

Two Stages of Uniform Delivered Pricing and a Monopolistic Network in Competitive Electricity Markets

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41st Congress of the European Regional Science Association
Zagreb, 29th August - 1st September 2001

Abstract

This contribution assesses the impact of spatial and non-spatial (*postage stamp*) network pricing schemes on market outcomes in deregulated electricity supply. Our analytical framework is a combination of spatial microeconomics and the theory of vertically related markets. The setting is characterized by a network monopoly remaining vertically integrated to one of the producers and at the same time providing an essential input to the entire industry, including its competitors. Our findings reveal some unexpected preferences towards these arrangement from the consumer-, firm- and welfare-perspective.

JEL-classifications: D43, L22, L94, R32

1 Introduction

Beginning in the 1980s, the electricity sector has seen sweeping reforms in many countries around the world. Starting from vertically integrated regional or national monopolies, numerous proposals have been made and various arrangements are about to emerge. This variety stems on the one hand from nation-specific physical, institutional and political backgrounds, on the other hand there persists a lack of understanding as to the functioning of this market (on the economic fundamentals of electricity deregulation see e.g. Joskow/Schmalensee (1983)).

This contribution assesses the impact of spatial and non-spatial pricing techniques on market outcomes in deregulated electricity supply. Our analytical framework is a combination of the theory of spatial pricing and the theory of vertically related markets. A model of the traditional regional monopolies with vertical integration serves as a point of reference. The deregulated framework is characterized by a monopolistic transmission-network (upstream) and competitive production (downstream). The monopolistic network remains vertically integrated with one of the competitive producers, and at the same time acts as an essential input-facility to all producers, making its access-conditions pivotal to the reforms. In this setting, we construct two alternative models to address one of the key issues under discussion: Uniform delivered pricing downstream coupled with distance-specific transmission prices upstream versus uniform delivered pricing on both market stages. The latter system corresponds with a type of transmission pricing commonly referred to as *postage stamp* pricing, for its analogy with the customary practice in national postal services: A postage stamp rate is a fixed charge per unit transmitted, regardless of the economic distance the energy travels. In the former model, by contrast, transmission rates are sensitive to distance, accounting for the specific costs an economic transaction causes in the transportation network due to the location-figure between production, grid pattern, and consumption.

The specific aim of this contribution is threefold: Firstly, the strategic pricing behaviour on both, the monopolistic and the competitive stage shall be made visible. This embraces the question: Does an unregulated, vertically integrated network-monopolist set prices in a way that completely excludes competition from

its traditional market area? In other words, is there an incentive for complete vertical foreclosure (Hart/Tirole (1990))? Secondly, which arrangement do traditional firms, newcomers and consumers favour respectively? Thirdly, the short-run welfare-effects of both cases shall be elaborated in order to uncover (static) efficiency-implications accruing from the (dis-)regard of space in transmission pricing. We find that the preferences of the economic agents vis-a-vis the spatial or non-spatial pricing policies deviate in part from intuition. Most importantly, it turns out that postage stamp tariffs are accompanied by short-run welfare losses. There is only fuzzy awareness of the economic costs the total abolishment of spatial components in network-pricing brings about, which tend to be neglected in political debate (Monopolkommission (2000)). Yet, they have to be weighed against the presumed advantages of the simpler postage stamp pricing (Hobbs/Schuler (1986)).

The theory of vertically related markets (for an early survey see Perry (1989)) is a branch of industrial economics, which has gained considerable popularity in the context of deregulating network industries. Many contributions are particularly dealing with vertical structures in telecommunication markets (e.g. Economides/Salop (1992), Laffont/Tirole (1994), Economides (1998)), which are, unlike the electricity sector, characterized by certain substitutionary relationships between the monopolistic and the competitive stages as well as by significant network externalities. A theoretical treatment of the vertical structures especially in electricity economics is carried out by Brunekreeft (1997) and Meran/Schwarze (1998). A number of authors are committed to the optimal allocation of (scarce) network capacity (Hogan (1992), Chao/Peck (1996), Armstrong et al. (1996) and Tabors (1996)). Yet none of the named approaches is explicitly spatial and focussed on a comparison of postage stamp pricing with other proposal. The distorting properties of uniform delivered pricing are well-known in regional science (DeCanio (1984)). An extensive application of spatial pricing theory on the deregulation of electric utilities is undertaken by Hobbs/Schuler (1985), (1986) und Hobbs (1986). These authors, however, do not account for the vertical relationship within the sector, which turns out to be a crucial aspect of deregulation. A theoretical exploration of both vertical structures and spatial markets can be found in e.g. Bittlingmayer (1983), McBride (1983), Schöler (1989), and Gupta et al. (1999). In its vertical architecture the model of Gupta

et al. is closest to the requirements of our specific application, with a monopolistic input- and a competitive retail-market.

