Incomplete Contracting and Price–Cap Regulation

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Abstract

This paper deals with price–cap regulation of a monopolistic distribution grid which sells a license to some retailer. The sale of the license is a long–term incomplete contract. Both the grid and the licensee engage in relationship–specific investments before the value and costs of the license are known. The resulting hold–up problem can be solved by the regulator by choosing a particular $RPI - X$ regulation and forbidding renegotiation of the contract. The optimal price–cap regulation of the incomplete contract looks quite different from the usual $RPI - X$ case which stipulates a functional relationship between a particular cost or productivity realization and a regulatory instrument X, without any dependence on further exogenous variables. In this paper, however, the Xs depend on many more exogenous variables, be it further realizations of costs and values, be it optimal probabilities of these realizations. If the regulator is only interested in efficient trade and efficient relationship–specific investments, moreover, the no–trade price, as chosen by grid and licensee, directly determines the values of the Xs.

1 Introduction

1.1 Long–Term License Contracting

Baumol's sustainability discussion[1] has succeeded in destroying the myth of the 'natural–monopoly' properties of many public utilities. In cases of telecommunication, electricity, gas or water, it has become clear that only the distribution grid exhibits those economies of scale which actually lead to a natural–monopoly position, whereas this does not hold for production and for retail sale. Consequently, public utilities may be disintegrated either vertically or horizontally, with possible privatization and market entry in those parts where no natural–monopoly properties prevail. There are many good examples for this kind of disintegration. Best–known are the split–ups of the telecommunication industries in several countries. Another case in question is the British electricity industry which has been disintegrated in the course of privatization. In the case of British Gas the possibilities of disintegration have been intensively discussed quite recently.

If a distribution grid and the retailers are separated, then the government will regulate the grid because otherwise it would exploit its monopolistic position in order to maximize its profits. In this paper we deal with a price–cap regulation which refers to the sale of a license from a distribution grid to some retailer. The license gives the licensee the right to procure particular goods like electricity or gas or water from the grid and to supply these goods to private customers, be it firms or individuals. We assume that such a license is given for a legally predetermined time, say, five or ten years.

For notational clearness in the following the terms 'buyer' and 'seller' will always be used with reference to the license: the distribution grid will always be called the seller (of the

[1] The best–known reference is Baumol–Panzar–Willig (1982).

license), the retailer will always be called the buyer (namely, of the license). The sale of the license will synonymously be called 'trade.'

If the license were sold to a single retailer, both grid and licensee would make monopoly profits (the well–known double–marginalization problem). In this paper, however, we assume that identical licenses are sold to many licensees, whence there is price competition in the retail market, the licensees do not make too high profits and, therefore, need not be regulated. The grid, however, will make a monopoly profit unless it is regulated. The present paper deals with one of the many identical contracts between the grid and one particular retailer.

The sale of a license is a long–term contract. The potential buyer calculates his valuation of the license which results from his future sales to his customers. The seller calculates how much it will cost to provide those goods which the buyer will purchase in order to supply them to his customers. Prior to the decision on the sale of the license, however, both buyer and seller have the opportunity to invest in value–enhancing and in cost–reducing activities. These investments are relationship-specific. Consider a distribution grid and one particular potential licensee who both have invested in the mutual future. If the would–be–buyer does not become the grid's licensee, then the technological innovations he has made for his future retailing are practically worthless. We assume that the same holds for the seller. This means that we restrict the analysis to specific investments of the grid which refer to this particular potential licensee, that is, they cannot be used if this potential buyer does not become the licensee and afterward some other firm buys the license. The latter assumption is not too far–fetched: it may well be that a potential licensee wants to implement a new technology which requires particular adjustments of the distribution grid. If the final licensee does not implement this technology, then the seller's adjustment investments are really worthless.

The relationship between seller and buyer of the license is a case of Williamson's (1985) hold-up setting. The amount of specific investments is non–verifiable before a court and so are the value and the costs of the license and therefore ex-ante only an incomplete contract can be written. Since the division of the net surplus from trade cannot be fixed ex–ante, the parties cannot be prevented from rewriting the contract when value and cost of the license finally become clear. However, at this date the costs of the relationship-specific investments are sunk and do not influence the final division of the net surplus. Anticipating this, both seller and buyer will underinvest in relationship–specific assets. In a formal analysis, Hart–Moore (1988) corroborated this general underinvestment result[2] under the assumption of at-will contracts: trade occurs if and only if the seller is willing to supply the good *and* the buyer is willing to take delivery of it. Hart–Moore's general underinvestment result holds if a profit–maximizing grid and a profit–maximizing licensee write an incomplete at–will contract on the granting of the license.[3]

[2]Hart–Moore (1988, proposition 4).

[3]For alternatives to at–will–contracting see, for instance, Chung (1991), Aghion–Dewatripont–Rey (1994).

As we shall see, the underinvestment problem can be overcome if the regulatory law makes the following provision: when the veil of uncertainty about benefits and costs has been lifted, *the court enforces the original contract if at least one contractor wants to trade at the initial terms of this contract.* This implies that grid and licensee can withdraw from the contract in mutual agreement (and will do so if otherwise both would suffer from a deficit). It also implies that the initially contracted regulated prices must not be renegotiated. For the final decision on trade there are four possible cases, depending on the relationship of the actual benefit and costs on the one side and on the contracted prices on the other side:

(i) at the contracted prices both parties would run a deficit. No party wants to trade. No license is granted.

(ii) at the contracted prices both parties attain a profit. Both parties want to trade and the license is granted accordingly.

(iii) the interplay of benefit, costs and prices implies a profit of the seller, but a deficit of the buyer. Here the seller is given the option to insist on trade. The license is granted, and the buyer has to suffer a deficit.

(iv) this is just the reverse of (iii): the seller faces a deficit, the buyer a profit. The buyer is given the option to insist on trade. The license is granted, the seller has to suffer a deficit.

Nöldeke–Schmidt (1995) have shown that the hold–up problem can be solved by an incomplete contract which gives the seller the option to insist on trade. In contrast to their paper, in our setting either the seller or the buyer *endogenously* may be given the option to insist on trade at the originally contracted prices.

