Hybrid revenue caps and incentive regulation

Björn Lantz

School of Business, Economics and Law, Gothenburg University, Box 610, 40530 Gothenburg, Sweden

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Abstract

This paper analyzes the incentive effects of a hybrid revenue cap on a regulated monopolistic firm using non-discriminatory two-part pricing. It is shown that the fixed and the variable part of the cap have different meanings in terms of regulation — the fixed part of a hybrid revenue cap should be used to control the profit level of the regulated firm while the variable part should be used to control the social efficiency level. Since detailed information about the firm’s cost function is required to determine the revenue cap parameters, the overall conclusion is that revenue caps are a rather bad idea in the area of incentive regulation.

Keywords: Revenue caps; Incentive regulation

1. Introduction

Revenue capping as a way of regulating monopolistic utilities has been subject to criticism in the literature (see e.g. Crew and Kleindorfer, 1996; Vogelsang, 2002). A lot of this criticism has focused on the revenue cap’s “disincentive for efficiency”. Crew and Kleindorfer (1996:42f) e.g. show that a fixed revenue cap that is binding will provide incentives for a regulated monopoly to raise price above the unrestricted monopoly level, and they eventually conclude that revenue caps simply “are a very bad idea”.

Even if this disincentive effect perhaps is yet to be proven in revenue cap regulation in practice (Littlechild, 2003), it is of course extremely thought provoking that regulators may use regulation models that in theory provide “disincentives for efficiency”. However, situations where a monopoly is regulated by an absolute fixed revenue cap while using simple linear pricing, as in the Crew and Kleindorfer (1996) base case analysis, are probably rather seldom in practice. For example, the new performance assessment model for evaluating the pricing of Swedish electricity
distribution companies that the Swedish Energy Agency has developed could be regarded as a hybrid revenue cap since the cap is a linear function of output quantity and includes fixed as well as variable components.\(^1\)

Furthermore, electricity distribution companies usually use two-part pricing tariffs rather than linear pricing. Thus, in a situation like this, the base case Crew and Kleindorfer model is not applicable. When the firm uses two-part pricing, the regulation challenge is also different. In the case of identical consumers, an unrestricted monopoly will set the variable part of its tariff equal to marginal cost and extract all consumer surplus with the fixed part (Oi, 1971). This maximizes social efficiency, so regulation can only reduce the total surplus. The political problem, however, is the same as with first-degree price discrimination: the monopolistic firm gets all surplus from the market. In this situation, the objective of the regulator may be to redistribute the total surplus while minimizing the reduction in efficiency due to regulation.\(^2\) In a hybrid cap setting, the regulator needs to balance these factors against each other and in addition consider the revenue cap’s potential “disincentive for efficiency”. Obviously, model incentives must be carefully analyzed.

In this paper, the potential efficiency problem of a hybrid revenue cap model, defined as a linear function of quantity, when the regulated firm uses non-discriminatory two-part pricing is analyzed with respect to incentives. The basic result is that a hybrid revenue cap creates a fundamental connection between costs and revenues — a connection which is supposed to be more or less nonexisting in incentive regulation. Thus, the Crew and Kleindorfer (1996) conclusion that revenue caps “are a very bad idea” is true for yet another reason.

Price cap regulation separates the cost side from the revenue side for the regulated firm. Thus, there are two distinct advantages with price caps (see e.g. Braeutigam and Panzar, 1993). Firstly, they provide full incentives for cost efficiency since profit maximization by definition will be based on cost minimization at the chosen output quantity. They also provide incentives to undertake cost-reducing innovations in the same way as an unregulated firm. Secondly, the regulator does not need detailed information about the firm’s cost function in order to calibrate the price cap parameters.

Revenue caps, hybrid or not, do not separate costs from revenues. In particular, this means that efficient revenue cap regulation will be impossible to exercise without information about the firm’s cost function. Since, as we shall see in this paper, a monopolistic firm will maximize its profit under a linear hybrid revenue cap at the output quantity where its marginal cost equals the slope of the cap, the regulator need to be very well informed about the firm’s cost conditions in order to set the revenue cap parameters properly. Since the core idea of incentive regulation is to make use of the firm’s information advantage (Vogelsang, 2002), revenue caps can even be said to be incompatible with the idea of incentive regulation. Thus, even though revenue caps are used occasionally in regulated industries, they simply do not seem to be a good idea, given that price caps are among the alternatives.