Special to the present study is the treatment of transport as a distinct market stage with endogenously determined transmission- or access-rates. The only similar approach can be found in Schuler/Holahan (1978). Common analysis on spatial oligopolies assumes transport at constant, exogenously set freight rates per distance and quantity unit. In this view transport is either supplied by each firm internally at constant marginal costs, or the transport market is perfectly competitive. We explore the case of monopolistic transport infrastructure as an input facility: The transport charge is derived in the optimization program of the network operator, whose decision influences the behaviour of the competing producers.

The remainder of this paper is organized as follows: Section 2 explains the theoretical framework by defining the basic assumptions. As a simplified picture of traditional regional monopolies, we give a brief replication of the spatial monopoly with uniform delivered pricing. Sections 3 and 4 each are dedicated to one model in detail, the spatial oligopoly with uniform delivered pricing downstream and vertical integration (oli-udp-vi, section 3) as well as the oligopoly with uniform delivered pricing on both market stages and vertical integration (oli-udp2-vi, section 4). In section 5 the market results are compared and discussed with respect to our above-mentioned objective.

2 Basic framework and status quo ante

The assumptions presented below largely rest on the standard spatial pricing literature (eg. Capozza/Van Order (1978)), while our modifications and extensions direct the analysis to the application outlined above. The stylized functional courses as well as the simplistic representation of space serves to reduce mathematical complexity. These simplifications allow us to derive consistent evidence to the problem at hand. Assumptions 1-7 shall be equally valid in all models considered.

General assumptions

Assumption 1: Homogenous demand continuously occupies one-dimensional space at uniform density equal to 1 per distance unit.

Assumption 2: Consumers purchase electrical energy from the cheapest supplier at their location at a distance r from the site of production. Individual demand q is a linear function of the delivered price p :

$$q = 1 - p. \tag{1}$$

Assumption 3: There are two market-stages, referred to as *upstream* and *downstream* respectively. The network operator acts upstream providing its output, transportation services, to producers (generators). The upstream output embraces high- and medium-voltage transmission, local distribution as well as other network functions, which are not distinguished hereafter. Producers act on the downstream stage, utilising the network services as an input for selling the final good, electricity, at their customers locations. Generation and transmission are fully complementary products (Brunekreeft (1996)). Economies of scope between these stages are assumed not to exist. All firms strive for maximal profits.

Assumption 4: Production is characterized by constant variable costs $0 < k < 1$ per quantity unit and fixed costs K . With respect to production technology all generating firms are identical. The product is not storable. Transmission is accompanied by distance- and quantity-related marginal costs τ as well as fixed costs F .

Assumption 5: The number of firms active on a particular fraction of the market in space is exogenously given in each model. The difference between the background case and the deregulated cases lies in the first round of market entry by newcomers. In our models, further entry does not occur. Therefore we permit positive profits, $\pi > 0$, to sustain. Once taken, firms' locations are fixed. These features, combined with the above-mentioned cost-structure, establish a short-run analysis.

Assumption 6: The sector is subject to regulatory conditions in two respects: Firstly, supply is to be exhaustive, i.e. provision is unbroken in space by rule. This implies that market areas of neighbouring firms always border on one another. Secondly, downstream firms are obliged to apply one single price per unit to consumers in all parts of their service area, i.e. to make use of uniform delivered pricing.

Assumption 7: All firms run exactly one production site at location L within their market area of length R . The transmission grid does not have one physical location. It rather stretches all across linear space, being managerially attached and divided by ownership. Each vertically integrated (former) monopolist runs a network infrastructure the size of its traditional service area.

Background case

Since we assume identical conditions for each single generator and each vertically integrated firm in space (assumption 4) it suffices to restrict our analysis to the service area of one network operator. The extend of this area evolves in the situation before liberalisation, which shall be sketched in the following. All symbols relating to this monopolist carry the subscript m . For the representation of the status quo ante of liberalization we need an additional assumption.

Assumption 8a: All firms are vertically integrated across the entire functions upstream and downstream. Each enjoys exclusive rights over its service territory, the size of which, $2R_m$ results from the individual firm's free choice.

For supply to be exhaustive, firms arrange themselves such that neighbouring market areas always border on each other. Thus, the locational pattern follows from assumptions 6 and 8a. Figure 1 illustrates this spatial configuration.