1.2 Price–Cap Regulation

Unconstrained profit maximization by the grid would lead to a high price at which the license is sold to the retailer. This high price would, in turn, increase the retail prices which are demanded by the licensee. Since we deal with a public utility, this is undesired by the government. Accordingly, a regulator enters the stage.

In recent years, the imposition of price caps has become a predominant way of regulation of public utilities. The best-known example of such a price–cap constraint is the $RPI - X$ regulation: an average price increase of some bundle of the firm's products must not exceed the increase of the retail price index minus an exogenously fixed constant X. This form of price regulation has been proposed by Littlechild (1983) and is the basis of the regulation of, *inter alia*, British Telecom, British Gas, and the UK public electricity suppliers (i.e. the twelve area companies responsible for the local distribution of electricity).

In this paper we assume that a regulator imposes a price–cap constraint on the sale of the license.[4] If p is the price of the license, then it is appropriate to write the price–cap constraint as follows:

$$0 < p \leq \alpha - \beta X. \tag{1}$$

This price–cap constraint exhibits the same properties as an $RPI - X$ constraint. In fact, price–cap regulation of a single good, which is contained in the basket of the retail–price index, leads to an $RPI - X$ constraint which looks like the simple constraint (1).[5] It corresponds to the $RPI - X$ idea to assume that the coefficients α and β are exogenously given to the regulator whose only instrument is X.[6]

As usual in $RPI - X$ regulation, most crucial is the determination of X. Usually, it is postulated that X should be chosen according to the firm's potential for price reduction: X should be high if productivity increases lead to considerable cost reductions which could be passed over from the firm to the customers. X should be low if productivity increases only slowly in some industry. In the British regulated utilities, for example, British Telecom always has had a high X, whereas British Gas has had a lower X. Accordingly, in this paper we will assume that the regulator chooses a high X if the regulated distribution grid realizes low costs and vice versa. In doing so, the regulator will attempt to give correct incentives for the attainment of relationship–specific investments. In other words, the regulator wants to solve the hold–up problem and to induce the grid and the retailer to write a contract which leads to the first best.

We assume that X is set for the whole term of validity of the contract, that is, for the whole life of the license. Hence, a revision of X is not considered in this paper. Moreover, we assume that it is legally forbidden to give another license to the same licensee after expiration of the present contract. This assumption is made to avoid the many compli-

[4] As already mentioned above, there is no regulation of the retail prices which the final customers have to face. The licensee as retailer operates in a competitive market: competition among retailers prevents exploitation of the consumers.

[5] As in Bös (1991, 164), let us start from the $RPI - X$ constraint

$$\frac{p}{p^b} - 1 \leq \frac{\sum_i \zeta_i^b \phi_i + z^b p}{\sum_i \zeta_i^b \phi_i^b + z^b p^b} - 1 - X,$$

where ϕ_i^b and ζ_i^b are base–period prices and quantities of all goods in the retail–price index except the regulated good whose base–period price and quantity are denoted by p^b and z^b. Solving explicitly for p, we obtain inequality (1) where α and β are positive constants which depend on exogenous variables only, namely on prices and quantities of the base period and on present prices of the other goods. We have

$$\alpha = \left[\frac{\sum_i \zeta_i^b \phi_i}{\sum_i \zeta_i^b \phi_i^b + z^b p^b}\right] \Bigg/ \left[\frac{1}{p^b} - \frac{z^b}{\sum_i \zeta_i^b \phi_i^b + z^b p^b}\right],$$

$$\beta = 1 \Big/ \left[\frac{1}{p^b} - \frac{z^b}{\sum_i \zeta_i^b \phi_i^b + z^b p^b}\right].$$

[6] Compare the transformation in the preceding footnote.

cations which arise in dynamic $RPI - X$ models.[7]

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The paper is organized as follows. In section 2 we present the model: we begin with the particular information and verifiability assumptions, then present the stages of the game and finally describe a benchmark optimum. Since we deal with a multistage game, it has to be solved by backward induction. Accordingly, we start at the end of the game and in section 3 deal with the efficiency of the decision on the sale of the license *(ex–post efficiency)*. Only then do we step back and in section 4 concentrate on the efficiency in the choice of relationship–specific investments *(ex–ante efficiency)*. Afterward, still in section 4, we consider the initial contract: do there exist initial prices which induce both ex-ante and ex-post efficiency ? Unfortunately, these first–best initial prices may induce a huge profit of the seller which is undesired by the regulator. Is it possible to attain the first best *and* extract the seller's rents ? The answer is affirmative as is shown in section 5. Finally, in section 6 we show that it is impossible to achieve the first best if the prohibition of renegotiation is relaxed. This final section justifies the exclusion of renegotiation which the regulator imposes on the grid's and the licensee's contract. A short conclusion follows.

2 The Model

2.1 Information and Verifiability Assumptions

The information and verifiability assumptions refer

- to the relationship–specific investments a and e of the grid and the licensee, respectively,
- to the licensee's valuation of the license v and to the grid's costs c which it will have to incur to provide those goods which the licensee will purchase in order to supply them to his customers. Abbreviating, we will call c the 'costs of the license'.

In this paper we assume that there are only two possible realizations of the value of the license, $v \in \{\overline{v}, \underline{v}\}$, and similarly for the costs of the license, $c \in \{\overline{c}, \underline{c}\}$. We assume that $\overline{v} > \overline{c} > \underline{v} > \underline{c}$, that is, we have overlapping supports of values and costs.[8]

At any point of time *grid and licensee* are symmetrically informed: both contractors observe both relationship–specific investments as soon as they are made; both share the same priors with respect to the expected value and costs of the license; and at the same time they learn to know the actual value and costs.[9] Both contractors are risk–neutral:

[7] For a brief overview see Bös (1994, 286–288).

[8] This is the interesting case to investigate. If the supports do not overlap, the investment decisions do not influence the probability of trade, and in this case the first best can always be attained. See, for instance, Hart–Moore (1988, proposition 3, case (1)).

[9] It is the state of the art to assume that both contractors have the same information. Extending this type of model to asymmetric information is a top priority on the research agenda.

if they are only incompletely informed, they maximize expected profits.