The paper is organized as follows. Firstly, we analyse the decision problem for a hybrid revenue cap regulated monopolistic firm using two-part pricing. The main claim here is that model incentives are determined primarily by the variable part of the cap while the fixed part only determines the profit level of the firm. More specifically, the regulated firm generally maximizes

\(^1\) A “hybrid” revenue cap is generally defined as a revenue cap that is a mix of a fixed revenue cap and an average revenue cap. See e.g. Comnes et al. (1995) and Littlechild (2003).

\(^2\) This problem was discussed by e.g. Loeb and Magat (1979) who suggested a regulation regime where the firm received a subsidy equal to the consumer surplus at the chosen price. In the subsidy setting, the problem has been more or less solved by Sappington and Sibley (1988) and Sibley (1989). In this paper, we only consider the problem in a hybrid revenue cap setting.
profit under a binding hybrid cap where its marginal cost equals the slope of the cap. Secondly, we analyze a special regulator problem that arises when the cost function of the firm is strictly linear. In this section, we see that the variable part of the cap needs to exceed the marginal cost of the firm in order to avoid perverse incentives. Then we look at the problem of determining optimal parameter values with respect to social efficiency. Here, we introduce a lagged adjustment process for the cap parameters that make the variable part of the cap converge towards marginal cost. Finally, a short discussion of the findings precedes the conclusion of the paper.

2. Analysis

The decision problem of the monopolistic firm is

\[
\begin{align*}
\text{Maximize} & \quad N \cdot F + P \cdot Q - C \\
\text{Subject to} & \quad N \cdot F + P \cdot Q \leq \bar{R} + B \cdot Q
\end{align*}
\] (1)

where \( N \) is the number of consumers, \( F \) is the fixed part and \( P \) the variable part of a two-part pricing tariff (the decision variables), \( Q \) is the demand function of the firm, assumed decreasing in \( P \), \( C \) is the cost function of the firm, assumed increasing and suitably smooth in \( Q \), and \( \bar{R} \) is the fixed part and \( B \) the variable part of the hybrid revenue cap. We assume that \( F = \frac{\bar{R} + B \cdot Q - P \cdot Q}{N} \) can be solved for \( F \) at the \( P \) chosen by the firm.

If the restriction in (1) is binding, i.e. if the revenue cap prevents the Oi (1971) unrestricted monopoly solution \((F^*, P^*)\), we can express the decision problem as

\[
\begin{align*}
\text{Maximize} & \quad N \cdot F + P \cdot Q - C \\
\text{Subject to} & \quad N \cdot F = \bar{R} + B \cdot Q - P \cdot Q.
\end{align*}
\] (2)

Substituting \( N \cdot F \) with \( \bar{R} + B \cdot Q - P \cdot Q \) in the objective function, the decision problem becomes unrestricted

\[
\text{Maximize} \quad \bar{R} + B \cdot Q - P \cdot Q + P \cdot Q - C
\] (3)

which simplifies to

\[
\text{Maximize} \quad \bar{R} + B \cdot Q - C
\] (4)

This means that the first order condition for a profit maximizing monopoly that uses two-part pricing under a binding linear hybrid cap is

\[
\frac{\partial [\bar{R} + B \cdot Q - C]}{\partial Q} = 0
\] (5)

which simplifies to

\[
\frac{\partial C}{\partial Q} = B.
\] (6)

Thus, the regulated firm maximizes profit under a binding linear hybrid cap at the quantity \( Q_R \) where its marginal cost equals the slope of the linear hybrid cap. Hence, the optimal behaviour of the regulated firm when the cap prevents unrestricted two-part monopoly pricing is to set its
marginal price to $P_R$ to ensure that $Q_R$ units are demanded and to set the fixed fee $F_R$ to the value that makes total revenue reach the cap, i.e.

$$F_R = \left[ \bar{R} + B \cdot Q_R - P_R \cdot Q_R \right] / N$$

or

$$F_R = \left[ \bar{R} + Q_R (B - P_R) \right] / N.$$  \hspace{1cm} (7)

This means that a reduction of $\bar{R}$ means theoretically nothing when it comes to social efficiency; it only reduces the profit potential of the firm. Thus, model incentives are determined by $B$, the variable part of the hybrid cap.

