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Working Paper

Price capping and peak-load pricing in network industries

Diskussionsbeitrag, No. 73

Provided in Cooperation with:

Institute for Transport Economics and Regional Policy, University of Freiburg

Suggested Citation: Brunekreeft, Gert (2000) : Price capping and peak-load pricing in network industries, Diskussionsbeitrag, No. 73, Albert-Ludwigs-Universität Freiburg, Institut für Verkehrswissenschaft und Regionalpolitik, Freiburg i. Br.

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Price Capping and Peak-Load Pricing in Network Industries

by
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**Diskussionsbeiträge des
Instituts für Verkehrswissenschaft und Regionalpolitik
73**

December 2000

Critical comments to the author are welcome!

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* The author would like to thank Richard Green, Wolfgang Gross, Mike Ryan, two anonymous referees and the participants of a seminar at the University of Hull (July, 2000) and the conference of the International Telecommunications Society (Sept. 2000, Lausanne) for useful comments.

***Abstract:** This paper examines the effects of various price-cap rules on peak-load pricing. The issue recently gains practical importance in regulated network industries. The formal approach reveals that efficiency properties of various price-cap rules are, notwithstanding some problems, fairly good. A discussion of some practically relevant objections suggests that these objections may be not sufficiently convincing to prohibit (or restrict) peak-load pricing. Overall, a strong case can be made for allowing price-cap regulated firms the flexibility to apply peak-load pricing, if the alternatives are to have either no peak-load pricing or have the regulator prescribe the peak-load structure.*

JEL-classification: D4, L51, L96

Keywords: regulation, peak-load pricing, network-industries

1. Introduction

The issue of peak-load pricing is gaining importance in price-cap regulated network industries. Prominent examples are airports, electricity and telecommunications. It is therefore unfortunate that the literature on price caps has somewhat neglected peak-load pricing. Bradley & Price (1988) and Bradley (1993) mention peak loads and price caps explicitly, but mention efficiency effects only in passing. They do not explicitly model the capacity problem, and consequently, only the so-called firm-peak case as developed by Steiner (1957) is dealt with. Cowan (1997) further examines the work of Bradley & Price (1988) very usefully, but is silent on the problem of peak loads. The literature on peak-load pricing, on the other hand, does not integrate price caps; there is some work on peak loads and regulation, e.g. Bailey & White (1974) and Bergstrom & MacKie-Mason (1991), but this focuses on rate-of-return regulation, rather than price caps.

The peak-load problem is also known as the capacity problem. Taking account of the capacity problem emphasises the empirically relevant shifting-peak case of Steiner (1957). In the firm-peak case the capacity costs are fully allocated to the peak period; in the shifting-peak case, the capacity costs are optimally allocated to both periods according to relative willingness to pay. OFTEL (1999,

p. 5) formulates precisely this point very nicely: "Whether [the appropriate pricing level for calls in off peak periods is zero] depends crucially on whether the off peak period in question has the potential to become a peak period if the price were reduced by a significant amount. If this is the case, then it would not be sensible to set a price of zero in this period. In those periods where demand is so low or so unresponsive to price changes that it would be impossible to generate a new peak of traffic, it would be sensible to set a price so that none of the capacity costs were recovered in that period."¹ Since optimal pricing in the shifting-peak case relies on demand rather than on costs, the problem of the allocation of common capacity costs gets particularly difficult in this case (in contrast to the comparatively easier task of the firm-peak case); in fact, a regulator may not want to have to determine the optimal allocation of these common costs and should be quite happy to leave it to the firm, which is bound to be better informed. It will be shown that this can be achieved optimally by a price-cap mechanism.

This paper relies on the peak-load pricing approach of Steiner (1957), Weil (1968) and Bergstrom & MacKie-Mason (1991), and the price-cap approach of Bradley & Price (1988), Cowan (1997) and to some extent Bradley (1993). Section 2 discusses practical relevance. Section 3 defines the setting and the reference case and section 4 then examines the welfare effects under three well-known price cap rules: first, the (Laspeyres) tariff basket, second, the average revenue cap (lagged), and third, the average revenue cap (non-lagged). The results extend Bradley & Price (1988) and Cowan (1997). The efficiency results imply that especially for the shifting-peak case appealing results can be expected from a price cap, compared to the alternatives of either having no peak-load price structure or having the regulator determine the peak-load structure. Moreover, the discussion in section 5 emphasises that some well-known counterarguments against price caps do not appear to be severe for the peak-load problem. It must thus be concluded that it is desirable to allow price-cap regulated firms the flexibility to use peak-load pricing within the price cap.

¹ The context assumes that short-run marginal cost is zero (see OFTEL, 1999, p. 4/5).

2. Peak loads and price caps in practice

Airports increasingly face congestion. As a consequence, the regulators are increasingly aware that the available capacity should be used efficiently. In a report, which raises issues for airport regulation reviews, the airports regulator in the UK, the CAA (2000, p. 8) remarks that "[a]t current airport charges, demand for access to Heathrow and Gatwick airports is greater than existing capacity." The report emphasises in some detail the necessity of efficient pricing to allocate available capacity. This position is underlined by Sibley (2000, p. 25), who remarks: "[i]f a price cap is designed properly, both NATS and the airlines can gain by allowing NATS to offer a set of price-quality combinations that cater to the varying needs for particular types of routings that different airlines may have at different times."² The view seems to be shared by the EU-commission, which, in the face of congested airports, explores the possibilities of slot-auctions on designated airports (e.g. EU, 2000). It should be remarked that a properly designed auction is just a sophisticated way of capacity charging, because the auction reveals willingness to pay; apart from the revelation mechanism, there is no essential difference with peak-load pricing where the prices are determined by the supplier. It should be noted, moreover, that peak-load pricing need not be used only if capacity is constrained. Provided that fixed (common) costs require a mark-up on marginal costs, peak-load pricing can efficiently achieve this. The point is that if capacity is constrained the problem becomes more urgent and more obvious.

