Strategic pricing of grid access under partial price-caps — electricity distribution in England and Wales

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Abstract

It is perceived in public debate that monopolistic network operators (who are vertically integrated into competitively organised activities) would raise excessive access charges to derail competition by newcomers. Economic reasoning, however, suggests that the level of access charges is — at least in a simple setting — irrelevant for the intensity of entry by newcomers. In a setting where access charges are price-cap regulated, theoretical considerations and empirical findings for the case of electricity distribution in England and Wales even suggest that inefficiently high access charges correspond with intense market entry. Efficiency concerns remain, nonetheless. If regulated by a practicable partial price-cap, the network operator may enforce monopolistic access charges in certain market segments. Access charges in other segments may be lowered strategically and may even be cross-subsidised. © 2000 Elsevier Science B.V. All rights reserved.

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1. Outline

In many industries the owner of the essential facility network is allowed to compete with entrants in final product markets. Regional Electricity Companies (RECs) in England and Wales, e.g. operate the electricity distribution grids, but are also engaged in electricity retailing (i.e. the sale of electrical energy [kWh] to final consumers). It has been argued that all vertically related businesses of the incumbent grid owner — in addition to his monopolistic grid activities — should be subjected to regulatory oversight (global price-cap approach). There is some concern about global price-caps on theoretical grounds, though, and partial price-caps (that only extend to grid functions) are, at any rate, applied to regulate electricity distribution charges in England and Wales. The paper also provides some background for the ongoing discussion of ownership separation between electricity distribution and retail supply.

The paper’s contribution to ongoing debate are twofold: (i) regulatee’s behaviour is formalised and channels and results of strategic action are analysed in a theoretical model. (ii) The hypothesis of strategic action is tested empirically for the case of electricity distribution in England and Wales and we find evidence supportive of the analytical model.

It seems intuitive that the incumbent attempts strategic pricing for grid access given that his retail business remains unregulated. This has previously been suspected, e.g. by Laffont and Tirole (1996). We formalise this idea and investigate in what direction and to what degree discrimination arises in equilibrium. We expect and empirically observe that high network access charges correspond with extensive entry. This result seems to contradict common wisdom (at first sight), but is shown to derive from pure economic reasoning.

For simplicity we describe a static (one period) setting. Analysis of regulatee’s incentives to dynamically lower cost levels over time under price-caps is neglected for simplicity. We rather focus on the feature of price-caps (or revenue-caps) to constrain an aggregate revenue figure of the regulated utility (e.g. in electricity distribution), where the development of a detailed access tariff structure is left to the discretion of the regulatee.

We commence by placing the concept of this paper in the context of recent debate on regulating grid access charges through price-caps (Section 2). Next we outline the respective institutional framework in England and Wales (Section 3). We develop a theoretical model to show how incentives for strategic discrimination of grid access charges (by strategically balancing the structure of access tariffs) could prevail under partial price-caps as applied in England and Wales. In Section

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1 See e.g. Brunekreeft, 1997, p. 16 and Riechmann (1999, p. 208).
4 we outline the model specification for electricity retail competition and price-cap regulation. In Section 5 the incumbent’s strategic pricing behaviour is assessed formally. We then outline the main propositions derived from the analytical model (Section 6) and empirically test some of the hypotheses derived from that model (Section 7).

2. Relevant recent research into regulating grid access

We identify two recent strings of research that relate to this paper. (i) Normative analysis (how to best regulate) was focussed on the derivation of efficient rules for pricing grid access from the perspective of a fully informed regulator (e.g. Laffont and Tirole, 1994, 1996; Armstrong et al., 1996; Armstrong and Vickers, 1998). This included a debate over the allocative efficiency of the so called ‘efficient component pricing rule’ (ECPR) as suggested by Baumol and Willig. (ii) Positive research investigated incumbents’ strategic action in a (one sector) homogenous product market with opportunities for discriminating with respect to the quality of network access. In this class of analytical models the incumbent network operator can ‘sabotage’ rivals’ technical network access conditions to downgrade rivals’ supply quality (i.e. relatively upgrade their own supply quality). This allows the incumbent’s supply business to earn additional retail rents. Both strings of debate were mainly held with particular reference to the telecommunications industry.

We take the route of positive analysis (how can we expect the regulatee to behave), but ignore opportunities for ‘sabotage’ (non-price discrimination). Our considerations apply to network industries such as electricity or gas which are characterised by several market segments (e.g. defined by supply voltage or pressure) and homogenous (final) products within market segments. We investigate how the incumbent behaves with respect to pricing access for different market segments given a practicable regulatory constraint on his monopolistic network business — a partial price-cap.

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4 For the case of an ill-informed regulator De Fraja (1999) proposes that newcomers should be subsidised through preferential access conditions. This may help to drive the incumbent out of competitive markets and allows for a better accounting separation of the incumbent’s monopoly network business.


7 We see little scope for non-price discrimination in electricity distribution — at least within a regulatory framework that enhances transparency of network access as in England and Wales. For example, the main quality characteristics — voltage and frequency stability — are system features from which individual consumers (e.g. those supplied by entrants) can hardly be excluded.
3. Institutional framework

The electricity industry of England and Wales has been restructured and market rules have been radically reformed with effect from April 1990. As part of reform the 12 Regional Area Boards have been privatised and transformed into Regional Electricity Companies (RECs) that are, as part of their license obligations, primarily responsible for maintaining and operating the regionally monopolistic distribution grids and initially also for supplying electrical energy [kWh] to franchise customers (households and businesses). The RECs can also compete in the electricity retail (supply) market, by selling energy to eligible customers within their own region or in other RECs’ areas. To a limited degree RECs are also allowed to diversify into electricity generation. RECs must keep separate accounts for monopolistic distribution, for retail sales to captive (franchise) customers and for competitive electricity generation and retail (‘financial ring fencing’). Monopolistic distribution and sales to franchise customers are regulated with separate price-caps (so-called distribution and supply price control). The focus of this paper will be on the competitive electricity retail market and the distribution price control.