Let us next turn to the *regulator*. Just as the two contractors, ex ante the regulator knows the supports of value and costs, and their distribution, that is, the probabilities that a particular v or c will be drawn by nature. Ex post, he is able to observe the cost realization, which enables him to set X depending on this realization. The regulator does not need information about the actual value of the relationship–specific investment, nor about the actual value of v as drawn by nature.

Finally, even if the contractors observe a particular variable, it may be impossible to verify this variable before a *court* and, consequently, the contract cannot be conditioned on this variable. In this paper we assume that a, e, c and v are non–verifiable. This is fully in line with the usual literature on incomplete contracts. The relationship–specific investments a, e can be considered as effort levels whose non–verifiability is a standard assumption. The valuation of the license can be influenced by subjective value judgments which are non–verifiable, for instance with respect to the discounting of future benefits. The same discounting problem plus possible accounting tricks are usually taken as a justification for the assumption of non–verifiable costs.[10] – What, then, is verifiable before a court? First, the events 'trade' or 'no trade', that is, whether the license is granted or not. Second, the payments of the buyer. Third, the value of X which the regulator has chosen. Assumptions one and two are standard. The third verifiability assumption, however, is a particularity of the present paper. It is due to the $RPI - X$ regulation and allows to write an initial contract which decisively deviates from the usual types of fixed–price contracts. More details on this will be given in the next subsection.

2.2 The Stages of the Game

0	1	2	3	4	5
regulator announces regulatory policy	contract signed $(p_0, \underline{p}_1, \overline{p}_1)$	specific investments (a, e)	nature draws v and c, regulator sets X	license granted (if desired by at least one party)	dispute?

Figure 1

There are three players in the game, the distribution grid as the seller of the license, a retailer as the buyer and the regulatory agency. Buyer and seller are going to write a long–term contract which governs their complete future relationship. This contract, however, has to abide by particular prescriptions of the regulator. The time structure of the game is illustrated by Figure 1.

[10] For a model of contracting in case of verifiable costs see Bös (1996).

At *date 0* the regulator announces the regulatory policy. This policy refers to a particular type of contract which is determined by the verifiability assumptions. The contract can only be conditioned on the ex–post verifiable events 'trade' or 'no trade', on the ex–post verifiable payment of the buyer, and on the regulator's choice of X. Therefore, the contract stipulates a separate trade price for each observation of X plus a separate price for the no-trade case. We denote the trade prices by p_1 and the no–trade price by p_0. The trade prices follow the price–cap formula as specified in (1).[11] At date 0 the regulator announces that he will fix a particular low value of X if ex post he observes the high–cost realization $\overline{c}$. This implies a relatively higher trade price,

$$\overline{p}_1 = \alpha - \beta \underline{X}. \tag{2}$$

In contrast, if he observes the low–cost realization $\underline{c}$, he will choose a particular high value of X, leading to a relatively lower trade price,

$$\underline{p}_1 = \alpha - \beta \overline{X}. \tag{3}$$

At *date 1* the grid and the licensee write an incomplete contract with the following content:

$$q = 1 \quad \Leftrightarrow \quad \text{licensee pays} \quad \begin{cases} \overline{p}_1 & \text{if} \quad c = \overline{c} \\ \underline{p}_1 & \text{if} \quad c = \underline{c}, \end{cases} \tag{4}$$

$$q = 0 \quad \Leftrightarrow \quad \text{licensee pays } p_0. \tag{5}$$

The quantity to be traded is either $q = 1$ or $q = 0$, since we deal with the 'trade' of one indivisible unit of a good, namely the license. In the contract, the no–trade price p_0 is set by the contractors, given the announced prices $\overline{p}_1$ and $\underline{p}_1$ which the regulator credibly commits to set at a later stage. The concrete choice of p_0 depends on the bargaining powers of seller and buyer in the contract negotiations. It is possible to leave the decision on p_0 to the contractors if the regulator is only interested in efficiency and not in the distribution of rents between seller and buyer. The reason is the following. It is well–known from models of this type that efficiency depends only on the difference between trade and no–trade price. (The absolute values of these prices determine the distribution of rents.) Since it is only the price differences which count, it is possible to choose optimal price differences whatever the value of p_0. In other words, the regulator announces an $\underline{X}$ and an $\overline{X}$ which formally depend on $\widehat{p_0}$ in such a way that the efficiency–inducing price differences $\overline{p}_1 - p_0$ and $\underline{p}_1 - p_0$ result. – The regulatory policy of section 5, which cares about the distribution of rents, will not accept the contractors' freely chosen no–trade price. This leads to an explicit regulation of the no–trade price in addition to the regulation of $\underline{X}$ and $\overline{X}$.

The regulatory law stipulates that no price must be renegotiated and that the contract is enforced by the court if at least one party insists.

The contract is only signed by the two parties if their participation constraints hold. This implies that there is a minimal p_0 which is required to meet the grid's participation constraint; in fact, it is that p_0 which induces a zero expected profit of the grid. The retailer,

[11] Since the seller is a profit maximizer, the price–cap constraints can always be written as equations.

whose prices are not regulated, faces a competitive market which allows him to set prices so as to achieve an expected profit which is high enough to ensure his participation in the game, but low enough to be considered as 'fair' by the government.

At *date 2*, both licensee and grid engage in relationship–specific investments. The licensee invests an amount of a at costs $\mu(a)$; the grid invests e at costs $\psi(e)$. Both investment–cost functions are convex in the arguments. The investment (effort) levels are commonly observed by the two parties, but are not verifiable before a court.

At *date 3* nature draws the actual realizations of value and costs of the license. This draw of nature depends on the relationship–specific investments: higher investments of the buyer increase the probability of nature's drawing the high benefit $\overline{v}$,

$$\pi(a) = \text{prob}\{v = \overline{v} \mid a\}; \qquad \pi' > 0,\ \pi'' \leq 0. \tag{6}$$

Similarly, higher investments of the seller increase the probability of nature's drawing the low costs $\underline{c}$,

$$\rho(e) = \text{prob}\{c = \underline{c} \mid e\}; \qquad \rho' > 0;\ \rho'' \leq 0. \tag{7}$$

At the same date 3, moreover, the regulator observes the cost realizations and sets the X variables of the price–cap formula, anticipating all further stages of the game.