Whereas peak-load pricing may seem like an obvious way to proceed, apparently in practice it is not. Starkie (2000, p. 5) notes illustratively: "... on the evidence of the three MMC reports reviewing Manchester, the Commission seemed to alter its position from positively encouraging the adoption of peak-load pricing (1987) to mild encouragement (1992) and then to indifference (1997) ..." One problem of peak-load pricing is income distribution. The Monopolies and Mergers Commission's (MMC) report on the London airports (1996, p. 97 and app. 3.6) shows how as a result of the Exchange of Notes

² The report by Sibley has been prepared for the CAA, with regard to the regulation of National Air Traffic Services.

between the UK and US governments, peak-pricing for international passengers was phased out at the London airports, with the inevitable result that the off-peak charge increased sharply. This deviation from efficient pricing is the result of income redistribution. The early morning trans-Atlantic peak charge was not in the interest of US airlines (cf. Starkie, 2000, p. 5). Another argument against peak-load pricing is that it is said to be discriminatory. With respect to the airports in Germany, Wolf (1999, p. 119) remarks: "[u]p to now no German airport has introduced a peak-load pricing structure [...]. But until now no permission was given by the regulator, who claims that different prices for the same (physical) infrastructure service would be unfairly discriminating between users." Recently, the Hamburg airport was privatised and regulated with a price-cap regime. The document which describes the price-cap regime does not mention peak-load pricing;³ at one stage, however, it explicitly prohibits discriminatory prices.⁴

Peak-load pricing is gaining relevance in the telecommunications sector for two reasons. First, with growing competitiveness of the market for interconnection services, the regulators tend to replace the regime of fixed prices with a price-cap regime. Thereby they allow more price flexibility to the regulated firm. Second, since the internet user is biased towards off-peak times, internet service providers have an interest in more refined peak-load pricing of call-origination charges. The UK regulator for telecommunications, OFTEL, has given these issues considerable attention. Most continental European countries have a regime of fixed prices for interconnection services; this is inspired by the EU-commission and implemented by the national regulatory authorities (NRAs). The idea is that the dominant provider of interconnection services (i.e. the incumbent) might have an incentive to predate newcomers by setting predatorily low interconnection prices. On the other hand, if not threatened by newcomers, the dominant firm may exploit its position by charging excessively high interconnection prices. The balance between these two incentives apparently

³ Except indirectly through time-dependent prices in relation to noisiness of aeroplanes.

⁴ Whether or not peak-load pricing is discriminatory has been a controversial subject in the literature; this will be discussed in more detail in section 5.

implies a regime of fixed prices. Within this set of fixed prices, the regulator may prescribe a peak-load structure by predefining the peak and off-peak periods and the respective prices. It should be stressed, however, that this regime does not allow the regulated firm any flexibility in prices; instead, the NRA should attempt to find an efficient solution. To this respect, OFTEL (1997a, p. 6) remarks that: "... this would require a very large amount of information about costs and demand" and that "... BT should possess (or be able to obtain) the necessary information about costs and demand." Indeed, this is the main reason for allowing a regulated firm some price flexibility; price structures should adjust to cost and demand conditions. The profit-maximising firm (albeit constrained by regulation) may be expected to be better informed and have stronger incentives to find these price-structures.

In contrast to continental Europe, OFTEL has introduced a (restricted form of a) price-cap regime for network access services in the UK. The regime allows price flexibility between a floor and a ceiling. OFTEL (1997a, pp. 5/6) is well aware of the efficiency properties of peak-load pricing of network access charges. Consequently, OFTEL is inclined to leave it to British Telecom (BT) to determine the optimal peak-load price structure within the price-cap regime, but simultaneously expresses concern about the possible anticompetitive effects. The concern is that BT might selectively squeeze the retail profit margin (being the difference between the retail price and the network access price) at certain times. As a practical solution, OFTEL suggests that the structure of BT's network access charges should roughly follow the structure of BT's retail prices (OFTEL, 1997a and 1997b).

Internet access has given new impulses to the discussion of peak-load pricing of network access. More specifically, the majority of (domestic) internet users rely on their normal telephone line to access their internet service provider (ISP). The costs of internet access thus depend on the charges for call origination. As a rule, call origination is a monopolistic service (i.e. the local loop). Internet users are biased towards off-peak times and thus, ISPs should have some interest in lower off-peak call origination charges, because this would increase the market for internet use as compared to voice telephony. Cave & Crowther (1999) and Welfens & Jungmittag (2000) both make an argument in favour of more

pronounced peak-load pricing of call origination.⁵ OFTEL (1999, pp. 4/5) picks up the argument, confirms the relevance, but states that in its view BT's current relation of peak versus off-peak charges of 4:1 seems appropriate. In particular, OFTEL argues (1999, p. 5) that: "the three peaks [...] are more or less of identical size."

In contrast, the regulator for telecommunications in Germany, the RegTP, has actually prohibited the existing peak-load structure for metered internet access call origination (MIACO) as from the middle of December 2000. The RegTP's basic argument is that there are no convincing arguments in favour of a peak-load structure. According to the RegTP the load is already flat during the day.⁶ Both the decision and the argument are at least questionable. The background of this rather curious decision probably can be found in the active encouragement of the use of the flat rate internet access call origination (FRIACO), which at first instance aims at the off-peak periods. The prohibition of peak-load charging for MIACO raises the off-peak MIACO charge, which increases the relative attractiveness of the (off-peak) FRIACO charge for the end-users.

Peak-load pricing has a long-standing tradition in electricity pricing. Due to liberalisation and the requirement of third party access to the networks, a relatively new phenomenon is separate pricing for use of networks. The networks are monopolistic bottlenecks and the main part of the costs are fixed. In contrast to airports and telecommunications, in electricity, capacity-charging for use of the electricity network appears to be an uncontroversial part of the regulatory regime. In the Netherlands, the network access charges are regulated by a price-cap regime (DTe, 2000), which determines the level of the charges, whereas the so-called Tariff Code lays down the structure of the charges. This Tariff Code states that it is left to the network operators to determine a peak-load element. Examination of existing so-called Distribution-Use-of-System charges in the UK reveals that the degree of differentiation with respect to time is large.

⁵ Both papers rely on studies commissioned by AOL.

⁶ Compare RegTP's press announcement on its flat-rate decision of 16 November 2000: <http://www.regtp.de/>. Unfortunately, there is no publicly available background document, which makes it quite hard to trace the RegTP's real arguments.

This concerns both time of day and time of year, for both domestic and non-domestic users. Moreover, the precise details as to what should be considered appropriate periods varies between the various network operators. There is a difference with telecommunications. A distribution network operator cannot predate a competitive network operator because the distribution networks are genuine monopolies. On the other hand, in correspondence with OFTEL's argument mentioned above, the distribution network operator could in principle squeeze the retail profit margin at selected times. Nevertheless, neither in the UK nor in the Netherlands does this appear to be an issue of great concern.