In their function as distributors, RECs must offer non-discriminatory grid access conditions to non-incumbent second tier suppliers. Distribution use-of-system (DUoS) charges are subjected to price-cap regulation where the price-cap formula restrains the overall revenue to be made in distribution. Within this restraint the RECs are free to devise charge structures. RECs annually (at the beginning of a financial year in April) publish leaflets for DUoS tariffs that contain all relevant price information valid for the following (financial) year.

Customer eligibility for access to competitive electricity retailers (so-called second tier suppliers) was gradually widened.\(^8\) As of April 1990 customers with a maximum demand at 1 MW or more were given competitive access. As of April 1994 customers with a maximum demand at or above 100 kW followed and since June 1999 all consumers have competitive access. In the following we will refer to these market segments as the ‘1-MW’, ‘100-kW’ (maximum at or above 100 kW and below 1 MW) and ‘under 100 kW’ markets. In terms of electricity units [kWh] the ‘1-MW’ market covers 30% of sales, while the ‘100-kW’ and the ‘under 100 kW’ segments cover 20% and 50% of sales, respectively.

Within this framework entrants in the competitive retail market competing against the RECs as first tier suppliers in their host market are RECs selling in other regions as second tier suppliers, the major electricity generators including Scottish generators (Scottish Power and Hydro-Electric), the retail branch of British Gas and some smaller suppliers without plant or wire assets in the UK market. In principle, all retailers commercially procure their power from the Electricity Pool. However, retailers have different options to insure against the volatilities of spot prices in the Pool [mainly vertical integration into generation and hedging contracts such as contracts for differences (CFDs) and electricity

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\(^8\)Non-eligible customers remained captive to their REC and were protected by the supply price control.
forward agreements (EFAs). Through these activities retailers attain different procurement conditions. Retail competition in principle puts pressure on retailers to devise efficient forms of hedging. There is not much scope for product differentiation in electricity retail and consumers usually conclude contracts with the retailer who offers the lowest price.\(^9\) Retail competition is intense and margins (on turnover) are slim. Although RECs supply businesses account for the major part of their turnover RECs largely make their profits in the distribution business.

4. Model assumptions

Major ingredients to the theoretical model, electricity retail competition and the distribution price-cap are outlined in the following.

4.1. Modelling electricity retail competition

We use a simple model of price competition that allows for asymmetric (procurement) cost between incumbents and newcomers (fringe competition) to characterise retail competition.\(^10\)

Starting point of the analysis is a segmentation of the electricity retail market by customer size. This segmentation could, e.g. follow the lines of the market segments ‘1 MW’, ‘100 kW’ and ‘under 100 kW’ as described above. This market segmentation is already determined technically, e.g. since the maximum demand [kW] of a customer largely determines the voltage level [kV] at which he is supplied. Consumers and retailers usually have no choice of changing from one segment (‘voltage level’) to another for the service of grid access (in formal terms: retail services offered in different segments are no strategic substitutes).\(^11\)

There is an integer \(n\) of market segments. Any retail supplier [incumbent (M) or entrants (E) without network assets in the relevant market] must procure one unit of the grid access service \(i\) — charged at \(a_i\) by the incumbent — and one unit of energy to supply one unit of electricity to a consumer in segment \(i\) (i.e. we imply fixed coefficient production). Retailers only incur cost of procuring energy and grid access.\(^12\) M’s retail business has total cost of energy procurement of \(G = G(q)\)

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\(^9\)Note that technical services relating to physical distribution lie in the responsibility of the operator of the distribution grid. Scope for product differentiation in electricity retail lies in side offers such as energy management services or financing options. Market research (e.g. Market Line (1996, p. 115)) suggests that additional services are readily imitated by retail suppliers so that differentiation only arises temporarily.

\(^10\)A modelling of retail competition with customer inertias is found in Green and McDaniel (1998).

\(^11\)Calculation of grid access charges is performed on a site specific basis. For an independent electricity retailer there are, therefore, no (significant) economies of scale with respect to grid access charges from supplying a larger number of customers.

\(^12\)This implies the assumption that the cost of retailing services is zero. Results extend to a situation were the cost of retailing services are identical for all retailers (i.e. where retailers only gain a competitive edge by the procurement conditions they can negotiate) or where differences in the cost function for retailing services can be incorporated into the cost function \(G(q)\) for energy procurement.
(bold face denoting vectors; with \( q = (q_1, \ldots, q_n) = \mathbf{q}(\mathbf{p}) \) where \( \mathbf{p} \) is the vector of final prices and \( q_i \) are quantities sold by M). M’s procurement cost are assumed to be convex \( \partial G / \partial q_i > 0; \) \( \partial^2 G / \partial q_i^2 > 0 \forall i = 1, \ldots, n \). There is perfect competition among the entrants (E) who are treated as one entity [labelled competitive fringe; see also Armstrong et al. (1996), Laffont and Tirole (1996)]. For simplicity we assume that entrants have constant average and marginal procurement cost \( (\partial G_E / \partial q_{EI} = g_{EI}) \) where \( q_{EI} \) are quantities sold by entrants.13

The retail business of the incumbent and entrants may potentially offer electricity supply in all \( n \) market segments. Final products offered by the incumbent (M) and the fringe firms (E) in the same segment \( i \) are perfect substitutes and we assume normal (elastic) demand behaviour without demand uncertainty. All actors are perfectly informed about their competitors’ cost position in competitive retail sales. All final prices \( (p) \), including those of the incumbent grid owner are unregulated. This implies that the competitive fringe will only be willing to sell at \( p_i \geq g_{EI} + a_i \). Perfect competition among independent retailers ensures that this holds with equality, i.e.

\[
p_i = g_{EI} + a_i, \quad \text{(imputation rule)}
\]

The competitive fringe, takes the position of a price leader (the pricing formula implies an ‘imputation rule’) as incumbents have no incentive to significantly undercut fringe prices (unless fringe prices are above monopoly prices which we rule out).