Finally, at *date 4*, the license is granted (if at least one party insists) and the corresponding payments are provided. The game ends unless there are disputes on delivery and on payments, which would be decided at *date 5*. However, in the subgame–perfect equilibrium no such disputes occur.

2.3 The Objectives of the Players

The grid as the seller of the license is a profit maximizer whose objective is as follows:

$$U^S = \begin{cases} E(p - c \mid q = 1) + p_0 - \psi(e) & \text{at dates } 1, 2, \\ q(p - c) + p_0 & \text{at date } 4, \end{cases} \tag{8}$$

where $p := p_1 - p_0$. The expectation operator E refers to the states of the world, that is, to nature's draw of benefit and costs, conditional on the parties' specific investments. Considering the expectation operator implies that the subgame–perfect continuation of the game is internalized. At date 4 the investment costs are sunk and $\psi(e)$ is no longer included in the seller's objective function. Recall that the seller's participation constraint requires U^S to be nonnegative at date 1.

The retailer as the buyer of the license also is a profit maximizer. His objective function equals:

$$U^B = \begin{cases} E(v - p \mid q = 1) - p_0 - \mu(a) & \text{at dates } 1, 2, \\ q(v - p) - p_0 & \text{at date } 4. \end{cases} \tag{9}$$

The investment costs are no longer relevant when the buyer maximizes U^B at date 4.

Finally, the regulator is a welfare maximizer. Let us first assume that he is only interested in efficiency. He uses his instruments to induce grid and licensee to choose efficient trade and efficient relationship–specific investments. He does not care about the profits which accrue to the grid. In section 5 this assumption will be given up. For the moment, however, we consider a regulator who is solely efficiency–oriented and, accordingly, has the following objective function:

$$U^R = \begin{cases} E(v - c \mid q = 1) - \mu(a) - \psi(e) & \text{at date 0,} \\ q(v - c) & \text{at date 3.} \end{cases} \tag{10}$$

To maximize this objective function, at date 0 the regulator announces how he will set $\underline{X}$ and $\overline{X}$ in dependence on the no–trade price $\widehat{p_0}$ which the contractors will set. This credible announcement is chosen so as to induce efficient relationship–specific investments of the contractors and efficient trade, which maximizes the first part of the objective function. At date 3, the regulator actually sets $\underline{X}$ and $\overline{X}$ according to the announced rule. This regulatory policy is selected so as to induce particular trade decisions of seller and buyer in such a way that they choose q efficiently thereby maximizing the second part of the regulator's objective function. As we shall see, there exist regulatory policies which induce both efficient trade and efficient relationship–specific investments. Hence, at date 3 the regulator has no incentive to deviate from the regulatory policy which he announced at date 0. Moreover, since any of these policies maximizes welfare, the regulator has no incentive to any collusion with either seller or buyer.

2.4 First–Best Benchmark

For later reference, we derive a *first–best benchmark*. This requires two notions of efficiency. First, *ex–post efficiency* refers to the decisions made at date 4. Recall that we deal with the sale of one unit of an indivisible good, the license. Hence, $q = 1$ and $q = 0$ denote 'trade' and 'no trade,' respectively. Efficiency requires that trade takes place if and only if this increases welfare, that is:

$$q^* = 1 \Leftrightarrow v \geq c, \tag{11}$$

$$q^* = 0 \Leftrightarrow v < c, \tag{12}$$

where v and c are the actual realizations of value and costs, respectively. Since $\overline{v} > \overline{c} > \underline{v} > \underline{c}$, trade is always efficient unless low value and high costs of the license occur simultaneously.

Second, *ex–ante efficiency* refers to the welfare–optimal choice of the relationship–specific investments a and e at date 2:

$$\begin{aligned} (a^*, e^*) \in \operatorname{argmax}_{a,e} W &= E(v - c \mid q = 1) - \mu(a) - \psi(e) \\ &= \pi(a)(1 - \rho(e))[\overline{v} - \overline{c}] + \pi(a)\rho(e)[\overline{v} - \underline{c}] \\ &\quad + (1 - \pi(a))\rho(e)[\underline{v} - \underline{c}] - \mu(a) - \psi(e). \end{aligned} \tag{13}$$

We obtain the following first–order conditions which are necessary and sufficient for a unique and interior solution $a^*, e^* > 0$:[12]

$$W_a = 0: \quad \pi'[\overline{v} - \overline{c}(1-\rho) - \rho\underline{v})] = \mu', \tag{14}$$

$$W_e = 0: \quad \rho'[\underline{v}(1-\pi) + \pi\overline{c} - \underline{c}] = \psi'. \tag{15}$$

The resulting efforts a^* and e^* will be used as benchmarks to be compared with the actual investments resulting from the two contractors' Nash equilibrium at stage 2 of the game.

Finally, let us define a *first–best result.* It is attained if in the subgame–perfect equilibrium the price differences $\overline{p}$ and $\underline{p}$, chosen at date 1, induce both ex–ante and ex–post efficiency.

3 Ex–post Efficiency

In this section we consider the contractors' decision on the granting of the license. At this stage of the game, date 4, value v and costs c are known to the contractors. They would like to trade if

$$p > c \qquad \text{(seller's condition)}, \tag{16}$$

$$v > p \qquad \text{(buyer's condition)}. \tag{17}$$

In formulating these conditions, we assume that (re)contracting is infinitesimally costly. Hence, the seller must be paid a price which at least infinitesimally exceeds his costs and the buyer must enjoy a benefit which at least infinitesimally exceeds the price he has to pay for the license. Therefore the seller's and the buyer's conditions for trade are defined as *strict* inequalities.[13]

To achieve the first best, the regulatory law does not allow all possible voluntary trade decisions. In particular, it does not allow renegotiation of the initially contracted prices. The regulatory law states that the license is to be awarded at the initial prices if at least one party insists on the fulfillment of the contract. Hence, we have to distinguish the following four cases:

[12] Formally, the existence of an interior solution is ensured since expected welfare as defined in (13) is concave in both of its arguments and the Inada conditions are assumed to be fulfilled. The maximum is unique if one assumes $\mid W_{ii} \mid > \mid W_{ij} \mid, i, j \in \{a, e\}$.

