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The ratchet effect in a two lag setting and the mitigating influence of yardstick competition

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The ratchet effect in a two lag setting and the mitigating influence of yardstick competition

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Abstract

In order to increase efficiency in the provision of power distribution networks, the German regulator Bundesnetzagentur plans to implement revenue cap regulation together with yardstick competition.
Revenue cap regulation could bear the ratchet effect: cost minimization need not to be optimal for the operator who anticipates that his revenue cap will become adjusted according to his cost performance. The regulator could extract all the rent by lowering an operator's revenue cap to the level of costs he revealed to be possible for him to reach.
The ratchet effect could be mitigated by yardstick competition at which the level of revenues that is allowed to one operator is tied to the performance of others that are comparable to him. One will only be allowed to accumulate revenues that recover the least cost level that has been adopted within the group of comparable decision makers.
In a setting of two sequential regulatory lags, this paper examines the occurence of the ratchet effect and the mitigating influence that yardstick competition has on it.

Keywords: ratchet effect, yardstick competition, regulation
JEL classification: L51

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1 Introduction

Networks are essential facilities for the distribution of electricity and constitute natural monopolies that are not contestable. In a liberalised market, the network for power distribution provides its services like wheeling and transformation to competitive suppliers of electricity. The final user of electricity is charged a fee that pays the network services. The demand for network services is derived from the demand of electricity and is beyond the influence of an unbundled operator (see Bundesnetzagentur, 2005, 24 (103) as well as Bundesnetzagentur, 2006, 178 (841)). All an operator can influence are its own costs of network provision.

The Bundesnetzagentur plans to implement regulation that gives the operators incentives for efficient provision of their network. According to the plan, revenue cap regulation will be imposed on the operators. In addition to this, yardstick competition will be established among comparable networks. The best practice among comparable networks will set the yardstick for the performance of those that are inefficient relative to it.

The Bundesnetzagentur assumes that the technology of power distribution features constant returns to scale, which implies that there is a unique efficient output-input ratio applying to all networks. This ratio is unknown by the regulator and will be approximated by the the best practice ratio that is revealed in comparison of network performance. An operator that has been revealed to work inefficiently relative to the best practice will be given a revenue cap that is sufficiently below his currently incurred costs. In order to secure the rate of return of the network, the operator has to reduce costs until his output-input ratio is equal to that of the best practice.

An operator's individual optimization under revenue cap regulation could bear the ratchet effect. Although he is a residual claimant of his costs during the regulatory lag[1], cost minimization need not be optimal for him because of the regulator's behavior that is triggered by this. From each unit of cost reduction the regulator learns that it is possible for the operator to run his network more efficient than he did before. At the next regulatory review, he can lower the revenue cap so that it just covers the revealed cost level. By this, he mandates the abidance to the revealed efficiency without granting any rent to the operator. The operator who anticipates this rent extraction does not minimize costs in order to hide from the regulator what his true level of minimum necessary costs is.

[1] A regulatory lag is a period of time in which there is no change, especially adjustment, of the regulatory mechanism that has been specified and announced.

In a setting of two sequential regulatory lags, I examine the occurence of the ratchet effect and the capability of mitigating it by yardstick competition.

The ratchet effect is discussed by Weitzman (see Weitzman, 1980) and Laffont and Tirole (see Laffont, Tirole, 1993, chpt 9). While Laffont and Tirole use a game-theoretic approach by which they provide a clear intuition for the mutual behavior of the regulator and the agent, Weitzman examines the ratchet effect within the framework of a dynamic programming problem. In his model, future demands for performance are adjusted to observed performance by application of a mechanistic rule. I use such a mechanistic rule to model the revenue cap adjustment at the regulatory review.
The concept of yardstick competition has been developed by Shleifer (see Shleifer, 1985).

The plan of this paper is as follows. After description of the components of the model, I will discuss the occurence of the ratchet effect and suggest that it is plausible in reality. Then yardstick competition will be introduced to the model. Its mitigating influence on the ratchet effect is a result of the analysis within a decision-theoretic as well as within a game-theoretic framework.

2 Model

From the fact that the demand for network services is beyond the influence of the operator I conclude that it is user-fee-inelastic. By this, wheeling and provision of a power distribution grid can be modelled as a single and onedimensional product that is fixed in amount by the actual demand situation in the particular area. All an operator can influence are his costs of network provision and so attention can be restricted to incentives for cost reduction that are set by the planned regulation.

There are I network operators $i = 1, \ldots, n$ each of which is a monopolistic provider of power wheeling in his specific region. Every i is given in lag 1 a cap R_1^i on his revenues. This cap recovers a certain cost level, for example the one that he had in some base period.

The individually incurred costs C^i of operator $i = 1, ..., I$ in this base period, and with that the revenue cap R_1^i, is supposed to be higher than necessary for efficient network provision. Historical regulation which gave the regulated firm scope for inefficiency is one among other potential motivations for this assumption. But the regulator does not know by how much costs are in excess. Denoting with $\underline{C}^i$ the minimum costs

necessary to incur for efficient provision by operator i, it follows $R_1^i > \underline{C}^i$.[2]

Given his revenue cap, the operator is a residual claimant of his costs for the particular regulatory lag $t = 1, ..., T$ and can by choice of actual lag costs C_t^i, with $R_t^i \geq C_t^i \geq \underline{C}^i$, realise some or all of his potential for profits $\bar{\pi}_t^i = R_t^i - \underline{C}^i$.