4.2. Distribution business and regulatory constraint

The grid owner has grid cost of \( C(Q) \), where \( Q \) is the vector resembling grid access by all retailers across all products \( i = 1, \ldots, n \) (with \( Q_i(p_i) = q_i(p_i) + q_{EI}(p_i) \) and \( Q = (Q_1(p_1), \ldots, Q_n(p_n)) = \mathbf{Q}(\mathbf{p}) \)). We assume that the incumbent’s cost function in energy procurement \( (G = G(\mathbf{q})) \) is linearly separable from the cost function for grid operation \( (C = C(Q)) \) so that we can ignore the (additional) problem of manipulations in cost allocation between businesses as previously analysed, e.g. by Sweeney (1982), Braeutigam and Panzar (1989) and De Fraja (1999).

Grid access charges \( a \) are subjected to regulation. Categorical rejection of grid access to third parties (and non-price discrimination) is not possible. We use a regulatory constraint that represents a simplified version of the regulation rule applied to UK electricity distribution businesses.14 In principle the regulatory rule defines that distribution revenues must not exceed a predefined budget or revenue \( (R) \) that is adjusted according to deviations of distributed quantities and numbers

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13 Constant marginal energy procurement cost of retailers from the competitive fringe is a simplifying assumption without major loss of generality. Model implications extend to situations where competitive fringe companies’ marginal cost of energy procurement \( G_E(q^*) \) increase less at the margin (*) than the marginal cost \( G(q^*) \) of the incumbent retailer M.

14 See also Offer (1993, 1994).
of customers from some reference level \( \overline{Q} \); in practice: units distributed and customer numbers of the previous year. We might state this regulatory constraint as

\[
\sum_{i=1}^{n} \left( a_i Q_i - r_i (Q_i - \overline{Q}_i) \right) - \overline{R} \leq 0
\]

(2)

where \( r_i \) represents the per unit revenue adjustment for deviations of units distributed \( Q_i \) from the reference level (i.e. for simplicity we ignore the impact of changes in customer numbers). For base revenue set close to (estimated) cost at reference quantities (i.e. \( \overline{R} = C(\overline{Q}) \))\(^{15}\) and the revenue adjustment factor set close to marginal cost of distribution (i.e. \( r_i = \partial C(Q) / \partial Q_i \))\(^{16}\) the price control formula collapses to cost based regulation:\(^{17}\)

\[
\sum_{i=1}^{n} a_i Q_i \leq C(Q_i).
\]

(3)

To avoid algebraic complications we continue with the simplified regulatory restraint as characterised by inequality (3). For our analysis it is important that restraint Eq. (3) captures regulatees’ discretion to develop charge structures (i.e. the vector \( a \)). As is shown in Riechmann (1999, p. 191) main findings of the following analysis extend to alternative regulatory rules, e.g. one where the revenue adjustment factor \( r_i \) does not equate with marginal cost of distribution \( \partial C(Q_i) / \partial Q_i \) and to the regulatory rule that was developed by Vogelsang and Finsinger (1979) under normative considerations.\(^{18}\)

5. Modelling pricing behaviour for access charges under partial price-caps

5.1. Analytical analysis of access pricing behaviour

Proposition 1: The level of a particular access charge \( a_i \) is not relevant for the extent of market entry (productive efficiency) and thus for the intensity of observable competition.\(^{19}\)

\(^{15}\)In a dynamic environment the regulatory constant \( \overline{R} \) might be determined by the regulator as the level of network cost observed in the previous period (i.e. \( \overline{R} = \overline{R}_i = C(\overline{Q}_{i-1}) \)).

\(^{16}\)In UK practice \( r \) has been set at 50% of average cost.

\(^{17}\)This is since \( \sum_{i=1}^{n} a_i Q_i - \sum_{i=1}^{n} (Q_i - \overline{Q}_i) \frac{\partial C(\overline{Q})}{\partial Q_i} dQ_i = \sum_{i=1}^{n} a_i Q_i - C(Q) \leq 0. \)

\(^{18}\)In our terminology the Vogelsang and Finsinger (1979) rule would be written as \( \sum_{i=1}^{n} a_i Q_i \leq \overline{R} \). This rule is intended to induce improvements in the allocative efficiency of the charge structure in a multi-period framework (where managers are only interested in the next period’s profits).

\(^{19}\)We note that the level of access charges is, however, relevant for the degree of allocative efficiency as by the ‘imputation rule’ the access charge \( a_i \) feeds through into the final price \( p_i \).
Proof: A floor price of the incumbent’s retail business is determined by the incumbent’s cost of energy procurement \( \partial G(q)/\partial q \) and the opportunity cost of earning revenue from providing grid access to the entrant and leaving a retail deal to the entrant of \( a_i \) (i.e. \( p_{i,\text{floor}} = \partial G(q)/\partial q_i + a_i \)). The incumbent leaves sales to entrants, whenever the market price is lower than his floor price (i.e. whenever \( \partial G(q)/\partial q_i < g_{Ei} \)), while he will sell in the retail market, whenever the market price exceeds his floor price \( \partial G(q)/\partial q_i > g_{Ei} \); the incumbent is indifferent with respect to retail sales if \( \partial G(q)/\partial q_i = g_{Ei} \). Altering the level of the access charge \( a_i \) has no impact on this result as the difference between market price and floor price is unaffected.

