta} = \frac{C^POC}{\Pi^POC_q - \delta C^POC^q},
\]
and from the first-order conditions we know that the denominator is negative. Hence, \( \frac{dq^POC}{d\delta} < 0 \). For a given price restriction a stronger ROCR increases quality. As a consequence, if the regulator sets \( \overline{p} = p^* \) and lowers \( \delta \) toward zero, \( q^POC \) increases. But quality cannot reach a level above \( q^* \), and thus costs are below \( C(q^*) \), which means that the product \( \delta C(q^POC(p^*, \delta)) \) converges to zero, and also does the profit \( \Pi^POC = \delta C(q^POC(p^*, \delta)) \). Hence, the point \( (p^POC, q^POC) \) converges to the point \( (p^*, q^*) \) on the zero-profit curve and we obtain:

**Proposition 2** With \( \overline{p} = p^* \) the following holds:

\[
\lim_{\delta \to 0} W^POC(p^*, q(p^*, \delta)) = W^*.
\]

The result is illustrated in figure 7. With the second-best price as price cap and a maximum allowable ROC close to zero, welfare is slightly below the second-best welfare. By reducing \( \delta \) further toward zero, welfare could be increased further.

![Figure 7: PC plus ROC Regulation and Second-Best Solution](image-url)
With the combined PC-ROC regulation we have developed a regulatory mechanism that leads arbitrarily close to the second-best solution but is easier to implement than the combination of PC and MQ regulation, because it only requires information on total costs and profit and no information on the complex aspects of quality.

5 Conclusion

Against the background of the suboptimality of price-cap regulation and the difficult implementation of a combination of price-cap and minimum quality regulation the aim of this paper was to develop an alternative regulatory mechanism that leads (approximately) to the second-best outcome and involves relatively low administrative costs. In a modelling framework which adequately describes the behaviour of market participants in network industries we found that both minimum quality and return-on-cost regulation have identical effects on price, quality and welfare as long as the allowed profit is strictly positive and have approximately the same effects if the regulator wishes the profit to be equal to zero. In our opinion, return-on-cost regulation is an attractive alternative to minimum quality regulation in terms of administrative costs, so that the first should be preferred by regulators to the latter and a price-cap plus return-on-cost regulation should be applied instead of a price-cap plus minimum quality regulation.

References