In the model there are no costs or disutility of cost reduction. These would diminish the profit the operator could achieve by reducing his costs. He would not reduce his costs at all, if the so generated yield did not recover the costs of cost reduction. The yield depends on the length of time for which saved costs remain at the operator. For any specification of costs of cost reduction, there can be found a duration of the regulatory lag that is sufficiently long to make sure that the operator actually gets profit by reducing his cost level. Equivalent to the assumption of sufficient duration of the regulatory lag is the assumption that there are no costs of cost reduction at all. Both make sure that the operator actually wants to reduce his cost level.

In this paper, a two-lag setting will be analysed in order to simplify the exposition. Within this setting, each lag is completely described by the operator's revenue cap and choice of costs. By that, a unit of cost reduction leads to the same profit in whichever lag it occurs. This implicitly assumes that both lags have the same length because a unit of cost reduction generates the more profit, the longer it remains at the operator. The author is aware of the fact that, because of this, the model is not capable of analysing all possible cases of subsequent lags that are relevant in reality. Indeed, the Bundesnetzagentur plans the first two lags to feature longer duration than the lags with index larger than two. Thus, the impact of the planned regulation has at the transition from lag two to lag three cannot be analysed within this model. But the model is capable of describing the impact in all other cases because they feature lags of equal length, so it does not mean a major drawback to assume equal duration.

An operator has available only one choice per lag. By performance based adjustment of the revenue cap, the possibility for future profit depends on the operator's current choice of costs. Within his single choice he has to trade-off current against future profit. The assumption rules out that the operator reduces costs at the beginning of the lag in order to realise profit and increases costs at the end of the lag in order to get a high revenue cap. In reality, such behaviour can be ruled out by gearing the cap to the average level of costs incurred during the lag.

The operator is assumed to act completely in the interest of the network owner. So the

[2]Note that there is no time index at the minimum costs. Because minimum costs are determined by technology, this means that there is no technological progress over time

specification that characterises the operator is the same as that of the general assembly of the network share-holders.

Let $u(y)$, with $u'(y) > 0, u''(y) < 0$ be the function that assigns to every level of profit y the utility the operator draws from this payoff, a specification that makes sure that the solution is indeed a utility maximum. Moreover, $u(\cdot)$ satisfies the Inada conditions $lim_{y\to\infty}u'(y) = 0$ and $lim_{y\to 0}u'(y) = \infty$. An operator modelled in such a way prefers balanced profit flows over time to extreme values like all in one and nothing in the other lags. By this, he has sufficient interest in future outcomes which assures the existence of the ratchet effect even in a two lag setting like that analysed in this paper.

Moreover, strictly concave preferences specify risk-aversion on the part of the operator, which is a deliberate assumption. It beats both alternatives of attitude towards risk. First, risk-loving (convex utility function) can be excluded because it would imply that an operator prefers gambling for his revenue cap to having a certain one with same expected value. In reality, rather, reliability is argued to be an important feature of successful regulation.
Second, risk neutrality (linear preferences) can be excluded for the following reason. Imagine that regulation were in fact not reliable. This would mean that both, the rate of return of the network and, due to network bankruptcy, its provision at all, are exposed to risk. It is reasonable to assume that each individual network share-holder is a risk-averter. If the Arrow-Lind theorem is not applicable, then the total of share-holders acts as a risk-averter when deciding on the general assembly at which they instruct the operator. The Arrow-Lind theorem is in fact not applicable because its constitutive assumption, that all other sources of share-holders' income are uncorrelated with their income from the risky asset, is violated. Indeed, any shock concerning the power distribution networks will be carried over to every sector in the economy that is dependent on electricity. Thus, all possible sources of income in an industrial economy are related to the risky situation in the electricity sector.

The performance based rule that determines the revenue cap of the next lag R^i_{t+1} is a function increasing in the currently incurred cost level C^i_t.

$$R^i_{t+1} = R(R^i_t, C^i_t), \quad \frac{\partial R}{\partial C^i_t} > 0 \tag{1}$$

A simple specification of this function is the following

$$R(R^i_t, C^i_t) = (1-\Omega)C^i_t + \Omega R^i_t \tag{2}$$

where $\Omega \in [0; 1]$ is a parameter governing the degree of profit extraction by the regulator, allowing for continuous adjustment of the incentive power of the mechanism. By Ω, the regulator can give rewards for cost reduction, leaving to the operator some of the generated profits beyond the adjustment process of the revenue cap at the regulatory review. Rule (2) covers a wide range of possible regulatory policies, for example the one that is planned by the Bundesnetzagentur. There, an extra rent accrues to the most efficient operator by the specific way the comparison of efficiency is designed (see Bundesnetzagentur, 2006, (342)).

2.1 Ratchet Effect

This section restricts attention to the analysis of an individual operator's behaviour, when he is faced with revenue cap regulation. Not until it is shown that the occurence of the ratchet effect is plausible, there is reason to analyse the impact of yardstick competition.