The situation within the part of space looked upon, i.e. within an individual firm's market reach of R_m in each direction, is equivalent to the textbook case of a spatial monopoly with uniform delivered pricing (see eg. Beckmann (1968)).

Maximizing profit

$$\pi_m = 2 \int_0^{R_m} (1 - p_m)(p_m - k - \tau r) dr - F - K \quad (2)$$

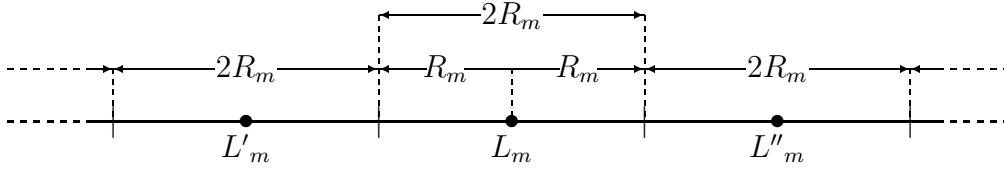


Figure 1: Spatial configuration in the background case

with respect to the delivered price, p_m , yields the optimal values for the firm's price p_m^* , the market area border R_m^* , total consumption Q_m , and profit at these values:

$$p_m^* = (k + 2)/3, \quad (3)$$

$$R_m^* = 2(1 - k)/3\tau, \quad (4)$$

$$Q_m(p_m^*, R_m^*) = 4(1 - k)^2/9\tau, \quad (5)$$

$$\pi_m(p_m^*, R_m^*) = 4(1 - k)^3/27\tau - F - K. \quad (6)$$

Consumer surplus Λ shows the aggregate advantage accruing to consumers from the difference between market price and highest marginal willingness to pay:

$$\Lambda(p_m^*, R_m^*) = 2(1 - k)^3/27\tau. \quad (7)$$

Social welfare is measured in the tradition of industrial economics as the sum of producer and consumer surplus, which amounts to:

$$\Omega(p_m^*, R_m^*) = 2(1 - k)^3/9\tau. \quad (8)$$

The size of an individual market area $2R_m^*$ constitutes the terrain, on which we examine competition within the subsequent models. The spatial order of the vertically integrated firms follows this distance-pattern hereafter.

3 Model: Oligopoly, vertical integration, uniform delivered pricing downstream

Now, liberalization of the sector opens the downstream market to competition, i.e. amongst producers. Assumption 8a needs replacement in this model. Instead, assumptions 8b, 9a and 10 establish the new situation.

Assumption 8b: Two generating firms enter the scene, competing downstream with the vertically integrated firm. The latter firm's monopoly position with respect to the transportation facilities is maintained.

From this constellation the crucial role of the grid arises. The transmission network is the monopolistic bottleneck the newcomers need to pass in order to reach their customers at the places of consumption. By control over the terms of access the vertically integrated firm determines part of the conditions of downstream competition. All symbols relating to the vertically integrated firm are marked by the subscript vi , those of the newcomers carry the subscript j .

Assumption 9a: The vertically integrated firm charges foreign producers a transmission price t per distance and quantity unit.

Total costs of the newcomers thus read:

$$C_j = 2 \int_0^{R_j} (1 - p_j)(k + tr)dr + K. \quad (9)$$

For the vertically integrated firm total costs are described formally by:

$$C_{vi} = 2\tau \int_0^{R_{vi}} r(1 - p_{vi})dr + 2\tau \int_0^{R_j} r(1 - p_j)dr + 2kR_{vi}(1 - p_{vi}) + K + F. \quad (10)$$

The former couple of terms symbolyse variable costs within the grid, which stem from delivering to the firm's own and to the foreign firms' customers respectively. The third term signifies variable costs in the generation-unit.

Figure 2 serves to visualize the arrangement of locations and market areas in the liberalized case. The focus is put on a fraction of linear space by the length of $2R_m$, which is the market area presented at the center of figure 1 zoomed in. Since the delivery to consumers causes costs which are sensitive to distance, it is the newcomers' rational choice to locate in points L_j at the former market borders, where they are the furthest apart from the traditional firm's location L_{vi} . Presuming identical new producers (assumption 4), with equal conditions to both sides of their markets, we can simplify the approach from two halves to one full newcomer on the inspected part of the market.