3. A potential regulator problem

The condition for profit maximization in the above section is not possible to apply in the specific case where the total cost function of the firm is strictly linear, since the condition

$$\frac{\partial C}{\partial Q} = B$$

will not be valid for any quantity (or valid for all quantities in the even more specific case where $C (Q)$ is strictly linear and has the same slope as the hybrid cap). However, if the cap is binding in this case, the decision problem of the regulated firm is closely related to the situation where a monopoly using linear pricing is regulated by a binding fixed revenue cap (see Crew and Kleindorfer, 1996). In that situation, the monopoly will always choose the inefficient solution $Q_1$ of the two possible solutions $Q_1$ and $Q_2$ (where $Q_1 < Q_2$) that provide the same total revenue, since the inefficient solution $Q_1$ by definition is characterized by a lower total cost.

To provide an incentive for the monopolist to choose the efficient one of the two possible solutions that exactly satisfies the revenue cap, total revenue must obviously be allowed to increase faster than total cost when quantity increases from $Q_1$ to $Q_2$. In other words, the value of the hybrid cap must increase faster than firm total cost when quantity increases. Thus, the formal condition that must be fulfilled in order to avoid the inefficient incentive described above is

$$\frac{\partial C}{\partial Q} < \frac{\partial \left[ \bar{R} + B \cdot Q \right]}{\partial Q}$$

or simply

$$\frac{\partial C}{\partial Q} < B.$$  \hspace{1cm} (10)

Thus, in the specific case of a strictly linear total cost function, the variable part of the hybrid cap cannot fall below firm marginal cost in order to avoid inefficient incentives. (If the variable

\hspace{1cm} Note that the fixed fee $F_R$ does not necessarily have to be positive. If $\bar{R} + B \cdot Q_R < P_R \cdot Q_R$ when $\partial C / \partial Q = B$, $F_R$ will become negative, which means that each consumer will receive a lump sum from the firm. See e.g. Vogelsang (1991:19) for a more detailed discussion of the meaning and some possible interpretations of a negative fixed part of a regulated two-part tariff.

\hspace{1cm} In the Crew and Kleindorfer (1996) base case, we have $\partial C / \partial Q > B$ by definition since they consider a fixed revenue cap. This explains why the monopolist always chooses an inefficient solution when it is regulated by a fixed revenue cap.
part is equal to marginal cost, the firm will of course be indifferent between an inefficient and an efficient solution.) Furthermore, in the specific case of a linear cost function, the level of the fixed part of the cap does affect social efficiency since the regulator cannot use $B = \partial C / \partial Q$ for the reason discussed above. Since total cost functions in practice are often approximated (by firms as well as by regulators) as linear functions, this is a potentially difficult problem.

4. The regulator’s decision on the cap parameters

Assuming the regulator’s objective is to maximize social efficiency, the fully informed regulator needs to determine the hybrid cap parameter $B$ so that $\partial C / \partial Q = B$ at the quantity where social surplus is maximized. However, the basic idea of revenue caps (or PBR in general) is of course to acknowledge information asymmetry between the firm and the regulator. To deal with this problem, we turn to the price cap literature where parameter adjustment processes under asymmetric information are well explored. Such mechanisms can sometimes provide a convergence of a price cap towards marginal cost even though the regulator has no ex ante knowledge about the firm’s cost and revenue functions (see e.g. Vogelsang, 1988). In this section, we will outline what such a mechanism could look like in a hybrid revenue cap context.

The simple approach we will use here is based on the fact that the firm under a binding cap maximizes short term profit at the quantity where $\partial C / \partial Q = B$, as we have seen before. Since only a two-part tariff with the variable part $P = \partial C / \partial Q$ can maximize social surplus, the regulator knows that the optimal binding hybrid revenue cap must be characterized by $P = B$. Thus, there are three different scenarios and corresponding regulator actions:

1. When the regulator observes that the firm has used a tariff where, the regulator can control the profit level of the firm by increasing or decreasing $\bar{R}$.  

If the regulator had perfect information about cost and demand, the regulator could of course simply tell the firm to e.g. use a price equal to marginal cost or to use a Coase tariff where the variable part of the tariff reflects marginal cost instead of using a revenue cap.

I owe this idea to an anonymous referee.

If the revenue cap is not binding, i.e. if total revenue does not reach the cap, then the regulator knows that the firm uses $P = \partial C / \partial Q$ by itself in order to maximize profit. Then it can set $B = P$ and use $\bar{R}$ to control the profit level of the firm.
2. If the regulator observes \( P > B \), the regulator should increase \( B \), perhaps in conjunction with a compensating reduction of \( R \).

3. If the regulator observes \( P < B \), the regulator should decrease \( B \), perhaps in conjunction with a compensating increase of \( R \).