Within the setting of two subsequent lags of equal duration, the operator maximizes his intertemporal utility by choice of his incurred cost level, given the adjustment rule of the revenue cap in (2). Whatever the choice in lag one, the operator chooses $C_2^i = \underline{C}^i$ because of the positive marginal utility of profit. The present value of utility is then

$$u(R_1^i - C_1^i) + \delta u\left((1-\Omega)C_1^i + \Omega R_1^i - \underline{C}^i\right) \tag{3}$$

where δ is the discount factor, that models the operator's time preference. The higher the value of δ, the more important are future profits from the operator's point of view. Maximizing this expression by choice of $C_1^i \in [\underline{C}^i, R_1^i]$ leads to the following first-order condition, which is necessary and sufficient for an unique maximum.

$$-u'(y_1) + \delta(1-\Omega)u'(y_2) \begin{cases} \geq 0 & \text{if} \quad C_1^i = R_1^i \\ = 0 & \text{if} \quad C_1^i \in (\underline{C}^i, R_1^i) \\ \leq 0 & \text{if} \quad C_1^i = \underline{C}^i \end{cases} \tag{4}$$

where

$$y_1 = R_1^i - C_1^i \tag{5}$$

$$y_2 = (1-\Omega)C_1^i + \Omega R_1^i - \underline{C}^i \tag{6}$$

If the regulator did without extraction ($\Omega = 1$), the operator will completely reduce his

costs to the minimum. If, conversely, complete extraction ($\Omega = 0$) was intended, then the solution would be an interior one because the Inada conditions hold. Leaving some profits beyond the review ($\Omega \in (0, 1)$) leads to cost minimization if

$$\delta \leq \frac{u'(R_1^i - \underline{C}^i)}{(1-\Omega)u'(\Omega(R_1^i - \underline{C}^i))} \tag{7}$$

is satisfied. Otherwise, $C_1^i = \underline{C}^i$ is impossible. The right hand side of (7) describes as a function of Ω an upper bound for δ that is depicted in figure 1 for logarithmic and square root preferences.

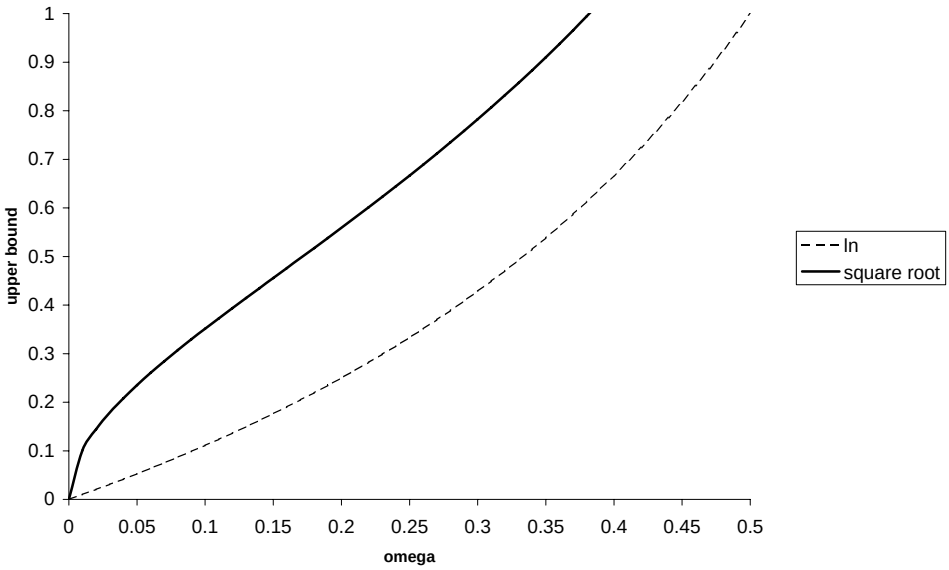

Figure 1: Upper bounds of the discount factor

Given a value of δ, the inverse upper bounds show how high the value of Ω has to be at the particular preferences, in order to induce cost minimization in the first lag. Albeit obvious differences between the two upper bounds shown, it can be seen that for values of $\delta > 0.8$ the regulator had at least to do without 30% of profit extraction if he wanted the firm to work efficiently. No cost reduction at all, $C_1^i = R_1^i$, is again impossible because of the Inada conditions.

An interior solution C_1^{i*} satisfies

$$\frac{u'(y_1)}{u'(y_2)} = \delta(1-\Omega) \tag{8}$$

so that the marginal rate of intertemporal substitution of profit is equal to the marginal rate of profit-transformation that is possible at a certain regulatory policy Ω. The specification of $u(\cdot)$ implies that the level of optimally incurred costs C_1^{i*} is the lower, the higher is the parameter value of Ω.

Every solution that is not cost minimization is equivalent to the occurence of the ratchet effect. The more profit extraction (the lower the Ω), the higher the costs and so the more pronounced the ratchet effect. Indeed, given a specified level of the discount factor δ, high enough a reward for cost reduction (high Ω) could delete the ratchet effect. The higher the level of δ, the higher the reward that is necessary to induce cost minimization.

Decisions concerning the operation of a power grid have long-term implications. I suggest that operators of a network feature high discount factors. If they did not, they would be impatient with respect to profits. Such an attitude is not reconcilable with the farsightedness that is necessary for the operator to exhibit within his decisions.

It is reasonable to assume that the regulator is not willing to leave an amount of profit to the operator that is sufficient to induce cost minimization. The regulator wants to pass the benefit of cost reduction to the consumers by reduced network fees. Leaving profits to the operator is in conflict to this aim.

This reasoning leads to the conclusion that the ratchet effect can be expected to occur and that, thus, there is a reason for further regulatory effort. This would also be true, a fortiori, if the number of lags were extended, because the weight that future profits get within the operator's optimization problem becomes the larger, the longer future lasts.