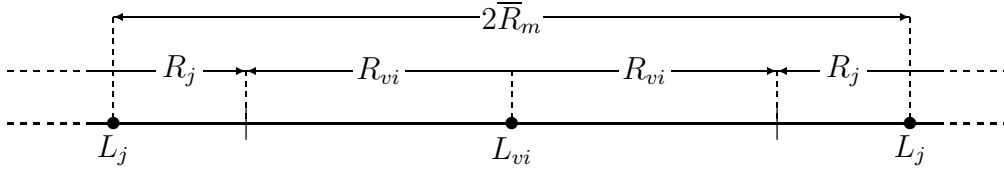


Figure 2: Spatial configuration in the deregulated cases

In order to depict the behaviour of firms, an assumption regarding the distribution of information across them and the conjectures they hold is necessary.

Assumption 10: We track a two-stage game with asymmetric information. The vertically integrated firm maximizes its profit π_{vi} with respect to both prices p_{vi} and t in foresight of the other firms' rational choice. The latter maximize their profit π_j with respect to their price p_j and their desired market reach R_j^* taking t as given, i.e. under the zero-conjecture $dt/dp_j = 0$.

Assumption 10 implies the following formal proceeding: In a first step the newcomers' price-reaction as a function the transmission charge, $p_j^*(t)$, is derived. In a second step the integrated firm employs this information in determining its optimal pricing t^* and p_{vi}^* . Finally, by substitution the newcomers' price p_j^* , the size of individual market areas as well as profit, and welfare results can be calculated.

Downstream profit is given by

$$\pi_j = 2(1 - p_j) \int_0^{R_j} (p_j - k - tr) dr - K. \quad (11)$$

Looking at gross profit equal to zero, $p_j - (k + tR_j) = 0$, we can solve the furthest sales-distance, $R_j = (p_j - k)/t$. The objective function then simplifies to

$$\pi_j = (1 - p_j)(k - p_j)/t - K. \quad (12)$$

First and second order conditions, $\partial\pi_j/\partial p_j = 0$ and $\partial^2\pi_j/\partial p_j^2 < 0$, determine the optimal values

$$p_j^* = (k + 2)/3 \quad (13)$$

and

$$R_j^*(t) = 2(1 - k)/3t. \quad (14)$$

If both types of firms made plans independently, an overlapping area would occur, which both would wish to serve. This easily follows from the fact that the integrated firm's optimization problem would correspond to the background case, yielding the entire area available, $2R_m^*$. Any consumer potentially served from the newcomers inhabits the same section of space. We are faced with the well-known conflict of spatial oligopoly in the presence of uniform delivered pricing. For the resolution of a spatial equilibrium in this case, there are a number of proposals in the literature, mainly to be distinguished with respect to the intensity of competition in the market (Beckmann (1973), Gronberg/Meyer (1981), Schuler/Hobbs (1982), and Schöler (1988), pp. 233-238). Our situation, however, is distinct from the commonly investigated cases by its specific asymmetry between the economic agents looked upon: The network-operator is informed about the newcomers' behaviour and sets two prices, p_{vi} as well as t , influencing by this means the size of its competitors market. These particularities evoke a different partition of the contested area.

The integrated firm's profit function expresses revenue and costs accruing upstream as well as downstream:

$$\pi_{vi} = 2(p_{vi} - k)R_{vi}(1 - p_{vi}) + 2(t - \tau) \int_0^{R_j} r(1 - p_j)dr - 2\tau \int_0^{R_{vi}} r(1 - p_{vi})dr - K - F. \quad (15)$$

Taking the identity $R_{vi} = R_m - R_j$ as well as the newcomers' decision, $R_j^*(t)$ and $p_j^*(t)$, into account we find how the integrated firm can control the spatial partition through the network charge t :

$$R_{vi}(t) = 2(1 - k)/3\tau - 2(1 - k)/3t. \quad (16)$$

Utilizing equations (13), (14) and (16) and rearranging terms we get

$$\begin{aligned} \pi_{vi}(t, p_{vi}) = & [4(1 - k)(k^2\tau(t - \tau) + k(3p_{vi}(t - \tau)(2t + \tau) - 6t^2 + \tau(t + 5\tau)) \\ & + 9p_{vi}^2t(\tau - t) + 3p_{vi}(t - \tau)(4t - \tau) - 3t^2 + \tau(7t - 4\tau)]/(27t^2\tau) \\ & - F - K \end{aligned} \quad (17)$$

subject to simultaneous maximization with respect to p_{vi} and t . The necessary conditions $\partial\pi_{vi}/\partial p_{vi} = 0$ and $\partial\pi_{vi}/\partial t = 0$ form a system of equations yielding three solutions for each price, amongst which two are economically admissible. Checking the