Assuming that the monopolist maximizes short term profit and that the environment is stationary, the simple decision rules (2) and (3) above can obviously provide convergence towards \( P = B \). However, the fact that \( P > B \) only tells the regulator that \( B \) should be increased, but not by how much. Without detailed knowledge about the slopes of the demand and marginal cost curves, it is not possible to create a total convergence immediately.

If the absolute values of these slopes can be assumed to be approximately equal, a simple but effective way of revising \( B \) is to define it as the average of \( B \) and \( P \) from the previous periods. The value of \( B \) in period \( t \), \( B_t \), then becomes

\[
B_t = \frac{(B_{t-1} + P_{t-1})}{2}
\]

and \( B_t \) will come close to the optimal \( B \) as Fig. 1 suggests.

If the absolute values of the slopes are likely to be different, one can use linear approximations of demand and marginal cost based on historical data from periods \( t-2 \) and \( t-1 \) to find \( B_t \), e.g.

\[
B_t = B_{t-1} + \frac{(P_{t-1} - B_{t-1})(B_{t-1} - B_{t-2})}{(P_{t-2} - P_{t-1})}
\]

which will obviously create a relatively large increase in \( B \) when marginal cost is steep in relation to demand, and vice versa. If the linear approximations are reasonable, \( B_t \) will come close to the optimal \( B \) as Fig. 2 suggests.

In both cases, it easy to approximate the resulting change in consumer surplus, which can be used as a basis for a revision of \( F \).

5. Discussion

In summary, the variable part of the firm’s two-part tariff (and thus social efficiency) is determined by the variable part of the hybrid cap, while the fixed part of the tariff is a function of
the entire cap. Thus, if the main focus of the regulator is social efficiency, the regulator should centre its attention on the variable part of the hybrid cap.

The fact that a hybrid revenue cap can be used in different ways depending on how the parameters are determined also highlights the main problem of revenue capping. To be able to avoid unexpected (and inefficient) results, the regulator must be able to determine the cap parameters with accuracy. This problem has been proven valid for other forms of revenue cap models as well, e.g. average revenue cap regulation (Cowan, 1997; Law, 1995) or hybrid models based on price (Connes et al., 1995). This is truly a contradictio in adjecto, since detailed knowledge regarding cost and revenue conditions of the regulated firm is what sound regulation should not be based on.

Furthermore, the analysis shows that the optimal behaviour of the firm under a binding hybrid revenue cap is to use the fixed part of the tariff to extract the amount of consumer surplus needed in order to reach the cap at the lowest possible quantity. It does not, however, show how large the proportion of extracted consumer surplus will be. Thus, in the consumer perspective, this regulatory regime will be preferred to the case of no regulation at all, since all consumer surplus will in general not be extracted. In a dynamic perspective, when the regulator can let the variable part of the cap converge towards marginal cost while reducing firm profit with the fixed part, the resulting tariff will be similar to an efficient Coase tariff.

But since a hybrid revenue cap (under the assumptions made here) only has the potential to reduce social efficiency, not to increase it, revenue caps in practice should be applied with care, even if consumer surplus and/or other variables are present in the regulator’s objective function.

There does not seem to exist any published empirical results on the differences between price caps and revenue caps. Kirkpatrik et al. (2004), however, report that regulators using price caps to regulate monopolies experience more problems about information asymmetries and misleading information from regulated firms than regulators using rate of return regulation. Since revenue caps, as we have seen here, require a lot more detailed information about the firm’s cost function, which contradicts the basic idea of incentive regulation as a way of acknowledging information asymmetry between the firm and the regulator. In this perspective, revenue caps are not a good idea.

6. Concluding remarks

In this paper, we have analyzed the regulation incentives of a hybrid revenue cap defined as a linear function of quantity. The regulated monopoly was assumed to be able to use non-discriminatory two-part pricing. The basic results of the analysis are that if the cap is binding, the fixed and the variable part of the hybrid cap have totally different meanings in terms of regulation. The profit maximizing variable price and output quantity of the regulated monopoly is controlled exclusively through the variable part of the cap. The fixed part of the cap is used to control the fixed part of the two-part tariff. One implication of these findings are that the fixed part of a hybrid revenue cap should be used by the regulator to control the profit level of the regulated firm while the variable part should be used to control the social efficiency level.

Another, and maybe more important, implication is that hybrid revenue caps should perhaps not be used at all. Compared to price caps, they require detailed information about the firm’s cost function, which contradicts the basic idea of incentive regulation as a way of acknowledging information asymmetry between the firm and the regulator. In this perspective, revenue caps are not a good idea.
References