This proposition is useful in determining profit maximising access charges from the incumbent’s perspective. The grid owners total profit consists of the profits earned in the retail business \( \sum (p_i - a_i)q_i - G(q) \) and in the grid business \( \sum a_iQ_i - C(Q) \). Should M’s supply business have better procurement conditions than the competitive fringe \( \partial G/\partial q_i < g_{Ei} \), M will still ask \( p_i = g_{Ei} + a_i \) in order to realise a marginal profit of \( g_{Ei} - \partial G/\partial q_i > 0 \). We can, therefore, rewrite retail profit as \( \sum g_{Ei}q_i - G(q) \). The grid operator will maximise his profits by optimising grid access charges \( a \) subject to a regulatory constraint \( [3] \). In the following formal analysis we must also take account of non-negativity constraints for retail sales \( q_i \geq 0 \ \forall \ i = 1, \ldots , n \). Writing \( \lambda \) and \( \gamma_i \) as Lagrange multipliers \( (\lambda, \gamma_i \geq 0) \) of the regulatory constraint and non-negativity constraints, respectively, the Lagrangean expression can be written as

\[
L = \sum_{i=1}^{n} g_{Ei}q_i(p_i(a_i)) - G(q(p(a))) + \left( \sum_{i=1}^{n} a_iQ_i(p_i(a_i)) - C(Q(p(a))) \right) - \lambda \left( \sum_{i=1}^{n} a_iQ_i(p_i(a_i)) - C(Q(p(a))) \right) + \sum_{i=1}^{n} \gamma_iq_i(p_i(a_i))
\]

From the FOCs with respect to access charges \( a_m \) we can derive equilibrium access prices charged by the incumbent (* denoting an equilibrium; see Appendix A for details):

\[
a_m^* = \frac{\partial C(Q(p(a^*)))}{\partial Q_m} + \frac{Q_m(p_m(a_m))}{-\partial Q_m(p_m(a_m))/\partial p_m} - \left( g_{Em} - \frac{\partial G(q(p(a)))}{\partial q_m} + \gamma_m \right) \left( 1 - \lambda(a^*, \ldots) \right) \forall m = 1, \ldots , n.
\]

\(^{20}\) Quantities \( q \) effectively sold by his retail supply business will be determined by the fringe (market) prices \( p_i = g_{Ei} + a_i \) and his competitive position relative to fringe companies.
We note that the RHS of Eq. (5) includes endogenous terms (in $a_m^*$) which, however, does not preclude meaningful interpretation of results. From complementary slackness conditions we can infer that whenever M’s retail business is competitive in supplying any relevant quantity of final product $m$ that $\gamma_m = 0$. If M's supply business is at a competitive disadvantage in supplying $m$ at some relevant positive quantity [i.e. if the incumbent’s cost procurement cost $G(q(p(a)))$ is increasing in a way that prevents it from serving any positive quantity or the entire demand in one segment], then $\gamma_m = \partial G / \partial q_m - g_{Em}$ as $\gamma_m$ is simply the shadow cost of supplying a good for which M has a competitive disadvantage at the margin (i.e. $\gamma_m$ is the marginal loss of selling good $m$ at market price $p_m$).

For Eq. (5) we, therefore, have to distinguish two cases:

1. If M’s supply business is not competitive in supplying the entire demand in segment $m$, then

$$a_m^* = \frac{\partial C(Q)}{\partial Q_m} + \frac{Q_m(p_m)}{-\partial Q_m/\partial p_m} \quad (\forall m \text{ such that } g_{Em} < \partial G(q^*)/\partial q_m). \quad (6)$$

This implies that the access charge in segments where M is uncompetitive (or becomes uncompetitive at the margin) will be made up of two elements. The first term on the RHS of Eq. (6) represents the marginal cost of grid access. The last term on the RHS of Eq. (6) is a monopoly-rent term. Note that while under a Ramsey pricing rule this last term would be pre-multiplied by a Ramsey term$^{21}$ which is smaller than 1, here it is pre-multiplied by 1. Rearranging would give the familiar inverse elasticity rule for monopolistic pricing.$^{22}$

The intuition behind this phenomenon will be outlined below.

2. If M’s supply business is competitive in supplying any relevant quantity of $m$, then (note that for $g_{Em} > \partial G(q)/\partial q_m$):

$$a_m^* = \frac{\partial C(Q)}{\partial Q_m} + \frac{Q_m(p_m)}{-\partial Q_m/\partial p_m} - \left(\frac{g_{Em} - \partial G(q)/\partial q_m}{(1 - \lambda)}\right) \quad \forall m \text{ for which } \exists q_m \text{, so that } g_{Em} > \partial G(q)/\partial q_m. \quad (7)$$

The formal expression in Eq. (7) is identical in structure to Eq. (6) except for an additional term on the RHS of Eq. (7). Note that this additional price component is negative.$^{23}$ This implies that access charges are reduced by the grid owner (M) in segments $m$ where M's retail business is at a competitive advantage ($g_{Em} > \partial G(q)/\partial q_m$) in the entire relevant range.

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$^{21}$See e.g. Laffont and Tirole (1994), Eq. (18) or Armstrong et al. (1996), Eq. (23).

$^{22}$I.e. $(a_m - C(Q))/a_m = 1/\eta$ with $C(Q) = \partial C(Q)/\partial Q_m$, $\eta = -(\partial Q_m/\partial a_m)/(Q_m/a_m)$ and $\partial Q_m/\partial a_m = \partial Q_m/\partial p_m$. See also Tirole (1988, p. 66).

$^{23}$From $\lambda \geq 0$ and $\lambda < 1$ (see also Riechmann (1999) we can infer that $(1 - \lambda) > 0$. Since we consider the case where $g_{Em} > \partial G(q)/\partial q_m$ the last term is positive, but has a negative sign.
5.2. Graphical illustration of access pricing behaviour

To illustrate our results so far, we intuitively derive equilibrium network access charges in a model reduced to two market segments (i.e. \( n = i, j \); it is straightforward to extend the analysis to any number of market segments). In segment \( i \) the incumbents retail business has a competitive advantage (in energy procurement) over the fringe (\( g_{i} > \frac{\partial G(q)}{\partial q_i} = G'_i \)). In segment \( j \) the fringe has a competitive advantage over the incumbent (\( g_{j} < \frac{\partial G(q)}{\partial q_j} = G'_j \)). We refer to this set-up as the ‘two sector scenario’ in the following. For the graphical analysis (Fig. 1) we further assume that the network operator has constant marginal cost of network access (\( \frac{\partial C(Q)}{\partial Q_{m}} = C'_m \)). Assume, e.g. that access charges \( (a_m) \) had initially been set at the level of marginal cost \( (C'_m) \) and that this would imply a binding regulatory constraint.\(^{25}\)