sufficient conditions, $\partial^2 \pi_{vi} / \partial p_{vi}^2 < 0$, $\partial^2 \pi_{vi} / \partial t^2 < 0$ and $(\partial^2 \pi_{vi} / \partial p_{vi}^2)(\partial^2 \pi_{vi} / \partial t^2) > (\partial^2 \pi_{vi} / (\partial p_{vi} \partial t))^2$, we can single out the optimal values:

$$p_{vi}^* = \frac{(\sqrt{61} - 1)k - \sqrt{61} + 19}{18} \quad (18)$$

and

$$t^* = \frac{(\sqrt{61} + 7)\tau}{4}. \quad (19)$$

Consequently, optimal delivered prices of the two types of firms differ, and because of $0 < k < 1$ we always have $p_{vi}^* < p_j^*$. The optimal transmission price, t^* , amounts to about 3.7-times the cost rate, τ . In each direction, market areas extend across

$$R_j^* = \frac{2(1 - k)(\sqrt{61} - 7)}{9\tau} \quad (20)$$

and

$$R_{vi}^* = \frac{2(1 - k)(3 - (\sqrt{61} - 7))}{9\tau}. \quad (21)$$

Thus, the integrated firm serves an area about 2.7-times the size of its competitors spatial market, independent of the cost parameter values, k and τ . It does not exclude the newcomers through prohibitively high transmission pricing. This outcome can be traced back to the following trade off: Starting from the monopoly situation with transport price sufficiently high to act as disincentives for market-entry to occur, the integrated firm weighs up profit-drawbacks downstream through letting customers switch to the competitors and additional gross profits upstream through transmission sales to the competitors at the fringes. These countervailing effects on the integrated firm's profit balance at the points described in equations (20) and (21).

Utilizing p_j^* , p_{vi}^* and t^* from equations (13), (18) and (19) takes us to the remaining market results. In equilibrium, a quantity

$$Q^* = 2R_{vi}^*(1 - p_{vi}^*) + 2R_j^*(1 - p_j^*) = \frac{(1 - k)^2(17(\sqrt{61} - 113))}{8\tau} \quad (22)$$

is produced and consumed. Firms' profits amount to

$$\pi_{vi}(p_{vi}^*, t^*) = \frac{(1 - k)^3(55 - 7\sqrt{61})(25\sqrt{61} + 179)}{729\tau} - K - F \quad (23)$$

and

$$\pi_j(p_j^*, t^*) = \frac{(1 - k)^3(\sqrt{61} - 7)4}{81\tau} - K. \quad (24)$$

Equations (23) and (24) tell a fixed ratio of gross profits: $\pi_{vi} + F + K/\pi_j + K \approx 4.2$, again independent of cost-parameter values¹.

Aggregate consumer surplus across all points in space reads:

$$\Lambda(p_{vi}^*, p_j^*, t^*) = 2R_{vi}^* \frac{(1 - p_{vi}^*)^2}{2} + 2R_j^* \frac{(1 - p_j^*)^2}{2} = \frac{(1 - k)^3(245 - 23(\sqrt{61}))}{729\tau}. \quad (25)$$

Social welfare sums up firms' gross profits and consumer surplus:

$$\Omega(p_{vi}^*, p_j^*, t^*) = \Lambda + \pi_{vi} + K + F + \pi_j + K = \frac{8(1 - k)^3(35(\sqrt{61}) - 239)}{729\tau}. \quad (26)$$

This value is called on to measure short-run efficiency when contrasted to the findings of our subsequent model.

4 Model: Oligopoly, vertical integration, uniform delivered pricing upstream and downstream

This section portrays the postage stamp case. Assumption 1-7, 8b and 10 are kept valid. The general spatial configuration continues to follow figure 2. The difference in the design of our models lies in a modification of assumption 9a through 9b and a supplement to our rules of the game assumption 10) by assumption 11.

Assumption 9b: For transportation services the newcomers pay a price t which purely quantity-related. The remuneration of the network services is not sensitive to distance.

In the terminology of the political debate, here, transmission pricing is replaced by the simplest form of access pricing, the postage stamp. Formally, we are dealing with a downstream market which is not spatial. There is no clear spatial assignment of individual production to individual demand². The variable costs upstream remain sensitive to distance.

Assumption 11: The newcomers assume the prices of their competitors to be fixed, i.e. their price conjecture is given by $dq_{vi}/dq_j = 1$.

As opposed to equation (9), the cost function of a market entrant simplifies to

$$C_j = 2R_m q_j (k + t) + K. \quad (27)$$

The multiplication with the number of places, $2R_m$, is undertaken because the commercial contracts of all firms spread evenly across the entire area under investigation.