For further discussion, it is necessary to know how the operator's optimal choice varies with the underlying parameters. Therefore, the implicit function theorem is applied to the the first-order condition (4) for an interior solution. Denote by S the derivative of this condition with respect to C_1^i.

$$S \equiv -u''(R_1^i - C_1^{i*}) - \delta(1-\Omega)^2 u''((1-\Omega)C_1^{i*} + \Omega R_1^i - \underline{C}^i) > 0 \tag{9}$$

Applying the theorem leads to the following results that are globally valid.

$$\frac{\partial C_1^i}{\partial \Omega} = -\frac{-[\delta(1-\Omega)u''(y_2)(R_1^i - C_1^{i*}) - \delta u'(y_2)]}{S} < 0 \tag{10}$$

$$\frac{\partial C_1^i}{\partial \delta} = -\frac{-(1-\Omega)u'(y_2)}{S} > 0 \tag{11}$$

$$\frac{\partial C_1^i}{\partial \underline{C}^i} = -\frac{\delta(1-\Omega)u''(y_2)}{S} > 0 \tag{12}$$

(10) shows that the optimal cost level is the lower, the higher is Ω. The second line tells that the operator chooses to incur a cost level that is higher, the higher his preference for profits in the future. The higher the discount factor, the more intensively the operator feels the reducing impact that low costs in the presence, and so high profits, have on his future revenue cap. Finally, it can be seen in (12) that operators with higher minimum costs incur higher costs C_1 given a certain cap R_1. Unlike in the two previous results, this is not evidence of a more intensive ratchet effect but of limited potential for cost reduction.

The direction of variation of optimal choice induced by variation of a particular parameter is now clear. Variations are strictly monotone because of the global validity of result (10), (11) and (12). Further, it follows from the theorem of the maximum (see Sundaram, 1996, 237) that the optimal cost level to incur varies continuously with the parameters.

As long as different operators have revenue caps that are at least proportional to each other, variations in δ and $\underline{C^i}$ are sufficient to model different characteristics of different operators that are relevant for their individual choice of costs. Differing discount factors could result from differing dispositions of the owners of the different power grids with respect to patience. Differing minimum costs are impossible if networks use the same technology. But it could be that operators do not exactly know what this minimum cost level is. They rather make the best guess they can given their information. An individual operator could think that his minimum cost level is $\underline{C^i} = X$ whatever the true level. Even if all power grids were in fact the same, the operators might differ in their cost characteristics, albeit by mistake of appreciation.

It can be stated that there exists a continuous and strictly increasing function G assigning to each value of a parameter $z \in Z$ the optimal cost level incurred in the first lag by an operator who features exactly that value, where z could be δ or $\underline{C^i}$.

2.2 Yardstick Competition

So far, discussion focused on the decision of a single operator that is subject to revenue cap regulation. The occurence of the ratchet effect has been reasoned. Now, the possibility of workable yardstick competition will be introduced to the model and it will be shown that yardstick competition mitigates the ratchet effect.

Take $I \geq 2$ operators which are comparable to each other. The course of regulation, including revenue cap regulation and yardstick competition, is the following. Prior to

the first lag, network performance is compared in order to find the best practice whose output-input ratio is used as an approximation of the true efficient ratio[3]. Operators will be forced to work at the best practice ratio by adequate cutting of their revenue caps. Consequently, the revenue caps, respectively cost levels, are proportional across different networks.

Thus, networks are symmetric at the beginning of the first lag. If they are still symmetric at its end, depends on the individual decision each operator makes given his revenue cap. However, at the regulatory review between the first and the second lag there will be made a comparison again. By the same process as described above, networks will be made symmetric prior to the second lag.

In the regulatory review between the first and the second lag, there can only be found a best practice if network operators made different decisions with respect to their incurred cost level. The comparative statics established that this will be the case if the operators feature different characteristics.

In the following, the realisation of the variable z denotes the particular characteristic δ or $\underline{C^i}$ of an individual network operator. By the function G, mentioned in section 2.1, a higher value of z implies a higher level of costs that is incurred in the first lag.

For both characteristics the analysis will be essentially the same, but the interpretation of the results differ. Denote by $\underline{z}$ the least value of z that is featured among all operators. It will be shown that yardstick competition induces operators with $z < \underline{z}$ to reduce their costs by more than they would have done without yardstick competition. This is evidence of the mitigating effect that yardstick competition has on the ratchet effect, only if z denotes individual discount factors. If, instead, z denotes the appreciations of minimum costs, then this result is evidence that yardstick competition is an instrument to accelerate improvement of overall efficiency in network operation by revealing the properties of the underlying technology to the ignorant operators.

Discussion will concern only two operators, 1 and 2, for whom collusive behavior is excluded explicitly. In reality, cooperative behaviour is excluded because the number of operators is sufficiently large to render it too expensive in terms of transaction costs.

Analysis will be done in a decision-theoretic as well as within a game-theoretic framework. In both, each operator has a set of possible decisions that are available to him and a probability distribution concerning the decision of his "‘opponent"’.

In the decision-theoretic framework, an operator does not take into account any reac-

[3]Note that technology is assumed to feature constant returns to scale

tions of his opponent. This allows to work with sets of possible decisions and with associated probability distributions that are continuous without having to deal with sophisticated mathematical formalism. Strategic interaction between the operators, which is relevant in reality, will be considered within the game-theoretic framework. The price for modeling this interaction without sophisticated formalism is that only discrete sets of possible decisions as well as discrete prior probability distributions are possible.