The contrast to the access pricing of the distribution networks in Germany is illustrative. The level of the network access prices in Germany is unregulated, whereas the structure is monitored by the antitrust agency. Close examination of the structure of the network access charges reveals that the degree of peak-load pricing is surprisingly low. Moreover, the structure of the network access charges differs significantly from the structure of the retail prices. This is nicely illustrated for one specific group of users who rely strongly on the off-peak period; for this specific user-group, the network access charges are higher than the retail prices, which in fact means that the network operator subsidises this specific group (Brunekreeft & Keller, 2000). Needless to say that competitors will not be able to compete for this group of users. If we assume that some degree of peak-load pricing is desirable and necessary, and if we further assume that this degree is approximated by the existing structure of the retail prices, then we might conclude that the apparently non-discriminating structure of the network access charges is in fact discriminating.

3. The setting and the social welfare maximiser

In the following two sections the capacity problem will be examined by means of a formal model. In order to set a benchmark for the results under various price-cap rules, section 3 will present the reference case of social welfare maximisation. The following notation will be used (this notation applies to both sections, unless stated otherwise):

$i=1, 2$ (peak-load) periods: $i=1$ is the peak period and $i=2$ is the off-peak period

$t=1 \dots \infty$ (regulatory) periods

Two different types of periods are relevant. The first (denoted by i) characterises the peak-load problem. Only two such periods are assumed: peak versus off-peak. The second (denoted by t) characterises the regulatory period, usually a year. This is relevant for the (lagged) price-cap rules, where this period's constraint depends on the values of the previous (regulatory) period. The index t will be omitted if it is superfluous.

δ time-preference

$p_{i,t}(Q_{i,t})$ inverse demand for good Q in (peak-load) period i and (regulatory) period t

K_t maximum capacity in period t

β (marginal) capacity costs

c_i (constant) marginal production costs for $i=1,2$.

λ Lagrange parameter, which differs for each case. Superscripts "F" and "S" are for the firm-peak case and shifting-peak case, respectively.

The proper use of capacity, K_t , and corresponding (marginal) capacity costs, β , is elementary for the capacity problem. The (marginal) capacity costs are denoted by β ; they represent the costs of one additional unit of capacity.⁷ In contrast, (short run) marginal production costs are denoted by c_i , which may differ for each (peak-load) period i , but are assumed to be constant otherwise. Capacity is taken throughout as variable for regulatory periods, but not for peak-load periods. Thus for each period t , the maximisation problem determines $Q_{1,t}$ and $Q_{2,t}$, and thereby $K_t = \max(Q_{1,t}, Q_{2,t})$. This approach is in accordance with Steiner (1957); taking K as fixed is possible, but does not provide additional insight.⁸

⁷ It may be noted that this notation has a strong empirical appeal, if β is interpreted as long run incremental costs.

⁸ An interesting extension might be provided by indivisible investment. In a context without price caps, Williamson (1966) explored this issue.

Social-welfare maximisation

$$\begin{aligned}
L(Q_{1,t}, Q_{2,t}, K_t) = & \sum_{i=1}^2 \int_0^{Q_{i,t}} p_{i,t}(Q_{i,t}) dQ_{i,t} - \beta K_t - \sum_{i=1}^2 c_i Q_{i,t} - \sum_{i=1}^2 \lambda_{i,t} (Q_{i,t} - K_t) \\
& + \lambda_{3,t} \left[\sum_{i=1}^2 p_{i,t}(Q_{i,t}) Q_{i,t} - \beta K_t - \sum_{i=1}^2 c_i Q_{i,t} - \sum_{i=1}^2 \lambda_{i,t} (Q_{i,t} - K_t) - \gamma \right] \quad (1)
\end{aligned}$$

Behind this Lagrange setting is the familiar Ramsey-pricing problem; social welfare is maximised subject to a cost-recovery constraint. The constraint here states that the firm's profit is larger than or equal to some predetermined level, γ , which may be zero. Note that the optimisation problem does not have a time lag and thus taking account of the regulatory periods t is superfluous here; the formulation through time will be relevant for the price-cap rules in section 4.

The capacity problem has been modelled explicitly with the Lagrange constraints denoted by $\lambda_{1,t}$ and $\lambda_{2,t}$. It states that in every (peak-load) period i , output cannot be larger than capacity. With positive β , this formulation sets the peak-load problem, i.e. the joint-supply case. Alternatively, a non-joint-supply formulation would require $Q_{1,t} + Q_{2,t} \leq K_t$, which differs systematically. In both sections the difference between the firm-peak case and the shifting-peak case is elementary. For the firm-peak it is assumed throughout that $\lambda_1 > 0$ and $\lambda_2 = 0$, which implies $Q_{2,t} < Q_{1,t} = K_t$. The alternative (firm-peak) solution would merely reverse the indices. Note that if $\lambda_{1,t} > 0$ and $\lambda_{2,t} = 0$ should imply $Q_{1,t} < Q_{2,t} = K_t$ it would be a contradiction and can thus not be part of a solution. For the shifting-peak case, $\lambda_{1,t} > 0$ and $\lambda_{2,t} > 0$, which implies $Q_{1,t} = Q_{2,t} (= K_t)$. Note furthermore that $\lambda_{1,t} = 0$ and $\lambda_{2,t} = 0$ cannot be a solution (with variable K_t and positive β) and is therefore ignored in the following; it would violate the first-order condition w.r.t. K_t .

For the maximisation problem in eq. (1), the first-order conditions w.r.t. $Q_{1,t}$, $Q_{2,t}$ and K_t for every t are derived. Furthermore, the usual Kuhn-Tucker conditions apply, in particular, the complementary slackness conditions. Working out the first-order conditions for the firm-peak case and the shifting-peak case gives:

Firm-Peak Case (social welfare maximising)

$$MR_1 - c_1 - \beta = -\frac{1}{\lambda_3^F} (p_1 - c_1 - \beta) \quad (2)$$

$$MR_2 - c_2 = -\frac{1}{\lambda_3^F} (p_2 - c_2) \quad (3)$$

Shifting-Peak Case (social welfare maximising)

$$MR_1 + MR_2 - c_1 - c_2 - \beta = -\frac{1}{\lambda_3^S} (p_1 + p_2 - c_1 - c_2 - \beta) \quad (4)$$