Total costs of the integrated firm generally resemble the functional course known from equation (10). Changes are due to the fact that at every location the jointly determined quantity, $q = q_{vi} + q_j$, is delivered, and some special information on physical transmission distances enters:

$$\begin{aligned} C_{vi} = & 2R_m k q_{vi} + 2\tau \int_0^{R_m q_{vi}/(q_{vi}+q_j)} r(q_{vi} + q_j) dr \\ & + 2\tau \int_0^{R_m q_j/(q_{vi}+q_j)} r(q_{vi} + q_j) dr + K + F. \end{aligned} \quad (28)$$

The first term on the left-hand side of the cost-equation depicts variable production costs, the second term variable grid-costs from delivery of self-generated electricity, and the third term reflects variable grid costs arising from foreign generation. Equation (28) takes account of the physical law, that in electricity networks the real source of electrical energy always is the closest one with available capacity. In this way, physical transactions, i.e. the actual distance energy travels, are not directly linked to economic transactions between production and consumption. The upper limits of integration represent the respective market shares, transferred to the actually delivered market areas.

Competition downstream at every location and all across space equals a non-spatial oligopoly, the multiplication of demand by the number of places, $2R_m$, put aside. Newcomers downstream are facing the Cournot-type of maximization problem. Inverse demand from equation (1) can be specified to

$$p = 1 - (q_{vi} + q_j). \quad (29)$$

The profit function of newcomers reads

$$\pi_j = 2R_m q_j ((1 - q_j - q_{vi}) - k - t) - K. \quad (30)$$

By maximization of equation (30) with respect to quantity q_j we derive the reaction function satisfying $\partial\pi_j/\partial q_j = 0$ as well as $\partial^2\pi_j/\partial q_j^2 < 0$:

$$q_j^*(q_{vi}, t) = \frac{1 - q_{vi} - k - t}{2}. \quad (31)$$

Quantity q_j^* is a function of the other firm's quantity q_{vi} and of the network access fee t . From a newcomer's point of view the latter is an exogenous part of variable costs. However, within our model it follows endogenously from the integrated firm's decision.

The integrated firm's profit takes the form

$$\pi_{vi} = 2R_m t q_j + 2R_m q_{vi}((1 - q_{vi} - q_j) - k) - C_{vi}. \quad (32)$$

Making use of the information about its competitors available from equation (31), taking into account the cost-structure (equation (28)), and substituting R_m , profit can be rewritten as a function of the integrated firm's choice variables q_{vi} and t alone:

$$\begin{aligned} \pi_{vi}(q_{vi}, t) = & 2(k - 1)(k^3 + k^2(5q_{vi} + 5t - 3) + k(5q_{vi}^2 + 2q_{vi}(t - 5) + (t - 1) \\ & (7t - 3)) - 3q_{vi}^3 + q_{vi}^2(3t - 5) + q_{vi}(1 - t)(3t + 5) + (t - 1)^2 \\ & (3t - 1))/(9\tau(k - q_{vi} + t - 1)) - K - F. \end{aligned} \quad (33)$$

Due to formal complexity, in this model the optimal values t^* and p_{vi}^* cannot be determined through common simultaneous maximization. Instead we approximate the profit-maximizing values employing the following method: Heuristic substitution of values for the quantity ratio $0 < (q_j/q_{vi}) < 1$, under consideration of the reaction function from equation (30), permits one-dimensional optimization with respect to t . Commencing with $q_j = 0$ we observe the integrated firm's profit to increase up to its peak in two-dimensional π_{vi} -space. The corresponding optimal $q_{vi}^* - t^*$ -Kombination calculated in this manner reads:

$$t^* = 0.5134(1 - k) \quad (34)$$

and

$$q_{vi}^* = q_i = 0.2492(1 - k). \quad (35)$$

This quantity corresponds with a ratio $q_{vi}^*/q_i^* \approx 2.1$. The resulting production of newcomers is:

$$q_j^* = 0.1187(1 - k). \quad (36)$$

As above, the vertically integrated agent does obviously have an incentive to leave part of the downstream-market to its competitors, driven by corresponding revenue upstream. The relation $t > \tau$ holds true for the postage stamp access price as well, since only positive gross profits of the upstream-devision allow a market-share of $q_j/q > 0$ to occur. The exact ratio t/τ cannot not be found with anonymous parameters k and τ . The optimal values t^* , q_{vi}^* and q_j^* yield all further market- and welfare-results. For total production and consumption we find