At first the decision-theoretic analysis will be exerted. The decision an operator makes when he is solely subject to revenue cap regulation[4] will be denoted by the adjective "'isolated"'. Operator 1, whose optimal isolated choice is denoted C^{1*}, does not know which value z characterises operator 2. All he has is a probability distribution F over the parameter space $Z = [z^L, z^H]$ from which z is drawn. The density f is assumed to be strictly positive on Z. The commonly known function G assigns to each z the optimal choice of an individual featured by that value. Thus, the space of 2's possible choices is $[C^L, C^H]$. By G, the distribution function F carries over from Z to $[C^L, C^H]$.

Given a pair of choices C^1 and C^2, operator 1 becomes relatively inefficient compared to 2, if $C^2 < C^1$. As a result, his revenue cap will be cut in lag two. If, instead, $C^2 \geq C^1$ were the case, then 1 would get a revenue cap according to the rule denoted in (2). So 1's second lag utility is

$$u_2 = \begin{cases} u(C^2 - \underline{C}^1) & , \quad \text{if} \quad C^2 < C^1 \\ u((1-\Omega)C^1 + \Omega R_1 - \underline{C}^1) & , \quad \text{if} \quad C^2 \geq C^1 \end{cases}$$

Facing this, there are two cases in which 1 wishes to deviate from his isolated optimum C^{1*}

1. $C^H < C^{1*}$ or
2. $C^L < C^{1*} < C^H$

In case 1, C^{1*} would always be underbidden by C^2 and 1 would choose $C^1 < C^{1*}$ in order to at least save his Ω-reward. In the second case, assume that cost minimization remains to be suboptimal. Operator 1 tries to stay as near as possible to his isolated optimum so that a choice $C^1 \leq C^L$ can be excluded. His problem can be considered in the following way: Given a choice $C^1 \in (C^L, C^H)$, 1 becomes underbidden with

[4]this is the decision analysed in the section about the ratchet effect

probability $F(C^1)$ by a choice $C^2 < C^1$ that has density $f(C^2)$. Because every value $C^2 \in [C^L, C^1)$ is possible in principle, 1's expected utility, when underbidden, is

$$\int_{C^L}^{C^1} u(C^2 - \underline{C}^1) f(C^2) \mathrm{d}C^2 \tag{13}$$

His expected utility when not underbidden at his choice is, following the same reasoning,

$$\int_{C^1}^{C^H} u((1-\Omega)C^1 + \Omega R_1 - \underline{C}^1) f(C^2) \mathrm{d}C^2 \tag{14}$$

The overall expected utility in lag two will be denoted $E[u(y_2)]$ and takes the form

$$\begin{aligned} E[u(y_2)] &= \int_{C^L}^{C^1} u(C^2 - \underline{C}^1) f(C^2) \mathrm{d}C^2 \\ &+ u((1-\Omega)C^1 + \Omega R_1 - \underline{C}^1)(1 - F(C^1)) \end{aligned} \tag{15}$$

so that the present value $U(C^1)$ of 1's utility, given a choice C^1, is finally[5]

$$U(C^1) = u(R_1 - C^1) + \delta^1 E[u(y_2)] \tag{16}$$

The rearranged first-order condition for maximization of (16) is

$$\begin{aligned} u'(R_1 - C^{1**}) &= \delta^1 (1-\Omega) u'((1-\Omega)C^{1**} + \Omega R_1 - \underline{C}^1)(1 - F(C^{1**})) \\ &+ \delta^1 \left[f(C^{1**})[u(C^{1**} - \underline{C}^1) - u((1-\Omega)C^{1**} + \Omega R_1 - \underline{C}^1)] \right] \end{aligned} \tag{17}$$

At the optimum C^{1**}, a marginal increase in costs lowers profit and by that also utility in lag one, see the left hand side of (17). In lag two, it has two effects that are balanced with that of lag one. As the first term on the right hand side of (17) shows, higher costs lead via a higher revenue cap to higher profits and thus to an increase of utility in the case that i is not underbidden. But at the same time, a marginal increase in costs leads to a marginal increase in the probability to become underbidden measured by $f(C^{1**})$. When underbidding takes place, 1 loses the difference in utility shown in the second bracket of the second summand in (17).

In order to compare C^{1**} with the isolated optimum C^{1*}, it must be assured that the

[5]Note that revenue caps of different operators are proportional to each other, by the assumption of constant returns to scale in network provision. For simplicity it will in the following be assumed that they are identical.

first-order condition is also sufficient for a unique utility maximum. As this is true if $U(C^1)$ is strictly concave, it is necessary to examine its second derivative with respect to C^1. Defining for simplification of notation

$$\begin{aligned} y_1 &\equiv R_1 - C^1 \\ y_2^l &\equiv C^1 - \underline{C}^1 \\ y_2^h &\equiv (1-\Omega)C^1 + \Omega R_1 - \underline{C}^1 \end{aligned} \tag{18}$$

this second derivative is

$$\begin{aligned} \frac{\partial^2 U(C^1)}{\partial^2 C^1} &= u''(y_1) && (19) \\ &+ \delta^1(1-\Omega)\left[u''(y_2^h)(1-\Omega)(1-F(C^1)) - u'(y_2^h)f(C^1)\right] && (20) \\ &+ \delta^1 f'(C^1)[u(y_2^l) - u(y_2^h)] && (21) \\ &+ \delta^1 f(C^1)[u'(y_2^l) - u'(y_2^h)(1-\Omega)] && (22) \end{aligned}$$

(19) and (20) are strictly negative because of the the strict concavity of $u(\cdot)$ and because $f(\cdot)$ is assumed strictly positive. By the same reasoning, (22) is strictly positive if $\Omega > 0$, what will be assumed in the following, in order to model the plan of the Bundesnetzagentur to establish a reward for efficiency (see Bundesnetzagentur, 2006, 80 (342)). Nothing can be said about the sign of (21) without further information on $f(\cdot)$.