By charging at the fringe price \( (p_j = a_j + g_{j}) \) in segment \( i \) the incumbent is able to exploit a rent in the retail business (characterised by \( E'F' \) at the margin). If access charges had initially been set at efficient levels \( (a_i = C'_i) \), the incumbent could increase the retail rent by reducing the access charge below cost \( (a_i < C'_i) \). This reduces the market price and lets the incumbent sell additional units (with positive rent) in segment \( i \). The marginal loss in the distribution business (by pricing grid access below marginal cost in segment \( i \); and thus cross-subsidising in the terminology of Faulhaber (1975)) can be financed by increasing network access charges in segment \( j \) in which the incumbents retail business has no stake \( (a_j > C'_j) \). The limit of raising funds in segment \( j \) in order to balance a reduction of access charges in segment \( i \) is given by monopoly prices for network access in segment \( j \). In equilibrium, the incumbent will raise an amount represented by the area ABCD in Fig. 1 in segment \( j \) and will reduce access charges in segment \( i \) correspondingly (so that ABCD = A'B'C'D'). This enables the incumbent to earn an additional retail rent characterised by the area C'D'E'F'.

5.3. Methodological remarks

With respect to the characterisation of possible equilibrium situations we note that:

1. Our specific modelling of the regulatory constraint is not critical to our main findings.\(^{26}\)

\(^{24}\)Constant marginal cost is an untypical characterisation for a natural monopoly business such as electricity distribution. We have shown main results for a more general specification of the cost function of distribution in the above formal analysis. The simplifying assumption of linear distribution cost is purely used for didactical purposes. This simplification allows us to isolate the regulatory problem of full cost recovery with (potentially) decreasing marginal cost and fixed cost of network provision (without loss of generality).

\(^{25}\)In the absence of fixed network cost this would be considered as efficient pricing. The absence of fixed cost is untypical of a network business but is a permissible simplifying assumption for our purpose (see footnote 24).

\(^{26}\)Similar results hold for practicable regulatory rules as is shown in Riechmann (1999).
Fig. 1. Strategic pricing for network access under partial Price-caps — graphical illustration (Source: Own illustration).
2. The above modelling allows for ranges of indeterminate solutions.\textsuperscript{27}

3. The above modelling only explains a downward manipulation of grid access charges for segments which are fully supplied by the grid owner’s retail business (i.e. segments where M’s retail business is able to earn non-negative retail profits). Results obtained above may extend to a framework where rivals also gain some market shares upon simple modifications to the model.\textsuperscript{28}

Within the above framework we could model this by setting \( \frac{\partial q}{\partial p} = (1 - \alpha_m) \frac{Q_m}{\partial p_m} \) in Eq. (7), where \( \alpha_m \) is the fraction of demand which can be supplied by the incumbent retailer at least cost, but which is contracted to rival retailers (note that for simplicity \( \alpha_m \) is determined exogenously). In this case Eq. (7) can be rewritten:

\[
a_m = \frac{\partial C(Q)}{\partial Q_m} + \frac{Q_m(p_m)}{-\frac{\partial Q}{\partial p_m}} - \frac{(1 - \alpha_m)(g_{E_m} - \frac{\partial G(q)}{\partial q_m})}{(1 - \lambda)}.
\]  

The primary effect of some share of sales always going to rival retailers [i.e. when moving from Eqs. (7) and (8)] is that the extent of charge manipulation to favour the own retail supply business tends to be lower.\textsuperscript{29} Eq. (8) can explain a downward trend in grid access charges [represented by the third term on the RHS of Eq. (8)] in market segments, where the grid owner’s retail business loses some market share to competitors while still being the dominant supplier. For conceptual clarity we focus on the model as characterised by access pricing rules Eq. (6) and Eq. (7) for the following discussion.

6. Main propositions on incumbents’ access pricing behaviour

Proposition 2: Given a simple regulatory constraint, access charges are held low

\textsuperscript{27}For example if M’s retail business was uncompetitive in all segments (and if revenue adjustment factors are set according to marginal cost), the grid owner (M) has no incentive to ask for monopolistic prices for grid access in any of the segments as his overall profits will ultimately be restrained by the price-cap formula Eq. (3). Similar reasoning applies, if the grid owner can exhaust any retail rents (by lowering access charges in segments where he is particularly competitive) before he arrives at monopolistic access charge levels in market segments where his retail business is uncompetitive. In this case, further retail rents cannot be exploited by manipulating the structure of grid access charges.

\textsuperscript{28}We may assume that rivals always gain some market share irrespective of their competitive position (in realistic ranges of rivals’ cost functions). Reasons for respective demand side behaviour could be incomplete information of consumers, brand loyalty (both arguments usually being subsumed under customer inertias) or supplier switching on principle. Supplier switching on principle might be used by consumers to demonstrate discontent with supply conditions during the monopolistic era or to signal for future negotiations the willingness to change supplier. Supply side reasons to explain a residual market share of (uncompetitive) rival retailers could be incomplete information by the incumbent retailer over the cost position of competitors. The incumbent retailer might occasionally set prices above the level of the competitive fringe and lose some sales.

\textsuperscript{29}Note that there are also secondary effects through a change in the shadow cost (\( \lambda \)) of the regulatory constraint when moving from Eq. (7) to Eq. (8).
in segments, where the incumbent’s retail business is competitive (i.e. has high market shares), while access charges are set high in segments where entrants have a competitive advantage (i.e. high market shares).

**Proof:** From Eq. (6) we saw that the incumbent applies a monopoly pricing rule (‘high access prices’) for access in segments in which the incumbent is not competitive in supplying the entire demand. By proposition 1 entrants’ competitiveness implies a positive — in typical cases a high-market share for entrants in the respective segment. In market segments in which the incumbent is more competitive [and thus serves the entire segment by proposition 1 or at least has a high market share assumed in Eq. (8)] access charges are ceteris paribus lower than in Eq. (6) by the third expression on the RHS Eq. (7) of.