$$Q^* = 2R_m(q_{vi}^* + q_j^*) = \frac{0.4905(1 - k)^2}{\tau}. \quad (37)$$

The delivered price, which is uniform for all consumers, follows from equation (28):

$$p^* = 0.3679k + 0.6321. \quad (38)$$

Profits result from equations (29) and (31) respectively, thus:

$$\pi_{vi}(q_{vi}^*, t^*) = \frac{0.1992(1 - k)^3}{\tau} - K - F \quad (39)$$

and

$$\pi_j(q_j^*, t^*) = \frac{0.0188(1 - k)^3}{\tau} - K. \quad (40)$$

Again we observe a fixed ratio of gross profits, namely $(\pi_{vi} + K + F)/(\pi_j + K) \approx 10.6$, which is clearly more accentuated in favour of the integrated firm than in the preceding case.

By means of consumer surplus we inspect the desirability of a case on behalf of demand. Here, it amounts to:

$$\Lambda(p^*, t^*) = 2R_m^* \frac{(1 - p^*)^2}{2} = \frac{0.0902(1 - k)^3}{\tau}. \quad (41)$$

Collecting values from equations (39), (40) and (41) we derive welfare as defined above:

$$\Omega(p^*, t^*) = \frac{0.3082(1 - k)^3}{\tau}. \quad (42)$$

This measure teaches us about the social desirability of the arrangement at hand in terms of efficiency.

5 Discussion

In this concluding section the findings of our formal analysis are systematically summarized and interpreted. To ease comparison the results are rounded to four decimals and collected in table 1. The values yielded in optimum are assigned to rows, whereas each column is assigned to one model respectively. The abbreviations mon-udp-vi, oli-udp1-vi and oli-udp2-vi signify the models presented in section 2 (background case), section 3 and section 4 (postage stamp case) in the named order. In table 1, to restrict our view to the essentials, we replace expression $(1 - k)$ by ψ , and $(K + F)$ by V . The market area terms, R_j^* and R_{vi}^* , in model oli-udp2-vi reflect the physically delivered distances, i.e. the market shares translated to space. Contrasting the market results outlined in table 1 with one another enables

value/ model	mon-udp-vi	oli-udp1-vi	oli-udp2-vi
price p_j^*	–	$0,3333k + 0,6667$	$0,3679k + 0,6321$
price p_m^* resp. p_{vi}^*	$0,3333k + 0,6667$	$0,3783k + 0,6217$	$0,3679k + 0,6321$
network charge t^*	$[\tau]$	$3,7026\tau$	$0,5134\psi$
area R_j^*	–	$0,1801\psi/\tau$	$0,2151\psi/\tau$
area R_m^* resp. R_{vi}^*	$0,6667\psi/\tau$	$0,4866\psi/\tau$	$0,4516\psi/\tau$
profit π_j	–	$0,0400\psi^3/\tau - K$	$0,0188\psi^3/\tau - K$
profit π_m resp. π_{vi}	$0,1481\psi^3/\tau - V$	$0,1685\psi^3/\tau - V$	$0,1992\psi^3/\tau - V$
total demand Q	$0,4444\psi^2/\tau$	$0,4883\psi^2/\tau$	$0,4905\psi^2/\tau$
consumer surplus Λ	$0,0747\psi^3/\tau$	$0,0897\psi^3/\tau$	$0,0902\psi^3/\tau$
welfare Ω	$0,2222\psi^3/\tau$	$0,3771\psi^3/\tau$	$0,3082\psi^3/\tau$

Table 1: Market and welfare results

to draw some interesting conclusions with respect to the above-stated objectives. Specifically, the outcomes can be interpreted thus:

- In both deregulated arrangements, network pricing does not exert complete vertical foreclosure. The integrated firm does have an incentive to welcome market entry³. The intuition behind this lies in the solution of a trade off-

³These findings are in line with those derived by Brunekreeft (1997) in a non-spatial context.

relation between shrinking revenue downstream and rising revenue upstream, both coming along with market entry.