These results are Steiner's (1957) solutions. The results for eqs. (2) and (3) are familiar Ramsey-prices and correspond to e.g. Bradley & Price (1988, p. 103). What actually happens in the firm-peak case is that within this solution the (marginal) capacity costs β are fully allocated to the peak demand. Thus, given the solution, a reformulation of the optimisation problem would actually set marginal costs in period $i=1$ equal to $c_1 + \beta$ and in period $i=2$, c_2 . The prices p_1 and p_2 are set accordingly, taking account for the profit-constraint, which is reflected by λ_3 . Things change for the shifting-peak solution. The (marginal) capacity costs, β , are allocated to both periods i , according to demand. Consequently, the optimal price structure is determined by the respective willingness-to-pay in each period i , given that output is the same in each period i and thereby the same as capacity. It can be seen from eq. (4), that the price structure is determined by vertical summation.⁹ Steiner (1957) called this case the shifting-peak case for the following intuitive reason. Assume the firm-peak solution. Now suppose that pricing according to eqs. (2) and (3) implies that output in the off-peak period turns out to be larger than output in the peak period, $Q_{2,t} > Q_{1,t}$. This would "shift the peaks". This is a contradiction in the

⁹ The zero-profit case is illustrative. First multiply both sides of eq. (4) with λ_3^S , and then take $\lambda_3^S=0$. It follows that the right-hand side should be equal to zero; it follows that the price rule states that the *sum* of the prices should be equal to the *sum* of marginal costs (including β). Similar reasoning for maximum profits (with $\lambda_3^S = \infty$) reveals that the *sum* of marginal revenue equals the *sum* of marginal costs (including β).

solution, and it is neither welfare maximising nor profit maximising. Instead the firm or the social planner would increase the off-peak price and decrease the peak price to forestall that output in the off-peak period becomes larger than in the peak period; in effect, output for both periods would be identical and equal to capacity and pricing would be according to eq. (4).

It should be stressed that in the shifting-peak solution, the capacity costs β , which are elementary for the joint-supply case, are optimally allocated to the different periods i according to demand. This creates a very difficult task for the regulator. Even if c_1 , c_2 and β are known, the regulator would still not know how to allocate β ; additional detailed information about demand is required. This is not so for the firm-peak case. With c_1 , c_2 and β known, the prices could be set directly. Consequently, especially for the shifting peak case, a regulator would gladly like to leave the allocation of β to the regulated firm, which is feasible as will be shown in section 4.

4. Price capping and the capacity problem

The basic structure of section 3 can be used to examine the effects of price caps on the peak-load price structure. Various forms of price caps are applied in practice and, in particular, the (Laspeyres) tariff basket and the (lagged or non-lagged) average revenue cap have received attention in the literature.¹⁰ Thereby, the superior efficiency properties of the tariff basket as compared to the average revenue cap have been stressed. The price structure under a tariff basket converges to a Ramsey-price structure, whereas the average revenue cap normally will not. The basic intuition is that under the tariff basket, the price structure chosen by the firm in this period determines its constraint in the next period and so on; this flexibility allows the firm to optimise its price structure (i.e. constrained profit maximisation) in the long term, which corresponds to a Ramsey-price structure (i.e. pricing according to elasticities). Under an average revenue cap, the constraint is adjusted only indirectly through the quantity

¹⁰ This has been the main focus of Bradley & Price (1988) and Cowan (1997).

weights and not directly through the prices themselves. The resulting inflexibility induces the deviation from the optimal price structure.

Relying on Bradley & Price (1988) and Cowan (1997) the distinction between the (Laspeyres) tariff basket and the average revenue cap is adopted; the latter is subdivided into a lagged versus a non-lagged average revenue cap. It is assumed throughout that in the price-cap constraints, RPI-X is zero. First the constrained maximisation problem will be formulated for each of these three cases, then the solutions will be presented and discussed successively. In each case a monopolist maximises its discounted stream of profits subject to a price-cap constraint. The notation is as given in section 3 unless stated otherwise.

Formally, maximise profit:

$$\pi(Q_{1,t}, Q_{2,t}, K_t) = \sum_{t=0}^{\infty} \left[\sum_{i=1}^2 p_{i,t}(Q_{i,t})Q_{i,t} - \beta K_t - \sum_{i=1}^2 c_i Q_{i,t} - \sum_{i=1}^2 \lambda_{i,t}(Q_{i,t} - K_t) \right] \delta^t$$

subject to:

Case 1: tariff basket (Laspeyres) - Lagrange-multiplier, $\lambda_{4,t}$:

$$\sum_{i=1}^2 p_{i,t}(Q_{i,t})Q_{i,t-1} \leq \sum_{i=1}^2 p_{i,t-1}(Q_{i,t-1})Q_{i,t-1} \quad \text{for all } t. \quad (5)$$

Case 2: average revenue cap (lagged) - Lagrange-multiplier, $\lambda_{5,t}$:

$$\sum_{i=1}^2 p_{i,t}(Q_{i,t})Q_{i,t-1} \leq \bar{p} \cdot \sum_{i=1}^2 Q_{i,t-1} \quad \text{for all } t. \quad (6)$$

Case 3: average revenue cap (non-lagged) - Lagrange-multiplier, $\lambda_{6,t}$:

$$\sum_{i=1}^2 p_{i,t}(Q_{i,t})Q_{i,t} \leq \bar{p} \cdot \sum_{i=1}^2 Q_{i,t} \quad \text{for all } t. \quad (7)$$

It may be noted that cases 1 and 2 have a time-lagged structure (in contrast to case 3); these cases require time dependency in the optimisation and they will be solved for the steady-state solution. In cases 2 and 3, \bar{p} denotes the average revenue cap, which is set by the regulator.

4.1 Solution of case 1: tariff basket (Laspeyres) - Lagrange-multiplier, $\lambda_{4,t}$:

The (Laspeyres) tariff basket is generally considered the most elegant variation of the price-cap rules. It relies implicitly on an equity consideration that a consumer should be able to purchase the quantities bought in the last period with the same sum of money in the current period. In other words, a weighted average of prices may not rise. A price increase in one product (or consumer group) should be accompanied by a price decrease in another product (or consumer group). The weights in this constraint are determined by the firm's output quantities (the "basket"); moreover, the constraint adjusts through time, because it is determined by the firm's previous period's price structure. After derivation of the first-order conditions w.r.t. $Q_{1,t}$, $Q_{2,t}$ and K_t , and the additional Kuhn-Tucker conditions, the steady-state solutions are straightforward:

Firm-Peak Case (tariff basket)

$$MR_1 - c_1 - \beta = -\frac{\lambda_4^F (1-\delta)}{1 - \lambda_4^F (1-\delta)} (p_1 - c_1 - \beta) \quad (8)$$

$$MR_2 - c_2 = -\frac{\lambda_4^F (1-\delta)}{1 - \lambda_4^F (1-\delta)} (p_2 - c_2) \quad (9)$$