Thus, the second derivative is negative, if the sum of (21) and (22) is negative. That is

$$f'(C^1)[u(y_2^l) - u(y_2^h)] + f(C^1)[u'(y_2^l) - u'(y_2^h)(1-\Omega)] < 0 \tag{23}$$

$$\Leftrightarrow$$

$$f'(C^1) > \frac{-f(C^1)[u'(y_2^l) - u'(y_2^h)(1-\Omega)]}{u(y_2^l) - u(y_2^h)} > 0 \tag{24}$$

It will now be derived analytically that $C^{1**} < C^{1*}$. The exposition is completely technical and does not provide any economic insights. Its purpose is solely to show how derivation works.

Assume condition (24) holds. Ignoring for a while the second summand of the right hand side of (17) and transforming gives

$$\frac{u'(R_1 - C^{1**})}{u'((1-\Omega)C^{1**} + \Omega R_1 - \underline{C}^1)} = \delta^1(1-\Omega)(1-F(C^{1**})) \tag{25}$$

Note, that (25) resembles the first-order condition for the isolated optimum which was

$$\frac{u'(R_1 - C^{1*}))}{u'((1-\Omega)C^{1*} + \Omega R_1 - \underline{C}^1)} = \delta^1(1-\Omega) \tag{26}$$

If $C^{1**} = C^{1*}$, then (25) could not be satisfied because, for $1 - F(C) \leq 1$ and $C^{1*} > C^L$, its right hand side is less in value than that of (26). Thus, the left hand side of (25) must decrease by a lowering of costs $C^1 < C^{1*}$, which in turn raises the right hand side so that costs must again increase a bit in order to satisfy (25). This kind of oscillation goes on until a cost level is reached that is lower than C^{1*}.

Including the second summand in (17) leads after rearranging to

$$\frac{u'(y_1)}{u'(y_2^h)} = \delta^1(1-\Omega)(1-F(C^{1**})) - \delta^1 f(C^{1**})\frac{u(y_2^h) - u(y_2^l)}{u'(y_2^h)} \tag{27}$$

The right hand side of (27) is even lower than in (25), so that at least the initial amplitude of the oscillation mentioned above is enlarged. How the oscillation continues will become clear, when examining the behavior of the added term, called P for simplicity, with respect to costs.

$$\begin{aligned}\frac{\partial P}{\partial C^1} &= \delta^1 \frac{u'(y_2^h)[f(C^1)[u'(y_2^h)(1-\Omega) - u'(y_2^l)] + f'(C^1)[u(y_2^h) - u(y_2^l)]]}{(u'(y_2^h))^2} \\ &- \delta^1 \frac{f(C^1)[u(y_2^h) - u(y_2^l)]u''(y_2^h)(1-\Omega)}{(u'(y_2^h))^2} > 0 \end{aligned} \tag{28}$$

The term in squared brackets in the numerator of the first fraction in (28) is the negative of (23) and thus strictly positive by condition (24). Because of the concavity of $u(\cdot)$ the second fraction in (28) is negative and finally the whole derivative is strictly positive.

This term P, increasing in costs, enters the first-order condition with negative sign so that the following holds true: At starting level C^{1*} there is downward pressure on costs. If it has decreased accordingly, there arises an upward pressure which is, because of $\partial P/\partial C^1 > 0$, slightly smaller than it was when P had been ignored. Thus, costs will increase and by that the downward pressure rises again but will not be as strong as initially, and so on. In a nutshell, the term P enhances downward- and lessens upward-pressure on the cost level. Finally, $C^{1**} < C^{1*}$.

So, the decision-theoretic discussion showed that yardstick competition is capable of mitigating the ratchet effect.

The decision-theoretic framework allowed to study the behaviour of an operator that

does not take into account what implications his decision has on that of his opponent. But in reality, operators might interact strategically. When optimizing, they anticipate their opponent's reaction to their decision.

Such strategic interaction will now be analysed. As before, there are two operators, 1 and 2, both having the same revenue caps R_1. Unlike before, the range of possible values of z is discrete and so are the individual priors of the operators. This allows the analysis to be done with basic formalism.

1 and 2 can individually be characterised by one of two possible values of $z \in \{z^L, z^H\}$ with $z^L < z^H$. An operator will be refered to as an H-type, respectively as an L-type, if his individual value of z is z^H, respectively z^L. Denote with C^k, where $k = L, H$, the isolated optimum of type k and note that $C^L < C^H$.

Let $\{C^1, C^2\}$ be a pair of cost choices by the two players. Because of yardstick competition, the revenue cap of the following lag will only recover $min\{C^1, C^2\}$. If type k can eventually remain at his isolated optimum, he gains Θ^{**} as a pay-off. An H-Type gets Θ^* when choosing C^L and Θ when instead choosing C^H and becoming underbidden by the other operator. When choosing C^H, type L gains Θ^* if he is not, and Θ if he is underbidden. By assumption $\Theta^{**} > \Theta^* > \Theta$, so that everyone most prefers his isolated optimum and most dislikes becoming underbidden.