[13] This assumption differs from the usual assumption of the incomplete–contract literature with renegotiation where any actor opts for trade if he is indifferent between not trading under the old contract and trading under the new one. There are two main reasons why this paper deviates from the usual assumption: (i) It seems more natural to think of the seller's and buyer's conditions in terms of *in*equalities. At least my students always have problems with those indifferent actors who always act just as the modelbuilder wants them to act in order to achieve some optimum. (ii) As we shall see in equation (22), the optimal regulation requires $\overline{p} = \overline{c}$. Therefore, according to the usual assumption of the literature, if nature simultaneously draws $\underline{v}$ and $\overline{c}$, in our regulatory setting the buyer would insist on buying, hence the court would enforce the contract, which would violate ex–post efficiency.

(i) $c > v$.
Given our specification, this situation arises if nature simultaneously draws $\underline{v}$ and $\bar{c}$. The regulator must make sure that in this situation no party wants to trade. Since $\bar{c}$ triggers the regulated price $\bar{p}$, this can be achieved by choosing a price difference $\bar{c} \geq \bar{p} \geq \underline{v}$. This price difference ensures that neither the seller nor the buyer wants to trade. (Compare the inequalities (16) and (17) above.)

(ii) $v > c \geq p$.
At this low price difference, the seller does not want to sell, whereas the buyer wants to buy. Any upward renegotiation of the price difference to a value between c and v would induce voluntary trade of the two parties. However, this is forbidden by the regulatory law. It is directly evident that regulated trade prices must not be increased by renegotiation. However, one could think of a downward renegotiation of p_0 to increase the price difference to a value $p^T = c+\varepsilon$, where ε is the infinitesimally small amount of costs of (re)contracting. However, this renegotiation must also be forbidden by the regulatory law if the first best is to be attained. The reason is the following. If the initial p_0 is replaced with a renegotiated $p_0^T = p_1 - c - \varepsilon < p_0$, the seller would always prefer not to trade since $p_0 > p_0^T$. However, this withdrawal of the seller would violate the ex–post efficiency, because $v > c$ so that trade would be efficient. Hence, the regulatory law forces the seller to sell in a situation where he does not want to. This gives an option to the buyer: if he insists on being awarded the license, the court will enforce the contract.

(iii) $v > p > c$.
At this price difference, both players are willing to trade at the initially contracted price difference. No renegotiation occurs.

(iv) $p \geq v > c$.
At this high price difference, the buyer does not want to buy, whereas the seller of course wants to sell. Downward renegotiation of the price difference to a value between v and c would induce voluntary trade of the two parties. However, such a downward renegotiation would imply too low investment incentives for the seller. Hence, the regulatory law forbids such a downward renegotiation and forces the licensee to accept the license at the initial trade price although he does not want to. This gives an option to the seller: if he insists on granting the license, the court will enforce the contract.

Hence, ex-post efficiency will always be achieved if the regulatory law states that the license is to be granted if at least one party insists on the fulfillment of the initial contract and if the regulated price difference $\bar{p} \in [\underline{v}, \bar{c}]$.

4 Ex–ante Efficiency

4.1 The Nash Equilibrium at Date 2

We now examine the Nash equilibrium at date 2 where both grid and licensee choose their relationship–specific investments for given initial price differences $\underline{p}$ and $\overline{p}$.

Grid and licensee maximize their objective functions, where, to avoid messy notation, we have suppressed the explicit functional dependencies of $\pi(a), \mu(a), \rho(e)$ and $\psi(e)$:

$$\begin{aligned} U^B &= \pi(1-\rho)(\overline{v}-\overline{p}) + \pi\rho(\overline{v}-\underline{p}) + (1-\pi)\rho(\underline{v}-\underline{p}) - p_0 - \mu, \quad (18) \\ U^S &= \pi(1-\rho)(\overline{p}-\overline{c}) + \pi\rho(\underline{p}-\underline{c}) + (1-\pi)\rho(\underline{p}-\underline{c}) + p_0 - \psi. \quad (19) \end{aligned}$$

Differentiation with respect to the investments yields the following marginal conditions:

$$\pi'[\overline{v} - \rho\underline{v} - (1-\rho)\overline{p}] = \mu', \quad (20)$$

$$\rho'[\pi\overline{c} - \underline{c} + \underline{p} - \pi\overline{p}] = \psi'. \quad (21)$$

These first–order conditions yield unique positive Nash–equilibrium efforts.[14] Since they result from profit maximization, these Nash efforts are not necessarily welfare–optimal. However, according to the above marginal conditions the Nash efforts depend on the initial price differences $\underline{p}$ and $\overline{p}$. Hence we can ask the following question: are there initial price differences which induce Nash efforts which are just equal to the welfare–optimal efforts ?

To begin our search for these optimal price differences, let us first look at the *buyer's investments*. Equality of the buyer's Nash effort and his welfare–optimal effort requires the simultaneous validity of the Nash equation (20) and the benchmark equation (14), under the assumption that the seller's effort is welfare optimal. This requires:[15]

$$\overline{c} = \overline{p}. \quad (22)$$

This price difference guarantees that there will be no trade if nature draws $\underline{v}$ and $\overline{c}$, since neither seller nor buyer is interested in enforcing the contract in this case. However, if nature draws $\overline{v}$ and $\overline{c}$, the buyer wants to trade. Hence, if the seller rejected his request, the buyer would approach the court which would enforce the contract. Since this is known to the seller, he will grant the license right away.

Let us next turn to the *seller's investments*. To achieve equality of the seller's Nash effort and his welfare–optimal effort we require the simultaneous validity of the Nash equation (21) and the benchmark equation (15). We obtain the following condition:

$$\underline{v}(1-\pi) = \underline{p} - \pi\overline{p}. \quad (23)$$

[14] The assumptions which ensure this result are the same as in the benchmark case of welfare–optimal efforts, see footnote 12 above.

[15] Compare the buyer's Nash effort a^N and his welfare–optimal effort a^*. Since $\mu(a)$ is monotonically increasing in a, a necessary and sufficient condition for $a^N = a^*$ is a tuple of price differences $\{\underline{p}, \overline{p}\}$ which equates the left–hand sides of (20) and (14). This equalization leads to condition (22). As mentioned in the text this condition is evaluated at $e = e^*$.