Shifting-Peak Case (tariff basket)

$$MR_1 + MR_2 - c_1 - c_2 - \beta = -\frac{\lambda_4^S (1-\delta)}{1 - \lambda_4^S (1-\delta)} (p_1 + p_2 - c_1 - c_2 - \beta) \quad (10)$$

As could be expected from the results of Bradley & Price (1988) and Cowan (1997), the tariff basket leads to superior efficiency results. Indeed, comparing the solutions here with the reference solution in section 3, it can readily be seen that the peak-load structures for both the firm-peak case and the shifting-peak case are equivalent with those for social-welfare maximising. The solution eqs. (8), (9) and (10) on the one hand and eqs. (2), (3) and (4) are equivalent, but for the correction term. It follows that a profit maximising monopolist, who is price-cap regulated with the (Laspeyres) tariff basket, will seek the efficient peak-load price structure. Section 4.4 will show that the choice between the firm-peak case

and the shifting-peak case is endogenous. Under the tariff basket the profit-maximising firm will always choose the option which is simultaneously welfare maximising.

The polar cases of λ_4 can be specified upon reflection.¹¹ Concentrating on one case only, denote the correction factor in eq. (8) by μ . If the price-cap constraint does not bind, λ_4 is zero and it follows that μ is zero. On the other hand, for the zero-profit case, $1/\mu$ should be zero, which implies that μ goes to infinity. This is achieved if the term $\lambda_4(1-\delta)$ goes to 1. For $\delta = 0$ (no time dependence, or a myopic firm), this implies that λ_4 goes to 1. For $\delta = 1$, however, it implies that λ_4 goes to infinity; i.e. by infinitely extended time-preference the price-cap constraint gets infinitely strongly binding. It should be noted that it is incorrect to conclude that from $\delta = 1$, it follows that $\mu = 0$, and thus the unconstrained monopoly solution would follow. This would imply that a sufficiently patient firm could always bypass the price-cap constraint. This is not so. If δ goes to 1, λ_4 increases sufficiently strongly, such that the term $\lambda_4(1-\delta)$ goes to, but remains smaller than, 1. Thus, $\mu > 0$, and $0 < \lambda_4(1-\delta) < 1$, with $\lambda_4 > 0$.¹²

4.2 Solution for case 2: average revenue cap (lagged) -

Lagrange-multiplier, $\lambda_{5,t}$

Average revenue caps can be and are used if quantities of different products (or different consumer groups) can be summed; e.g. in electricity, quantities for small and large users are both expressed in kWh. An average price, \bar{p} , for the products under consideration is then set by the regulator, which determines the constraint. Note that the average price, which may in principle be any number, is

¹¹ It would be interesting (although not essential) to find an expression for λ_4 (in terms of starting values), but this turns out to be rather tricky; the problem is that the constraint serves as the additional equation, which equates the number of variables with the number of equations. In steady state, however, the constraint becomes a tautology, so that it cannot be used anymore. Instead, the general solution to the difference equation should be derived in which the starting values could be substituted; this, however, will be left for further research.

¹² Compare to Cowan (1997, ft. 12, p. 65).

not adjusted through time. Consequently, the price structure chosen by the regulated firm in this period does not affect the constraint in the next period directly. The resulting rigidity provides the intuition that inefficient price structures may arise. The expression "lagged" concerns the quantity weights in the constraint, which are the quantities of the previous period. In contrast, in case 3 (see below) the average revenue constraint is determined by the quantities of the current period, and is thus labelled "non-lagged".

Solving for the steady-state solutions for both the firm-peak case and the shifting-peak case results in:

Firm-Peak Case (Lagged Average Revenue Cap)

$$MR_1 - c_1 - \beta = -\frac{\lambda_5^F}{1 - \lambda_5^F} (\delta(\bar{p} - p_1) + p_1 - c_1 - \beta) \quad (11)$$

$$MR_2 - c_2 = -\frac{\lambda_5^F}{1 - \lambda_5^F} (\delta(\bar{p} - p_2) + p_2 - c_2) \quad (12)$$

Shifting-Peak Case (Lagged Average Revenue Cap)

$$MR_1 + MR_2 - c_1 - c_2 - \beta = -\frac{\lambda_5^S}{1 - \lambda_5^S} (p_1 + p_2 - c_1 - c_2 - \beta) \quad (13)$$

Comparing these solutions with the reference case (or with the tariff basket), it becomes clear that there is a difference between the firm-peak case and the shifting-peak case. Whereas the price structure of the firm-peak case may deviate from the optimal price structure, in the shifting-peak case the constrained profit-maximising price structure will correspond to the optimal price structure. This is the main difference with the approach of Bradley & Price (1988) and is the result of modelling the capacity problem explicitly, which thereby distinguishes this type of problem from non-joint-supply types of problems. The deviation implies that the firm will tend to opt for the shifting-peak case more often than would be socially optimal; more to this effect follows in section 4.4.

The price structure in the firm-peak case refers to the average revenue cap, \bar{p} . Comparing eqs. (11) and (12) with eqs. (2) and (3) provides additional insights. Assuming that the price-cap constraint binds, it must be true that $p_1 > \bar{p} > p_2$. It follows that $(\bar{p} - p_1) < 0$, and $(\bar{p} - p_2) > 0$. For reasons of illustration, assume a zero-profit situation. It follows that in eq. (12) the right-hand side is more negative than in eq. (3), from which in turn it follows that output in eq. (12) will be larger than in the reference case of eq. (3). From similar reasoning it follows that output in eq. (11) will be smaller than in eq. (2). Consequently, in the firm-peak case, the lagged average revenue cap will tend to result in too much output in the off-peak period and too little output in the peak period, and thus capacity would be too small as well. Equivalently, the off-peak price will be too low and the peak price too high. For a zero-profit situation, this implies that the off-peak price in the firm-peak case of case 2 is below marginal costs, c_2 . The empirical implications of this effect may be modest, however. In practice, there is a countereffect which is typical for price-cap regulation. More investment is likely to ease the price-cap constraint determined by the regulator in the next review; this will set an incentive to increase capacity. Consequently, the overall effect on capacity may be small.¹³

4.3 Solution for case 3: average revenue cap (non-lagged) - Lagrange-multiplier, $\lambda_{6,t}$

The non-lagged average revenue cap differs from the lagged average revenue cap only with respect to the time-reference of the quantity weights. The non-lagged average revenue cap has a considerable practical advantage over the other price-cap rules. It is far easier to compute for the regulator. A closer look at the constraint reveals that all that is required to monitor the constraint is *total* revenue and *total* quantity.¹⁴ The other rules require more detailed information; in particular, they require separate quantity information for each and every

¹³ The author would like to thank Richard Green for pointing this out.