**Proposition 3:** The incumbent may exploit the price cap constraint strategically, not only to avoid marginalisation of his own retail business, but also to create cross-subsidies.

**Proof:** Consider the ‘two sector scenario’ of Section 5.2. Further assume that the incumbent sets access charges \(a_i\) at marginal distribution cost \((\partial C(Q)/\partial Q_i)\) in segment \(i\) in which he is more competitive (i.e. in which he receives a positive unit retail margin). Next assume that access charges in segment \(j\) (where newcomers are more competitive) are set so that the regulatory constraint is binding with the level of access charge \(a_j\) lying below the monopoly level (as e.g. characterised by Eq. (6)) and above marginal cost \((\partial C(Q)/\partial Q_i)\). Consider changes in profits when the incumbent further raises the access charge in segment \(j\). He incurs a partial distribution profit but — to abide with the regulatory constraint — has to lower the access charge in segment \(i\) (below marginal cost) until increased distribution profits in segment \(j\) are exactly offset by additional distribution losses in segment \(i\). With elastic demand in segment \(i\) the incumbent sells additional units in the retail market with a positive rent. With this pricing strategy the incumbent can gain a first order retail profit. That is, in the defined scenario he has incentives to charge access in segment \(i\) (in which his distribution business is more competitive) below marginal cost. Marginal cost — in equilibrium — do not necessarily represent the lower bound of access tariffs charged for the segment in which the incumbent’s retail business is at a competitive advantage.

It is sometimes argued that access charges ‘paid’ between the incumbent’s distribution and retail businesses merely have a pass-through character (e.g. Weisman and Zhang, 1997, p. 311), so that the incumbent bases decisions regarding network access of its own retail business in his host retail market on marginal cost (of the network) whatever the nominal access charge may be. By the considerations of proposition 3 this need not be true.

**Proposition 4:** Under price-cap regulation, access charges ‘payable’ from the retail
to the distribution business of the incumbent are not always of pass-through nature, but may imply an opportunity cost.

Proof: Under the proof to proposition 3 we saw that under certain circumstances it may be beneficial for the incumbent to nominally set the access charge below the level of marginal cost in segment \( i \) (implying cross-subsidies between market segments in the distribution business) exactly to induce increased retail demand in the segment \( i \) through low access charges (assuming the ‘two sector scenario’ of Section 5.2). If the incumbent raised access charges from this level he would have to balance the regulatory constraint by lowering access charges to another segment \( j \). Distribution profits remain unchanged. However, the market price in segment \( i \) would rise (by the imputation rule Eq. (1)). With elastic demand the incumbent’s retail business would be selling less units at a positive retail rent: retail profits decline. We interpret this profit decline as an opportunity cost of nominally raising the access charge in segment \( i \). Under the described scenario the nominal level of access charge in segment \( i \) is, therefore, relevant for the incumbent’s profit position and does not merely have pass through nature (as long as retail rents may be lost).

7. Empirical analysis of pricing behaviour

The hypothesis of a strategic manipulation of grid access charges in market segments opened to retail competition — with the extent of manipulation depending on the competitive position of the incumbents supply business in the retail market — will be subjected to empirical analysis.

From our above considerations we expect that the level of access charges in a particular market segment will depend on a cost term, a rent term, the competitive position of the host RECs supply business and the design of the price-cap formula that changed from April 1995 to include a ‘revenue adjustment mechanism’; see Riechmann, 1999 for details. We use a regression analysis to test and estimate the impact of these variables. Indicative access charges for selected market segments serve as an explained variable.

For the ‘100-kW’ and ‘1-MW’ segments indicative access charges \( a \) were calculated for several years using price data from tariff leaflets of 10 RECs.\(^{30}\) Indicative charges were calculated by taking the arithmetic mean of the average distribution charges for typical customer cases as defined by the European Statistical Office (EUROSTAT).\(^{31}\)

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\(^{30}\) Included RECs are Eastern Electricity, East Midlands Electricity, London Electricity, Midlands Electricity, Northern Electric, NORWEB, Southern Electric, SWALEC, SWEB, Yorkshire Electricity. Excluded are SEEDBOARD and Manweb.

\(^{31}\) The indicative ‘100 kW’ charge comprises the customers ID (500 kW, 2500 h/a) and IE (500 kW, 4000 h/a). The indicative ‘1 MW’ charge comprises the customers IF (2500 kW, 4000 h/a), IG (4000 kW, 6000 h/a), IH (10 000 kW, 5000 h/a) and II (10 000 kW, 7000 h/a). For each customer case the average price has been calculated as the lowest average price out of three maximum demand tariff options.
We use annual average cost [p/kWh] as instrument for the marginal cost term in the regression\textsuperscript{32} and approximate average cost by extrapolating the 1990/1991 average distribution revenue \( (c) \) as stated in RECs regulatory accounts for the distribution business with the RPI + X price-cap formula.\textsuperscript{33} We may regard the revenue term so derived as an instrumental variable for marginal cost that allows us to limit endogeneity between the explained indicative access charge and the explanatory term derived from average revenues. Sharp corrections in average distribution revenues in 1995/1996 (14% [real]) and 1996/1997 (11% [real]) are already included in the average revenue \( (c) \) variable.

As an indicator for the competitive position of the host RECs’ supply businesses, we use market shares \( (v) \) of RECs in their host retail markets (in % of units [kWh]).\textsuperscript{34} This empirical modelling corresponds with the modified theoretical model [Eq. (8)] which allows fringe firms and the incumbent to sell positive quantities in all market segments (even if one group of retailers is at an absolute competitive advantage in a respective segment). We argue that when setting access charges for 1 financial year, the RECs can only use market share information of the previous year to determine their retail business’ competitive position in the host market. In instrumenting the incumbent’s competitive position (unit retail rents in the analytical model) by market shares we relax potential endogeneity between \( a \) and the competitive position \( (v) \). By lagging market shares \( v \) by one period (for reasons of intuition in the process of price planning) we should expect to further relieve any endogeneity. For the redesign of the price-cap formula we use a dummy variable \( (d) \) that takes on the value of 1 from 1995 to 1996 (and 0 beforehand).