The regulatory policy which induces optimal seller's investments must be compatible with the regulatory policy which induces optimal buyer's investments, that is, $\overline{p} = \overline{c}$. Substituting this price difference into (23), we obtain:[16]

$$\underline{p} = (1 - \pi(a^*))\underline{v} + \pi(a^*)\overline{c}. \tag{24}$$

This price difference guarantees that there always will be trade if nature draws $\underline{c}$. There are two possible cases: (i) nature draws $\underline{v}$ and $\underline{c}$. Then the seller wants to grant the license, the buyer would prefer not to become licensee. However, the seller can unilaterally ensure enforcement of the contract; (ii) nature draws $\overline{v}$ and $\underline{c}$. Then both parties want to trade.

Hence, we have found two price differences which induce efficient relationship–specific investments of both buyer and seller, and hence achieve ex–ante efficiency. Since ex–post efficiency is always attained, we are now in the position to state the following lemma.

LEMMA. *There is a unique pair of price differences which induces the first best:*

$$\begin{aligned}\overline{p} &= \overline{c},\\ \underline{p} &= (1 - \pi(a^*))\underline{v} + \pi(a^*)\overline{c}.\end{aligned}$$

Regulation has to make sure that the grid and the licensee write a contract with $\overline{p}$ and $\underline{p}$ according to the above lemma. This is achieved by an adequate choice of the regulatory instruments $\overline{X}$ and $\underline{X}$. For this purpose, the efficiency–oriented regulator accepts as given the no–trade price $\widehat{p_0}$ which at date 1 is contracted by the grid and the licensee. The result is presented in the following proposition 1.[17]

PROPOSITION 1. *The efficiency–oriented regulator chooses the following $RPI - X$ regulation:*

$$\begin{aligned}\underline{X} &= (1/\beta)(\alpha - \widehat{p_0} - \overline{c}) && \text{if } c = \overline{c},\\ \overline{X} &= (1/\beta)\{\alpha - \widehat{p_0} - [(1 - \pi(a^*))\underline{v} + \pi(a^*)\overline{c}]\} && \text{if } c = \underline{c}.\end{aligned}$$

As usual with $RPI - X$ regulation, the regulatory choice of a particular X is triggered by the nature's draw of a particular cost realization. However, here the similarity ends. The usual regulation stipulates a functional relationship between a particular cost or productivity realization and a regulatory instrument X. This traditional regulation would require $\underline{X} = f(\overline{c})$ and $\overline{X} = f(\underline{c})$ without any dependence on further exogenous variables. Here, however, both Xs functionally depend on the high–cost realization. This holds even for $\overline{X}$ which we would have expected to depend on $\underline{c}$ and only on $\underline{c}$. Moreover, $\overline{X}$ depends on the low–value realization and on the optimal probability for the high–cost realization. Finally, the no–trade price $\widehat{p_0}$ directly determines the price–cap regulation. – The complexity of the incomplete–contract approach to regulation, therefore, reveals that the usual $RPI - X$ regulation is far too narrow an approach.

[16] Note that $\pi(a^*)$ is a constant value which is verifiable before a court: a^* can directly be calculated from the benchmark welfare optimum without any knowledge of the buyer's actual choice of relationship–specific investments.

[17] Recall the regulated–price formulas (2) and (3). Consider, for instance $\overline{p}_1 = \overline{p} - \widehat{p_o} = \alpha - \beta\underline{X}$. Now substitute $\overline{p} = \overline{c}$ and solve for $\underline{X}$. The term for $\overline{X}$ is found analogously.

5 Extracting the Seller's Rents

Until now the regulation was only used to induce efficient trade and efficient relationship–specific investments. The regulator did not care about the seller's rents. Accordingly, when setting the Xs he took as given the no–trade price which grid and licensee had contracted at date 1. In the present section we give up this assumption. This is very plausible since regulation of public utilities typically aims at extracting monopolistic rents.

Let us assume that the regulator has a lexicographic preference ordering, first valueing efficiency as presented in the preceding sections, second valueing the extraction of seller's rents. This implies that the regulator will never compromise between efficiency and seller's rents. If he can achieve efficiency, but at the price of high seller's rents he will not be willing to accept inefficiently low relationship–specific investments only because this allows to reduce the seller's rents. However, if efficiency can be achieved at either a high or a low or a zero rent of the seller, then the regulator will choose the policy which implies the zero rent.

Since any price is paid by the buyer to the seller, one could argue that low prices which extract seller's rents are only a redistribution of rents from the seller to the buyer whence the consumers do not gain from such a regulatory policy. Recall, however, that we assume that the retailer faces competition. This was the reason why the regulator abstained from explicit regulation of the retailer. By the same argument, extracting seller's rents does not imply redistribution of the rents to the buyer. Rather, he will have to reduce his own retail prices if the price of the license is reduced. If the no–trade case occurs, a lower p_0, chosen to extract seller's rents, reduces the deficit of the buyer, which we assume to be acceptable from the welfare point of view.

5.1 Extracting the Seller's Ex–post Rents

To extract all ex–post rents of the seller, the regulator waits until date 3 and then sets

$$\begin{aligned} p_1 &= \overline{p}_1 = \overline{c} && \text{if nature has drawn } \overline{c}, \\ p_1 &= \underline{p}_1 = \underline{c} && \text{if nature has drawn } \underline{c}, \\ p_0 &= 0. && \end{aligned} \tag{25}$$

This policy of rent extraction can either directly be announced at date 0 (honest policy) or can be applied at date 3 in spite of any other initially announced prices (cheating policy). The cheating behavior will be anticipated by the two contractors unless there is some mechanism which makes sure that the regulator will not fully extract the seller's rents at date 3. (For details see the following subsection.)

Ex–post efficiency is attained by setting prices according to (25). Given this regulatory policy, the seller is never interested in trade since p never exceeds c as the seller's condition for trade would require. If nature simultaneously draws $\{\underline{v}, \overline{c}\}$, we have $\overline{p} = \overline{c} > \underline{v}$ and the buyer also is not interested in trade. No trade results, which is the efficient solution of this particular case. If nature draws any other combination of benefits and costs, the buyer always wants to trade and his claim is enforceable before the court. This completes the proof of ex–post efficiency, since it is always efficient to trade in these cases. Note that we have assumed that the seller is willing to sign the contract if his expected profit is zero. Hence, he will do so although he knows that all his profits will be extracted by regulation.