¹⁴ This is actually how the CAA regulates the London airports. The regulatory review (CAA, 2000), however, questions this approach and discusses a change to a tariff-basket approach.

defined product. In turn, this implies that the products will have to be defined in the first place. For the peak-load problem at hand, this implies that the time-structure would have to be defined. As Bradley (1993) shows, this induces additional problems. The non-lagged average revenue cap would not require precise definition of the periods; it can be left to the firm, since the constraint is defined in terms of total revenue and total quantity. The disadvantage of the non-lagged average revenue cap is that the regulated firm will have to forecast the quantities in order to fulfil the constraint; in the lagged variations, the constraints are based on the quantities of the previous period, which are known per definition. Forecasting the quantities introduces additional uncertainty for the firm.¹⁵

The solutions for case 3 are as follows (due to the problem's non-lagged structure, the time-dependence can be dropped immediately):

Firm-Peak Case (Non-Lagged Average Revenue Cap):

$$MR_1 - c_1 - \beta = -\frac{\lambda_6^F}{1 - \lambda_6^F}(\bar{p} - c_1 - \beta) \quad (14)$$

$$MR_2 - c_2 = -\frac{\lambda_6^F}{1 - \lambda_6^F}(\bar{p} - c_2) \quad (15)$$

Shifting-Peak Case (Non-Lagged Average Revenue Cap):

$$MR_1 + MR_2 - c_1 - c_2 - \beta = -\frac{\lambda_6^S}{1 - \lambda_6^S}(p_1 + p_2 - c_1 - c_2 - \beta) \quad (16)$$

Again, the shifting-peak case gives the optimal price structure; the average price \bar{p} drops out in the solution. A deviation remains in the firm-peak case. In contrast to case 2, however, this deviation does not vanish for $\delta = 0$. By re-writing the firm-peak solution for cases 1, 2 and 3, it becomes clear that the lagged average revenue cap is a hybrid form between the tariff basket and the

¹⁵ Compare to Bradley & Price (1988, p. 102).

non-lagged average revenue cap. Concentrating on rewriting the peak-period solution of eqs. (8), (11) and (14) gives:¹⁶

$$MR_1 - c_1 - \beta = \lambda_4^{FP} (1 - \delta) \frac{\partial p_1}{\partial Q_1} Q_1 \quad (8')$$

$$MR_1 - c_1 - \beta = \lambda_5^{FP} \left[(1 - \delta) \frac{\partial p_1}{\partial Q_1} Q_1 + \delta (MR_1 - \bar{p}) \right] \quad (11')$$

$$MR_1 - c_1 - \beta = \lambda_6^{FP} (MR_1 - \bar{p}) \quad (14')$$

It may be seen directly that eq. (11') comprises (if one likes, "a time-preference-weighted average of") the other two equations. For $\delta=0$, the lagged average revenue cap is equivalent to the tariff basket, and for $\delta=1$ the lagged and non-lagged average revenue caps are equivalent. The reason is straightforward: the deviation effect is caused mainly by the effects on the constraint, for the lagged cap in the next period and for the non-lagged cap in this period. A myopic firm does not consider the effects on the next period, and in a non-lagged situation, time-preference does not matter. To conclude, for the non-lagged average revenue cap the deviation from the optimal tariff structure in the firm-peak case is likely to be more severe than under the lagged average revenue cap. Nevertheless, the shifting-peak case still gives the optimal tariff structure.

4.4 Comparison

This deviation under the average revenue cap has the following intuition. Assume that \bar{p} has the optimal value as would be the case for social-welfare maximisation (for any level of the constraint). This then reflects the optimal quantity weights. Under the average revenue cap, the firm should increase the weight of the low price (by lowering the low price) and decrease the weight of the high price (by raising the high price). This would decrease the weighted average of the overall price. This in turn allows the weighted average of the

¹⁶ The same can be done for the off-peak period which does not differ from the peak period, but for β . This would merely give a repetition of the argument.

overall price level to be raised until it equals \bar{p} again. Thus, by rebalancing the weights, the firm eases the constraint. This can be profitable, because the price increase of the high price is multiplied by a larger quantity than the price decrease of the low price. Thus, although the price decrease of the low price is necessarily larger than the price increase of the high price, the profit increase associated with the latter can be larger than the profit decrease associated with the former. This effect becomes smaller as the difference between the quantities becomes smaller.

The regulatory answer would have to be to lower \bar{p} in response to the weight rebalancing. Effectively, however, this would lead to the tariff basket, because the firm would anticipate this and would internalise the effect the weight rebalancing would have on the price cap. In the tariff basket, the effect of the changed quantity weights is nullified by the associated change of the prices, such that rebalancing (away from the optimum) is exactly non-rewarding at the margin. In the non-lagged average revenue cap, the weight rebalancing has a direct effect and is thus immediately profitable. In the lagged average revenue cap, the weight rebalancing only has an indirect effect, in that it affects next period's constraint. The patient firm will ease the future constraint to make future profits at the expense of current profits. The myopic firm on the other hand will not be interested in future profits and will thus behave as under the tariff basket.¹⁷

The deviation of the average revenue cap also implies that the firm's endogenous choice between the shifting-peak and firm-peak case is not socially optimal. This can be shown most conveniently by assuming a parametric representation of linear demand. Assume $p_1 = a_1 - bQ_1$ and $p_2 = a_2 - bQ_2$, where $a_1 > a_2$. What is to be determined is the endogenous switching point, which is the point where the firm switches from the shifting-peak case to the firm-peak case; the switching point is described as a relation between the cost and demand parameters. Formally, the profits in both cases should be compared, which is rather

¹⁷ That this must be the case for $\delta=0$ can be seen directly from the optimisation problem. The constraints for cases 1 and 2 would be equivalent and thus the same results should arise.

cumbersome. Instead, a shortcut can be made by equating both solutions of the firm-peak case for $Q_1 = Q_2$; this sets the bordercase of the firm-peak case. For the firm-peak solutions of the tariff basket (case 1) it follows:¹⁸

$$\beta_{SP}^* = (a_1 - a_2) - (c_1 - c_2). \quad (17)$$

and for case 2 (the "hybrid" case):

$$\beta_{SP} = \left[\frac{1 + \mu^F (1 - \delta)}{1 + \mu^F} \right] (a_1 - a_2) - (c_1 - c_2). \quad (18)$$