Available data only allows an analysis of 3 consecutive years for the ‘1-MW’ segment and 2 consecutive years for the ‘100-kW’ segment. As the variable values of indicative access charges (explained variable) and market shares (explanatory variable) within RECs vary strongly between years (e.g. Fig. 2 for the ‘1-MW’ segment), we treat available information as panel data and treat observations for each REC and each year as one ‘event’. We, therefore, operate with a sample size of \( n = 30 \) for the ‘1-MW’ segment and \( n = 20 \) for the ‘100-kW’ segment.

Before we proceed with the formal empirical model some major points can be highlighted using a graphical representation. By 1995/1996 host RECs retail market shares had reduced to between 51% (NORWEB) and 11% (SWEB) in the ‘1-MW’ segment Fig. 2 and to between 71% (Yorkshire) and 49% (East Midlands) in the ‘100-kW’ segment. When regressing indicative access charges linearly

\textsuperscript{32}This approach is justifiable as long as average and marginal cost stand in some fairly constant relationship within the relevant range of cost.

\textsuperscript{33}I.e. we use an ‘ex post forecast’ of average revenues. In comparison to the alternative option of using actual average distribution revenues for all years this modelling has the advantage that we can difference out the impact of the RPI + X price path and the redesign of the precise price-cap formula from 1995 to 1996.

\textsuperscript{34}These were surveyed by the Monopolies and Merger Commission [MMC (1996)] for the ‘1-MW’ segments for the years 1993/1994 through 1995/1996 and for the ‘100-kW’ segment for 1994/1995 and 1995/1996.
Fig. 2. Level of indicative distribution use of system charges and market share of the host REC in the ‘1-MW’ segment — 10 RECs in England and Wales; 1994/1995–1996/1997; p/kWh nominal, excl. VAT and Fossil Fuel Levy, % (Source: author’s calculations based on tariff leaflets, MMC (1996)).

Source: author’s calculations based on tariff leaflets, MMC (1996).
on market shares in the host market, we obtain a negatively sloped regression line (i.e. indicative access charges are decreasing in the market share of the host REC), which is in line with our economic reasoning.

In its stochastic, log–linear form the model can be expressed (with \( \alpha \) as regression constant)\(^{35}\)

\[
\ln a_i = \alpha_i + \beta_{c_i} \ln c_i + \beta_{t_i} \ln t_{i-1} + \beta_{d_i} d_i + \varepsilon_i \quad \text{with } i = \text{‘100 kW’, ‘1 MW’}.
\]

In this model \( \ln a_i \) corresponds to the marginal cost term in Eqs. (7) and (8).\(^{36}\) The regression constant (\( \alpha \)) corresponds to the ‘monopoly-rent term’ [third term on the RHS of Eqs. (7) and (8)]. The ‘market-share term’ (\( \ln t_{i-1} \)) represents the ‘manipulation with respect to competitiveness’-term [last term on the RHS of Eqs. (7) and (8)]. The coefficients for \( \ln c_i \) and \( \ln t_{i-1} \) can be interpreted as elasticities. The coefficient of \( d_i \) can be interpreted as a rate of change in access charge levels (beyond those already included in \( c \)) between 1994/1995 and 1995/1996 as result of a redesign of the price-cap formula. The hypothesis of a manipulation of access charges depending on the competitive position of the supply business is formally expressed as \( H_0: \beta_{t_i} < 0; H_1: \beta_{t_i} \geq 0 \).

Results from an OLS regression for the ‘1-MW’ and ‘100-kW’ segments are shown in Table 1. All coefficients take the expected or hypothesised signs. In particular, we estimate an elasticity of indicative access charges with respect to the market share of the host REC of –13% (significant at the 1% level for a one-sided test) for the ‘1-MW’ segment and of –19% (significant at the 2.5% level for a one-sided test) for the ‘100-kW’ segment. The estimated elasticities imply, e.g. that with on average some 68% of market share in the ‘1-MW’ market and some 42% in the ‘100-kW’ market lost to second tier suppliers, RECs have raised the access charges in these segments after the loss of market share by some 8%. Note that the estimated manipulation in the level of access charges (significant values for \( \beta_{t_i} \)) also implies a change in the charge structure as the average revenue term used as instrument (also) represents the relative access charges for the other market segments. Regressions on subsamples by years suggest the same results. Details are found in Riechmann (1999, p. 270).

The elasticity of indicative access charges with respect to average revenues is only 45% (significant at the 5% level for a one-sided test) in the ‘1-MW’ segment and 58% (significant at the 2.5% level for a one-sided test) in the ‘100-kW’ segment.\(^{37}\)

---

\(^{35}\)The log–linear specification was found to be preferable over a linear model. Systematic regression errors of the linear are already identified from visual inspection of (linear) regression results represented in Fig. 2.

\(^{36}\)Using ‘forecast’ average revenues (see footnote 33) as an instrument for (marginal) cost, we imply a constant relationship between the two variables in the relevant range of observations.

\(^{37}\)Note that one cannot directly interpret the estimated value of the regression constant (\( \alpha \)) as the estimated value for the rent term, e.g. because the level of the instrument used for marginal cost will tend to lie above the actual marginal cost.
Table 1
Regression results for grid access charge in electricity distribution — explained: indicative access charges (nominal, excl. VAT and FFL); 10 RECs; logarithmic format; 1994/1995–1996/1997