- Locational electricity prices are lower or at most equally as high as before deregulation. The lowest consumer price is set by the integrated firm in case oli-udp1-vi. Network charges are in both deregulated regimes a strategic instrument of the grid operator. In both cases, they surpass marginal costs associated with network usage.
- The emerging interests of the economic agents involved deviate in part from those commonly assumed:
 - In our setting, all firms stand to gain from deregulation. Strikingly, newcomers are better off with distance-specific transmission pricing, whereas the integrated firm prefers postage stamp tariffs. In the presence of the latter pricing-regime the ratio of gross-profits is clearly stronger in favour of the integrated firm. This evidence contradicts the view, distance related pricing components as such were the central instrument of traditional service providers to save their incumbencies to the disadvantage of competitors. In this light, the lobbying of firms might be worth some rethinking.
 - Deregulation is to the advantage of consumers. They enjoy their greatest surplus in competition with grid-pricing of the postage stamp type, although this preference appears to be weak.
- Welfare effects exhibit an increase of efficiency after deregulation. The most important result emerges from a comparison of the deregulated arrangements: The sum of consumer and producer surplus is higher in the presence of distance-specific transmission-pricing. We detect short-run efficiency losses associated with postage stamp pricing.

All these findings are derived and valid within the analytical framework outlined above. To put them into perspective, some critical aspects of the analysis shall be identified. In this context the absence of regulation, the role of distance in grid costs and the rigidity of locations deserve some attention.

The traditional design of electricity supply includes regulatory control to various extents, which we abstract from. Therefore in the comparison of results with the background case this should be kept in mind. However, excess profits earned by traditional service companies were part of the impetus for liberalization in the first place, putting the effectiveness of the exerted regulation into question. In the deregulated cases we deliberately forego price-regulation in order to obtain a clear view of the effects of market power exploited through the infrastructure monopoly. In practice, the handling of the network ranges from state-owned to privately run in the absence of regulatory measures (for Germany, see BDI/VIK/VDEW (1999)). Implementing and assessing price-regulation-techniques in our framework, indeed, is a worthwhile task for future research.

The relevance of the present analysis hinges on the existence of short term spatially related costs in electricity networks (Annahme 4) and the possibility of ascribing them to specific transactions. The transmission of electricity induces coordination-costs and line-losses rising with distance. The latter require, depending on voltage and capacity usage, extra generation of up to 10 percent (Scherer (1977), Bolle (1990), O'Neill (1997)). Ascribing these short-run costs to specific deliveries in a multi-line network, however, is technically difficult with possible approximation in line-flow simulations. According to Kirchoff's laws electricity inductions and withdrawals change line flows all across the interconnected grid following the way of least resistance and subject capacity constraints. Therefore, taking the network pattern as given, each induction and associated withdrawal in the grid causes specific costs that hinge on its location relative to the given grid pattern and all other users but is not directly linked to geographic distances. Therefore, for our line of reasoning to make sense it is essential to strictly stick to economic space, as is usual in spatial economics: Locations are to be defined points in space relative to given grid capacities as well as to other production and consumption (Bohn et al. (1984, S. 361-369), Woo et al. (1995, S. 111-112)), i.e. reflecting costs of service. Interpreting our results in this sense the distances grid-pricing should be based on must not be measured in terms of physical geography. Much rather a zonal or spot pricing system as proposed by Schweppe et al. (1988) where economic distance indirectly enters through the addition of location- or zone. specific prices calculated for both

sides of the market. Such systems are practiced in e.g. England and Wales (Green (1997)), whereas in Germany the postage stamp regime is presently in duty.

Restricting the analysis to the short run, as embodied in an exogenous number of firms and locational rigidity, is common to the analysis of deregulated electricity networks (Boucher/Smeers (1999)). Nevertheless, it signifies, that not all influences of (non-)spatial price signals are captured. According to e.g. Chao/Peck (1996) and Bushnell/Stofft (1997) efficiency effects through capacity- and locational decisions of network-pricing are at work in the long run, in particular. An adequate treatment of these long-run mechanisms escapes the scope of our framework. The intuition is, that disconnecting locational considerations from existing spatial scarcities through the introduction of postage stamp transport charges induces misled locational decisions, and negative welfare effects in suit. Accepting this view, these long-run effects carry the same sign as those derived in this paper. The direction of the combined influence on efficiency is unequivocal.

Thus, if the simplification of network-pricing schemes by the abolishment of location- or distance-specific components induces transparency, intensified competition and - as the popular argument goes - enhanced productivity in suit, these gains have to be weighed against the negative welfare effects caused by the disregard of relevant distances. Too little attention is being paid to the latter side of the named trade off. This contribution attempts to shed some light on possible short-run efficiency losses associated with postage stamp network pricing in a theoretical analysis under special consideration of the debate's central element, i.e. space.

Footnotes

1. A similar regularity of relative profits in vertically related spatial markets is detected by Schöler (1989).
2. Strictly speaking, the locational choice of newcomers is indetermined as well. Assuming, however, that they do not know a priori which of the regimes occurs, they position themselves in the same way as with distance-related transmission pricing.

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