Unfortunately, however, ex–ante efficiency is not attained. The regulatory policy (25) does not consider the relationship–specific investments, since they are sunk at this point of time. Unfortunately, by extracting the seller's ex–post rents the regulator is caught in the hold–up trap. The seller anticipates the extraction of ex–post rents. Hence, when it comes to the decision on relationship–specific investments, he has no incentive whatsoever to invest.[18] If the regulator were to extract only parts of the ex–post rents, the hold–up problem would arise as well: any extraction of ex–post rents leads to underinvestment. Of course, the extent of underinvestment is more relevant the higher the percentage of rents which is extracted.

5.2 Extracting the Seller's Ex–ante Rents

In the preceding subsection we have shown that it is impossible to extract the seller's ex–post rents and still attain the first best. Hence, according to his first–ranked interest in efficiency, at date 0 the regulator would prefer to commit to ignore any seller's rents after the initial contract has been signed. Unfortunately, however, such a commitment of the regulator is not credible. The costs $\underline{c}$ and $\overline{c}$ are not verifiable before a court. Therefore, it can never be verified whether the regulator has extracted the seller's ex–post rents, that is, has chosen $\underline{p}_1 = \underline{c}$. The regulator will always get away with such a regulation, and accordingly he will always extract the ex–post rents, whatever his announcement at some previous stage of the game. This is the end of the story as long as we assume that the regulator has a lexicographic preference ordering with respect to (a) efficiency and (b) extraction of the seller's rents. The only way out of the dilemma is a split–up of governmental functions:[19] at date 0, the ministry of economics, which has the above–mentioned lexicographic preferences, announces the regulatory policy and explicitly commits itself not to intervene in the further regulatory policy. Only then does the regulator take over. This regulator must be purely efficiency oriented, whence he has no incentive to extract the seller's ex–post rents.

Given this institutional setting, which regulatory policy should the ministry of economics announce at date 0 ? The ministry knows that the non–extraction of ex–post rents is credibly secured whence the seller will not fear for his rents and invest efficiently. However, if efficiency is secured, the ministry's second–ranked interest comes to the fore: it

[18] The seller's objective function (19) reduces to $p_0 - \psi(e)$ and the maximization over e leads to a marginal condition $\psi' = 0$ which implies $e = 0$.

[19] For other settings where the attainment of the first best requires a split–up of governmental functions see Tirole (1994) and Bös–Lülfesmann (1996b).

will extract the ex–ante rents of the seller, that is, it will write a contract where at date 0 the expected profit U^S is equated to zero. Of course, this is only done by the ministry if it does not violate efficiency. Hence, we have to answer the following question: is it possible to extract the ex–ante rents of the seller and still achieve the first best ?

Equating the ex–ante profit U^S to zero, we obtain the following condition for p_0:

$$p_0 = \psi - \rho\mathcal{P}, \tag{26}$$

where $\mathcal{P} = (1-\pi)\underline{v} + \pi\overline{c} - \underline{c}$.

The extraction of the seller's ex–ante rents, therefore, requires the explicit regulation of p_0, in addition to the regulation of $\overline{p}_1$ and $\underline{p}_1$. Since regulation of p_0 does not require any knowledge of the actual realizations of benefit and costs, and since renegotiation of p_0 is forbidden, the ministry can directly *set* the price p_0 at date 0. Note that in (26) the term $\rho\mathcal{P}$ is always positive and, therefore, the regulated no–trade price is lower than the relationship–specific investment costs ψ. Hence, the innovation stage causes a deficit for the seller. In extreme cases, p_0 may even be negative.[20]

The regulated no–trade price replaces the contracted price $\widehat{p_0}$ which the purely efficiency–oriented regulator took into account in the preceding sections. Accordingly, the optimal values of the Xs do no longer depend on $\widehat{p_0}$ as in Proposition 1. Now take, for example, the optimal high–cost price $\overline{p} = \overline{c}$ and recall that $\overline{p} = \alpha - \beta\underline{X} - p_0$. Substitute for p_0 from equation (26) and solve for $\underline{X}$. An analogous procedure holds for $\overline{X}$. We obtain the following result:

$$\begin{aligned} \underline{X} &= (1/\beta)(\alpha - \psi + \rho\mathcal{P} - \overline{c}) && \text{if } c = \overline{c}, && (27)\\ \overline{X} &= (1/\beta)[\alpha - \psi - (1-\rho)\mathcal{P} - \underline{c}] && \text{if } c = \underline{c}. && (28) \end{aligned}$$

Note that the Xs now only depend on variables which are either directly drawn by nature, like $\underline{c}, \overline{c}, \underline{v}$ or which can directly be calculated from the benchmark welfare optimum without any knowledge of the buyer's or seller's actual choice of relationship–specific investments, like $\psi(e^*), \rho(e^*)$ and $\pi(a^*)$.[21]

Once again it is interesting to note that the regulatory choice of a particular X is triggered by the nature's draw of a particular c, but that the equilibrium value of any X depends on both $\overline{c}, \underline{c}$ and on $\underline{v}$. A comparative–static analysis on the basis of (27) and (28) shows that the equilibrium values of any X are reduced if either the low or the high cost increases,

$$\frac{\partial X}{\partial \overline{c}} < 0, \quad \frac{\partial X}{\partial \underline{c}} < 0; \qquad X \in \{\underline{X}, \overline{X}\}. \tag{29}$$

In contrast, changes in the value of $\underline{v}$ have an opposing effect on the Xs,

$$\frac{\partial \underline{X}}{\partial \underline{v}} > 0, \quad \frac{\partial \overline{X}}{\partial \underline{v}} < 0. \tag{30}$$

[20] For a similar effect in public procurement see Bös–Lülfesmann (1996a).

[21] To avoid notational clumsiness these values have been abbreviated in (27) and (28).

We have now succeeded in finding a unique regulatory policy which induces the first best. The content of this policy may be summarized in the following Proposition 2.