Here $\mu^F = \frac{\lambda_5^F}{1 - \lambda_5^F}$. If β is larger than β_{SP}^* the firm will choose the shifting-peak

case and reverse. For $\beta = \beta_{SP}^*$ the firm is exactly indifferent. Note first that if $\delta = 0$ in (18), the term between squared brackets becomes 1: the myopic firm under a lagged average revenue cap switches at the socially optimal point. Note furthermore that the term between squared brackets is also 1, if the constraint is non-binding ($\mu^F = 0$): the unregulated firm switches at the socially optimal point. For $0 < (\mu^F, \delta) < 1$, the term between squared brackets will be smaller than 1, which implies that $\beta_{SP} < \beta_{SP}^*$. This means that the firm, which is bindingly regulated with an average revenue cap, "stays too long" in the shifting-peak case.¹⁹ This is in accordance with the quantity deviations indicated above. The firm regulated by an average revenue cap increases the off-peak quantity relative to the peak quantity and is thus more likely to opt for the shifting-peak case.

5. Assessment

5.1 Is peak-load pricing discriminatory?

A useful and widely accepted definition of price discrimination is provided by Philips (1983, p.6, italics in original):

¹⁸ Since the structure of the outcome under the tariff basket is the same as under social welfare maximisation, the switching point is the same as well.

¹⁹ An interesting extension would be to examine the firm's incentives if β (in trade-off with c_1 and c_2) can be chosen by the firm endogenously.

"[P]rice discrimination should be defined as implying that two varieties of a commodity are sold (by the same seller) to two buyers at different *net* prices, the net price being the price (paid by the buyer) corrected for the cost associated with the product differentiation."

Note the phrase "... two varieties of a commodity ...". Whereas it correctly broadens the scope of application to obvious cases such as first and second class in trains, it also introduces an inherently subjective element into the definition. Whether or not two items are varieties of the same commodity rather than two different commodities is largely a matter of consumer perception.

Following this definition, the firm-peak case is not discriminatory. The difference in prices reflects the difference in costs, because the capacity costs are allocated to the peak period; that is, to those users who are responsible for a capacity expansion. Whether the shifting-peak case is discriminatory is subject to controversy.²⁰ Steiner (1957, p. 590) claimed that it is discriminatory. Given that in this case the output in both periods are identical and equal to capacity it is impossible to determine which users are responsible for which part of the capacity costs. In the face of equal outputs, unequal prices thus imply discrimination. Hirshleifer (1958) and later Demsetz (1973) object to this claim by applying the concept of opportunity costs. If willingness to pay at the margin is seen as opportunity costs, it follows that the unequal prices do in fact reflect cost differences. Chamberlin (quoted in Steiner, 1957, fn. 9, p. 590), on the other hand, objects to Steiner's argument by pointing out that the two periods are different products and thus the prices cannot be discriminatory by definition.²¹

The arguments above are rather academic. The more practical question remains whether peak-load pricing should be prohibited, even if strictly speaking the shifting-peak solution would qualify as discriminatory? Several arguments speak against prohibition. First, peak-load pricing is an efficient way to handle (scarce)

²⁰ The discussion goes back to the Pigou-Taussig controversy at the beginning of the 20th century. Compare to Ekelund & Hulett (1973) or Brunekreeft (1998) for a more extensive discussion.

²¹ Note that airport regulation authorities in Germany are on the side of Steiner as they claim that different prices for the *same physical infrastructure* are unfairly discriminating (see section 2).

capacity. Instead, uniform pricing would be highly inefficient. Second, in contrast to other forms of price discrimination, peak-load pricing is rather unlikely to impede competition. The joint-supply structure of the problem is, irrespective of size, the same for all firms. In contrast to for example quantity discounts, peak-load pricing is unlikely to change the industry structure. It may very well be that some firms have an interest in more or less refined peak-load pricing, but redistribution of rents should not be confused with impediments to competition. Third, peak-load pricing is the one form of price discrimination which is stable in competition; this contrasts with other forms of price discrimination.²² This implies that if the industry under consideration were competitive rather than monopolistic, the exact peak-load pricing structure would necessarily be the result. Peak-load pricing is not an exposition (let alone abuse) of market power. It seems justified to conclude, that a prohibition of peak-load pricing (based on the argument that it would be discriminatory) seems to lack a solid foundation.

5.2 The "predation problem"

The "predation problem" is one of the toughest price-cap intrinsic problems (compare e.g. OPTA, 1999). The predation argument in an unregulated setting runs as follows. A (dominant) firm may have an incentive to cut its prices in order to predate a (smaller) competitor. To do so the firm should lower its price sufficiently so that the competitor actually runs a loss and ultimately must leave the market. There are several problems with this argument, one of which is that this strategy is rather expensive for the predating firm; it will run losses itself as well, which should be compensated after the predated firm has left the market. One counterargument against this flaw is that the predating firm may have two markets and that the degree of competition differs in these markets. The argument then runs that the firm may attempt to predate competitors on the relatively competitive market while financing or compensating this battle with

²² In fact, this was the point of consensus in the Pigou-Taussig controversy. The claim has been formalised by Officer (1966). It can easily be shown in the context of this paper that the efficient peak-load structure would arise if the setting were competitive, rather than monopolistic.

its (excessive) profits from the uncompetitive market. Whereas it may be true that the battle can be financed with the profits from the uncompetitive market, it is not true that the losses made on the competitive market can be compensated on the uncompetitive market. The excessive profits on the uncompetitive market can be achieved irrespective of what happens on the other market. If the firm was making maximum excessive profits on the uncompetitive market, then it is irrational to want to raise the price there in order to compensate for the price decrease in the competitive market; the firm would only make less profits on the uncompetitive market, because it would raise the price level above the profit-maximising level. Here is where the price-cap problem comes in.

Under a price-cap constraint it is rational to raise the price in the uncompetitive market in order to compensate the price decrease in the competitive market. Lowering the price in one market allows a price increase in another market, *because* the price-cap constraint is formulated as such. Thus, due to the price-cap constraint, predation may become relatively cheap for the predating firm, while simultaneously not so for the predated firms, which are not active on the uncompetitive market by assumption.²³ In practice this is perceived as a serious problem. The regulators' answer to this problem is to define separate baskets for markets with different degrees of competitiveness. Notwithstanding the fact that this approach may be necessary, it complicates the regulation and introduces new inefficiencies. It seems desirable to avoid such a subdivision of the tariff basket.