The following figure shows the normal form representation of this game. Capital letters

2

H

		h	l
1	H		
	h	$(\Theta^{**}, \Theta^{**})$	(Θ, Θ^*)
	l	(Θ^*, Θ)	(Θ^*, Θ^*)
1	L		
	h	(Θ^*, Θ^{**})	(Θ, Θ^*)
	l	(Θ^{**}, Θ)	(Θ^{**}, Θ^*)

L

		h	l
1	H		
	h	(Θ^{**}, Θ^*)	(Θ, Θ^{**})
	l	(Θ^*, Θ)	(Θ^*, Θ^{**})
1	L		
	h	(Θ^*, Θ^*)	(Θ, Θ^{**})
	l	(Θ^{**}, Θ)	$(\Theta^{**}, \Theta^{**})$

Figure 2: Normal form representation of the two person game

H, L denote types, small type letters l, h label high or low cost level as the possible actions. The upper left matrix, for example, illustrates the game that is played between H-types and the other matrizes do in an analogous manner.

Choosing C^L is a dominant strategy of an L-type of operator. The Nash equilibrium in

the lower right matrix game of two L-types is an equilibrium in dominant strategies. Playing C^H is thus only reasonable for an H-type. A player is type H with probability p and L with counterprobability $1-p$. Each individual knows his own type but not that of the other. With respect to this, he applies the probability distribution $\{p, 1-p\}$.

Given he is type H, operator 1 plays C^H with probability x_1. He does so with certainty ($x_1 = 1$) if the expected utility at this choice exceeds the one he would gain at C^L, where the expected utility is calculated with respect to $\{p, 1-p\}$ and x_2, the respective choice of 2. Formally:

$$\begin{aligned} x_1 = 1 \quad &\Leftrightarrow \quad p\left[x_2\Theta^{**} + (1-x_2)\Theta\right] + (1-p)\Theta > \Theta^* \\ &\Leftrightarrow \quad x_2 > \frac{\Theta^* - \Theta}{p(\Theta^{**} - \Theta)} \end{aligned} \tag{29}$$

1's best response correspondence is thus

$$x_1 = \begin{cases} 1, & \text{if} \quad x_2 > \frac{\Theta^*-\Theta}{p(\Theta^{**}-\Theta)} \\ \in [0;1], & \text{if} \quad x_2 = \frac{\Theta^*-\Theta}{p(\Theta^{**}-\Theta)} \\ 0, & \text{if} \quad x_2 < \frac{\Theta^*-\Theta}{p(\Theta^{**}-\Theta)} \end{cases}$$

The according correspondence of 2 is a mirror image to that of 1 because of the symmetry of the game.

Denote by $\hat{x}$ the probability that the opponent plays C^H, given that he is an H-type. If this probability exceeds a critical value, then an H-type of player chooses C^H. This critical value consists of the probability p that the opponent is H at all and of the fraction $\frac{\Theta^*-\Theta}{\Theta^{**}-\Theta}$ of maximum possible loss that can be avoided by playing C^L from the very beginning.

The higher this fraction, the higher the threshold for $\hat{x}$ beyond which an operator expects to be better off by C^H. If the spread between the certain payoff Θ^* and the risky one Θ^{**} is small, then an operator is hardly willing to gamble, choosing C^H.
The other way round for p: the higher the probability of the opponent to be an H-type, the lower the threshold.

Fix values for the payoffs Θ^{**}, Θ^* and Θ and define $p^c \equiv \frac{\Theta^*-\Theta}{\Theta^{**}-\Theta}$. Whenever $p = p^c$, respectively $p < p^c$, then $x_i = 1$ with $i = 1, 2$, respectively $x_i \in [0, 1]$, cannot be the optimal choice because $\hat{x}$ as a probability can take at most value 1. In such a situation, an H-type does not expect to gain his isolated maximum but instead to be underbidden. He prefers to ensure Θ^* by choice of C^L.

The game is symmetric. For all probability distributions $\{p, 1-p\}$ with $p < p^c$, $\{x_1 = 0, x_2 = 0\}$ is the only Bayesian equilibrium. In this equilibrium, both choose C^L irrespective of their type.

This can be seen in figure 3 in which the reaction functions are drawn. They run along the axes because $x_i(x_j) = 0$ is the best response of i to whatever value of x_j. The equilibrium is in the origin and highlighted by a circle. For all distributions with

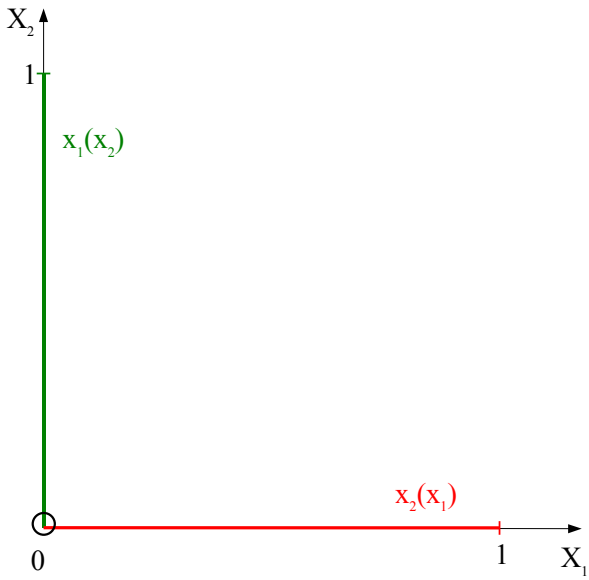

Figure 3: Reaction functions when H-types are unlikely

$p > p^c$, there are three equilibria, that of before $\{x_1 = 0, x_2 = 0\}$, one in mixed strategies $\{x_1 = \frac{\Theta^* - \Theta}{p(\Theta^{**} - \Theta)}, x_2 = \frac{\Theta^* - \Theta}{p(\Theta^{**} - \Theta)}\}$ and finally $\{x_1 = 1, x_2 = 1\}$. They are shown in the reaction correspondence graph of figure 4, again highlighted by circles.