<table>
<thead>
<tr>
<th>Explanatory variables</th>
<th>Coefficient</th>
<th>t-value</th>
<th>Additional statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explained: indicative access charge (log scale)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>'1 MW' market</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sample: 10 RECs, 1994/1995–1996/1997 (year of access charge); i.e. n = 30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>2.181</td>
<td>8.350***</td>
<td>$R^2 = 0.5219$</td>
</tr>
<tr>
<td>Dummy (= 1 from 1995 to 1996)</td>
<td>-0.104</td>
<td>-1.609</td>
<td>RSS = 0.3616</td>
</tr>
<tr>
<td>ln(average revenue)</td>
<td>0.452</td>
<td>1.963*</td>
<td>$F_{3,26} = 9.4602$</td>
</tr>
<tr>
<td>ln(market share $\cdot 1$ ('1 MW' market)]</td>
<td>-0.131</td>
<td>-2.588***</td>
<td></td>
</tr>
<tr>
<td>'100 kW' market</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sample: 10 RECs, 1995/1996–1996/1997 (year of access charge); i.e. n = 20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>2.629</td>
<td>7.812***</td>
<td>$R^2 = 0.4326$</td>
</tr>
<tr>
<td>ln(average revenue)</td>
<td>0.577</td>
<td>2.308**</td>
<td>RSS = 0.2211</td>
</tr>
<tr>
<td>ln(market share $\cdot 1$ ('1 MW' and '100 kW' market)]</td>
<td>-0.186</td>
<td>-2.265**</td>
<td>$F_{2,27} = 6.4809$</td>
</tr>
</tbody>
</table>

***Significance levels for one-sided test: 1%.
**Significance levels for one-sided test: 2.5%.
*Significance levels for one-sided test: 5%.

We find that the overall market share in the ‘100-kW’ and ‘1-MW’ segments explains the indicative access charge for the ‘100-kW’ segment at a higher level of significance. The ‘overall share’ has, therefore, been used in the regression shown.

8. Conclusion

In a theoretical model it was shown that grid owners who are also engaged in competitive activities and who are only subjected to (price-cap) regulation with their monopolistic (grid) activities (partial price-cap) have incentives to strategically manipulate their charge structure. This manipulation implies a price discrimination as the incumbent has been shown to apply different access pricing rules depending on whether his retail business or fringe companies are more efficient in electricity retail in respective segments. In particular, the incumbent will favour (through lower access charges) market segments where his retail business has a competitive edge. High access charges in segments where rivals are at a competitive advantage are used to generate distribution revenues until the regulatory revenue constraint is binding. Low access charges in some segments where the incumbent has a competitive advantage are, therefore, implicitly financed through high access charges in other segments (where the entrants have a competitive advantage). In extreme cases, access prices in some segments may be set at monopolistic levels and access prices in other segments may be so below marginal cost (implying a cross-subsidisation). Empirical analysis provided support for strategic pricing of use of system charges in electricity distribution in England and Wales.

These results have interesting implications: we should expect to observe the highest access charges in those regional markets where competition is most...
intense, i.e. where competitors have gained significant market shares. In contrast to arguments in public debate, high access charges, do not seem to restrain competition at the retail level (the level of access charges is — at least in a simplified setting — irrelevant for the intensity of competition). Excessively high access charges are rather an indication of relatively intense competition. Nonetheless, such manipulated access tariff structures are allocatively inefficient.

Vertically integrated network operators who are accused of charging excessively for grid access sometimes point out that intensive entry would indicate that their behaviour has not been abusive. From our analysis it follows that from observing intense entry in the retail market we cannot infer that access pricing has been non-discriminatory.

Inefficient distribution of cost in regulatory accounting between regulated and unregulated businesses has been perceived as a major problem in regulatory practice. This has induced regulators to impose ‘financial ring fencing’ or ‘Chinese walls’ between utility businesses. We have shown that even where competitive and monopolistic businesses are ‘ring fenced’ (this is modelled though our assumption of cost separability between retail and distribution), opportunities and incentives for access pricing that discriminates newcomers can prevail.

‘Unbundling’ ownership of electricity distribution and electricity retail businesses has been considered as alternative measure to eliminate distributors interest in favouring the associated retail business. This may, however, be a rather restrictive measure to overcome allocative inefficiencies (and costly as well, if scope economies exist between the functions). Nonetheless, regulators in Sweden and the Netherlands have opted for such unbundling and the regulator in England and Wales has expressed a similar commitment (although ownership of separate businesses can lie with one holding companies in all mentioned cases). Future research should follow up, whether strategic price discrimination for grid access is a sustained problem, or whether incumbents find it hard to identify which customer groups to discriminate against, once they have lost substantial market shares in the retail business.

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Appendix A: Technical Appendix

The expression to be maximised by the incumbent is:

\[ L = \sum_{i=1}^{n} g_{E_i} q_i(p_i(a_i)) - G(q(p(a))) \]
\[
\begin{align*}
\sum_{i=1}^{n} a_i Q_i(p_i(a_i)) - C(Q(p(a))) - \lambda \left( \sum_{i=1}^{n} a_i Q_i(p_i(a_i)) - C(Q(p(a))) \right) \\
+ \sum_{i=1}^{n} q_i(p_i(a_i))
\end{align*}
\]

FOCs with respect to \( a_m \) for all \( m \) are (since customers are not able to switch between segments we can neglect (demand) cross-price elasticities between market segments):

\[
\frac{dL}{da_m} = \frac{\partial L}{\partial a_m} + \frac{\partial L}{\partial q_m} \frac{dp_m}{da_m} + \frac{\partial L}{\partial q^m} \frac{dp_m}{da_m} = 0 \quad \forall m = 1, \ldots, n
\]
or explicitly

\[
(1 - \lambda) a_m = (1 - \lambda) \frac{\partial C}{\partial Q_m} + (1 - \lambda) \frac{Q_m}{\partial Q_m/\partial p_m} \\
- \left( \frac{g^m}{\partial q_m/\partial p_m} + \frac{\gamma_m}{\partial Q_m/\partial p_m} \right) \quad \forall m = 1, \ldots, n.
\]

After rearranging (and under assumed homogeneity of final products \([\partial q_m/\partial q_m]/[\partial Q_m/\partial p_m] = 1\) we obtain

\[
a_m = \frac{\partial C}{\partial Q_m} + \frac{Q_m}{-\partial Q_m/\partial p_m} - \left( \frac{g^m}{\partial q_m/\partial p_m} + \frac{\gamma_m}{\partial Q_m/\partial p_m} \right) (1 - \lambda) \quad \forall m = 1, \ldots, n.
\]

References