PROPOSITION 2. *If the seller's ex–ante rents are fully extracted by the ministry, the first best is achieved by setting the no–trade price p_0 and the values of the Xs in the RPI – X formula in the following way:*

$$\begin{aligned} p_0 &= \psi - \rho\mathcal{P}, && \\ \underline{X} &= (1/\beta)(\alpha - \psi + \rho\mathcal{P} - \overline{c}) && \text{if } c = \overline{c}, \\ \overline{X} &= (1/\beta)[\alpha - \psi - (1-\rho)\mathcal{P} - \underline{c}] && \text{if } c = \underline{c}, \end{aligned}$$

where $\mathcal{P} = (1-\pi)\underline{v} + \pi\overline{c} - \underline{c}$.

6 Relaxing the Prohibition of Renegotiation

It is disturbing that the regulatory law has to forbid any kind of renegotiation of the initially contracted prices if the first best is to be achieved. This section investigates whether this prohibition of renegotiation can be relaxed. For this purpose let us assume that only upward renegotiation of p_1 is forbidden by the regulatory law. Otherwise, trade is a voluntary decision of both actors; no side has an option to buy or sell if the other side is unwilling; no side can be blamed for a possible breach of the contract; between dates 3 and 4 of our time schedule (figure 1) the initial contract can be rescinded and replaced by a new one. We denote by p^T the realized price difference, that is, either the initially contracted price difference or a modified price difference resulting from renegotiations. Once again, we assume that (re)contracting is infinitesimally costly whence the actors want to trade if $p^T > c$ and $v > p^T$.

The decision on trade or no trade is as follows:

(i) if $c > v$, there is no trade because the voluntary trade decision requires $p^T > c$ *and* $v > p^T$ and these two conditions cannot hold simultaneously if $c > v$.

(ii) if $v > c \geq p$, the seller does not want to sell, whereas the buyer wants to buy. Unfortunately, in this case it is impossible to relax the prohibition of renegotiation. Any upward renegotiation of p_1 is incompatible with regulation, and any downward renegotiation of p_0 would induce the seller to prefer no trade to trade which would violate the ex–post efficiency. Hence, the regulatory law will enforce trade at the initially contracted prices.

(iii) if $v > p > c$, there is trade at the initially contracted price difference. No renegotiation occurs.

(iv) if $p \geq v > c$, the buyer does not want to buy, whereas the seller wants to sell. Here the prohibition of renegotiation can be relaxed, because downward renegotiation of

p_1 is well compatible with the regulatory principles. Hence, renegotiation is not forbidden and the seller offers a lower price p_1^T. Let us assume that $p^T = v + \varepsilon$.[22]

Application of the above rules (i) to (iv) ensures the achievement of *ex–post efficiency.*

For explanatory clearness let us describe in some more detail the price difference p^T. For this purpose we distinguish three cases A,B,C, corresponding to those value–cost combinations which induce trade. We denote the final price differences in these cases by p^A, p^B and p^C (which are all special cases of p^T). The detailed presentation of all of these price differences is given in Table 1.

	$v > c \geq p$	$v > p > c$	$p \geq v > c$
	no renegotiation	no renegotiation	downward renegotiation
A: $\overline{v}, \overline{c}$	$p^A = \overline{p}_1 - p_0$	$p^A = \overline{p}_1 - p_0$	$p^A = \overline{v} + \varepsilon$
B: $\overline{v}, \underline{c}$	$p^B = \underline{p}_1 - p_0$	$p^B = \underline{p}_1 - p_0$	$p^B = \overline{v} + \varepsilon$
C: $\underline{v}, \underline{c}$	$p^C = \underline{p}_1 - p_0$	$p^C = \underline{p}_1 - p_0$	$p^C = \underline{v} + \varepsilon$

Table 1: Final Price Differences

For the achievement of *ex–ante efficiency* we proceed as in the main part of the paper. However, we now have to distinguish between p^A, p^B and p^C. To induce efficient *buyer's investments* requires the simultaneous validity of the respective Nash equation and the benchmark equation (14), under the assumption that the seller's effort is welfare optimal. We obtain:

$$\overline{c} = p^A + \frac{\rho}{(1-\rho)}(p^B - p^C). \tag{31}$$

However, the seller will only agree to trade if $p^A > \overline{c}$.[23] Hence, the above equation requires $p^B < p^C$. But this is an impossible requirement as can be seen from Table 1. Unfortunately, therefore, we have to conclude that the first best is not achieved any longer if the prohibition of renegotiation is relaxed.

7 Conclusion

Regulation in this paper is used for a twofold purpose. On the one hand, the regulation is used to solve the hold–up problem which typically arises in case of relationship–specific

[22] We apply the Hart–Moore (1988) renegotiation game which endogenously gives full bargaining power to that party which is willing to trade under the initial prices. In our case (iv) it is the seller who has this bargaining power.

[23] If the seller would agree to trade if $p^A \geq \overline{c}$, the equation (31) could be made valid by price differences $p^A = \overline{c}, p^B = p^C$. However, it can be shown that these price differences do not induce efficient relationship–specific investments of the seller.

investments whose costs are sunk when the final decision on trade is taken. On the other hand, consumer exploitation is avoided: the price at which a monopolistic grid sells a license is held low and this low license price induces low retail prices to be paid by the consumers.

It is shown in this paper that $RPI - X$ regulation fails to achieve the first best if the agents are allowed to trade voluntarily and to renegotiate the contract after learning the actual benefit and costs of the license. This difficulty can be overcome if the regulatory law forbids renegotiation of the contracted prices: when the veil of uncertainty about benefits and costs has been lifted, the court enforces the original contract if at least one contractor wants to trade.

The complexity of the incomplete–contract approach to regulation reveals that the usual $RPI - X$ regulation is far too narrow an approach. This usual $RPI - X$ regulation stipulates a functional relationship between a particular cost or productivity realization and a regulatory instrument X, which would require $\underline{X} = f(\overline{c})$ and $\overline{X} = f(\underline{c})$ without any dependence on further exogenous variables. In our approach, however, both Xs depend on many more exogenous variables, be it further realizations of costs and values, be it optimal probabilities of these realizations. If the regulator is only interested in efficient trade and efficient relationship–specific investments, moreover, the no–trade price directly determines the price–cap regulation.

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