For $\hat{x} < x^c(p) \equiv \frac{\Theta^* - \Theta}{p(\Theta^{**} - \Theta)}$ the correspondences run on the axes because then $x_i = 0$ is the best response. At $(\hat{x} = x^c)$, indifference between cost levels occurs, illustrated by the dotted line. To every $\hat{x}$ beyond that value $x_i = 1$ is the best response.

$x^c(p)$ shifts to the origin the higher is p, enlarging the intervall of $\hat{x}$ over which $x_i = 1$ is optimal. That is the graphical illustration of the fact that an H-type is the more willing to actually play C^H, the higher is the probability that the opponent is H, too. In figure 3, p was so low that $x^c(p)$ lied beyond the value 1.

Pair $\{C^H, C^H\}$ occurs with probability $p^2 x_1 x_2$, which is simply the product of the marginal probabilities for C^H. Without yardstick competition, each operator would choose his most prefered cost level C^k, and $\{C^H, C^H\}$ would be the result with prob-

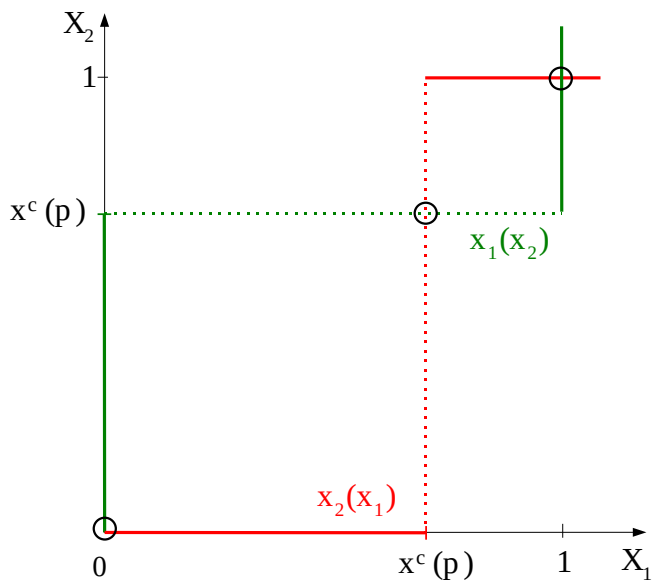

Figure 4: Reaction functions when H-types are sufficiently likely

ability $p^2 \geq p^2 x_1 x_2$. So, it can be stated that yardstick makes this result -least prefered by the regulator- almost as or even less probable.

If only one operator chose C^L, then, by yardstick competition, the resulting caps in lag two would only recover C^L. This would also be the case if both chose C^L. Thus, the probability for this result -most prefered by the regulator- is simply $1 - p^2 x_1 x_2$, the counterprobability to result $\{C^H, C^H\}$. Without yardstick competition, that probability were $(1-p)^2$ and by that less.

With yardstick competition, the result most prefered by the regulator is more, that least prefered at most as probable than without. So, the simple game studied implies, too, that yardstick competition is capable of mitigating the ratchet effect.

3 Conclusion

In setting of two subsequent lags, the paper studied the occurence of the ratchet effect and the mitigating influence that yardstick competition has on it. This is relevant because it allows to check the implications of the regulation that is planned by the Bundesnetzagentur to be imposed on German power distribution networks. The two-lag setting allowed to study these implications without having to rely on any assumption about the actual length of time of its implementation.

The result of the model was, that the ratchet effect will occur under two reasonable assumptions. First, network operators feature high preference for future profits. Second, the regulator wants to extract almost all of the operator's rent.

Moreover, by a decision- and a game-theoretic examination, it was shown to be true that the ratchet effect can be mitigated by applying yardstick competition if network operators feature different characteristics, that are relevant for their choice of costs. An operator will reduce his costs as a precaution when he is faced with the threat of becoming underbidden by the cost choice of another one, resulting in an unwanted cut of his revenue cap.

The whole reasoning relied on the assumptions of network-fee inelastic demand for wheeling and constant returns to scale in network provision.
By the first assumption, all an operator can influence is the level of costs that he incurs for the provision of his network. Because of this, increasing an operator's efficiency is equivalent to reduction of his costs, so that it was possible to restrict attention to cost reduction. The latter assumption is empirically borne (see Bundesnetzagentur, 2006, 178(847)) and, thus, lacks direct theoretical justification. If it failed, revenue caps of different networks could never be made at least proportional to each other before the beginning of a lag. Consequently, the comparative statics result would not be sufficient to describe different characteristics of network operators because comparative statics are done "'ceteris paribus"'.

Further interesting work could be to examine the ratchet effect in cases that feature different duration of subsequent lags. I suppose that the result will depend crucially on the concrete specification of preferences.

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