The predation argument as formulated above does not hold for the peak-load-pricing problem, or at best it will only be a weak argument.²⁴ The peak-load problem is a problem of joint supply. In principle, the degree of competitiveness is the same on both markets, due to joint supply. It is not rational for a firm to concentrate on say the peak market and ignore the off-peak market (which can very well be a rational strategy in the non-joint-supply situation); the capacity

²³ Even this is not completely convincing. After successful predation, the firm would like to raise the price on the competitive market, but therefore it would have to lower the other price in order to fulfil the constraint (see further Vogelsang, 1989, p. 37).

²⁴ Compare also Cave & Crowther (2000).

would be idle in the off-peak period. In principle, all firms are equally present in both markets (i.e. both periods). Consequently, if the incumbent firm attempts to predate competitors in say the off-peak market by lowering the off-peak price, while raising the peak price, the competitors will indeed suffer from the lower off-peak price but will simultaneously profit from the higher peak price. The trick is to consider the peak and off-peak markets as virtually one market connected through the joint-supply characteristic.

Two remarks are in order. First, normal predation may nevertheless occur; i.e. the incumbent might consider to lower the price on both markets. This is not the issue here, however. This type of predation is not inherently a problem concerning the price flexibility of a price cap.²⁵ Second, there may be reasons why the joint-supply relation is not strict. It is not unrealistic for example to assume that commercial users (e.g. of telecommunication services) may be biased towards the peak period, whereas residential users are not biased or are biased towards the off-peak period. If firms had a reason to specialise in only one of these two groups, then the joint-supply relation would not be strict. The argument against predation formulated above would be toned down. However, specialising in one of the two groups may be a good marketing strategy if the firms have to choose at all, but it is unlikely to be a necessity. Predation of one of the groups is likely to achieve nothing but to shift the competitors' attention to the other market. In all, predation is even under normal circumstances not an entirely convincing strategy and is unlikely to be a feasible strategy for the peak-load situation.

5.3 Distributive concerns

Distributive effects of allowing the price flexibility associated with price caps is a matter of serious concern for regulators. The examples of the airport charges and the call origination internet access charges mentioned in section 2 are illustrative. Apart from balancing the interests of various firms, the main

²⁵ It may be interesting to consider a price cap which binds on both sides; i.e. the "lower than or equal to" in the constraint would be exchanged by "is equal to".

concern is biased towards price increases for the large group of small (residential) users and in particular those with small budgets. First, the latter group is of political concern, but second the pre-liberalisation price structures (in e.g. telecoms and electricity) tended to cross-subsidise these groups. In for example telecommunications the problem of "rebalancing" expresses this concern. Adjustment to more competitive conditions requires that fixed charges increase relative to variable charges, which means that relatively small users lose. Moreover, prices for long-distance services tend to fall relative to prices for local services; the consumers of local services lose. These are actually the effects of liberalisation, not *of* the price cap; they are allowed by the price flexibility of the price cap. Such concerns are of practical importance and determine the details of the price caps to a non-negligible extent. Normally the basket is subdivided into separate baskets or separate "safety-caps" are set within the basket.

For these reasons some reflections will be made here on distributive effects of introducing a price cap for the peak-load problem in e.g. telecommunications. A comparison is made with the situation without peak-load pricing. Consumer profiles of telecommunication users²⁶ reveal that, under current price structures, commercial users are heavily biased towards the peak period. Residential users are hardly biased and if so then towards the off-peak period due to the internet users. If introducing a price cap for the peak-load problem implies that peak-load pricing gets more refined, such that the peak price increases relative to the off-peak price, then the residential users would gain. More generally, distributive concerns are mainly associated with small residential users; since these have more or less equal consumption in peak and off-peak, the effects will be minimal, while on average they would gain, because the entire situation would improve. Thus, distributive concerns do not seem to offer a convincing counterargument against a price cap for the peak-load problem.

²⁶ Compare e.g. OPTA (2000) or Teligen's T-Basket.

6. Concluding remarks

This paper examines the effect of various price-cap rules on the peak-load price structure in network industries. Surprisingly little research has been undertaken in this direction. In their influential work on price caps, Bradley & Price (1988) set out the frame but do not tackle the capacity problem explicitly. Perhaps the lack of interest in this problem can be explained by its relatively minor practical relevance in the recent past. Partly inspired by growing congestion in the regulated network industries, practical relevance seems to grow rapidly, however. Topical examples are set by airports, telecommunications (especially with respect to internet access) and electricity networks.

The primary aim of this paper is to examine the (static) welfare effects of three well-known price-cap rules on the peak-load price-structure. The formal approach relies heavily on the setting developed by Steiner (1957). It is shown that the prospects for optimal results are good. In the so-called shifting-peak case (i.e. if peak and off-peak demand do not differ too much) the price cap regulated firm will generally seek the socially optimal tariff-structure. In the so-called firm-peak case (i.e. if demands differ strongly), the firm may have an incentive to deviate from the optimal tariff-structure. The deviation occurs under the average revenue cap, but not under the tariff-basket approach. The deviation implies that the firm regulated under an average revenue cap may opt for the shifting-peak case, where the firm-peak case would be socially optimal.

Nevertheless, if the regulatory alternative is uniform pricing (i.e. no peak-load structure), then the results of a flexible price cap always seem preferable. Moreover, if the alternative is that the regulator will prescribe a peak-load structure with the associated prices, the informational requirement will be huge. Especially so for the shifting-peak case, where the common capacity costs should be allocated to the different periods according to demand (rather than to costs). It may be expected that the profit-driven firm will be better informed than the regulator, which makes a strong case for allowing the firm the pricing flexibility.

A counterargument against peak-load pricing is that it is said to be discriminatory. Reflection quickly suggests that although the claim might be

true theoretically, it is hardly a convincing argument to prohibit peak-load pricing. Furthermore, it can be argued that two practically relevant drawbacks of price caps do not apply to the peak-load problem. One is the "predation problem" if two markets with different degrees of competitiveness are regulated with one and the same price cap. Due to the joint-supply character of the peak-load structure this is not a problem. The second problem concerns distributive effects which may be allowed by the flexibility of a price-cap rule. More refined peak-load pricing is likely to advantage residential users relative to commercial or industrial users. This implies that distributive concerns are low. Moreover, since more refined peak-load pricing improves efficiency overall, the relative disadvantage of the latter may be quite limited.

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