Price and Quality Regulation in the Water Industry The Need for Coordination

Georg Meran
Deutsches Institut für Wirtschaftsforschung, 14195 Berlin, Germany
gmeran@diw.de

Ulrich Schwalbe
Department of Economics, University of Hohenheim, 70593 Stuttgart, Germany
schwalbe@uni-hohenheim.de

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This paper analyzes different regulatory regimes for the European water industry. It is shown that the regulation of environmental standards and the price regulation of water providers or waste water facilities cannot be separated. In the case of franchise bidding and yardstick competition the strong competitive elements within these mechanisms lead to prices that are too low and hence to a water consumption for drinking water as well as waste water that is inefficiently high. To induce economic efficiency and to guarantee that an environmental target is met, requires an integrated regulation approach. The price regulation mechanism must include an environmental price which, in turn, can only be fixed if the regulation authority can anticipate total emissions as a result of both regulatory instruments.

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1 Introduction

In the last few years, the pressure on European states to implement the European Commission's Water Directive[1] has been rising steadily. Especially the German water sector (drinking water industry, waste water treatment) still exhibits many deficiencies that are due to the very specific nature of the distribution of responsibilities of the local water management. Water supply and waste water treatment are mainly run by municipal institutions, i.e. either public enterprises or firms of mixed ownership (private public partnership). The municipal jurisdictions have developed over time and do not correspond to the natural geography of watersheds. Germany lacks an integrated watershed management as it has been defined by the European Commission. Article 3 states[2] that *"Member states shall identify the in-*

[1] See European Commission [9].
[2] European Commission [9].

dividual river basins lying within their national authority and, for the purpose of the Directive, shall assign them to individual river basin districts." Moreover, *Member state(s) shall ensure the appropriate administrative arrangements, including the identification of the appropriate authority for the applications of the rules ... "*.

This paper deals with the problems of how this call for an integrated management approach can be implemented. Various institutional settings are conceivable. There are two strands of modern institutional approaches, the Anglo–Saxon way and the "French" alternative.[3] Whereas the English approach is characterized by a privatized and re–regulated water industry, the French way shares the typical features of a franchise bidding system. Here, municipalities auction water service rights (water supply and waste water treatment) that are valid for a certain period of time. The discussion about the various merits of either approach is mainly centered on its economic performance. It is interesting that scientists and professionals alike seem to be more concerned about the efficiency properties of these institutional settings, whereas political institutions focus on what has been called the "recovery of costs for water services"[4].

The question is whether the environmental and economic regulation should be coordinated, and if so, how. It seems that the need for coordination has not been recognized until now. This is surprising since there exists a well established branch of literature coping with the optimal design of new regulatory institutions to monitor the performance of privatized industries[5]. The main focus is on the degree of coordination (or, in the extreme, even merger) necessary to efficiently regulate a local monopolist. The need for coordination stems from different objectives on the part of the various regulatory authorities, or else from asymmetric information between the regulator (called the principal) and the regulated institution (called the agent). In what follows, we take up this question and analyze how much coordination between environmental and economic regulation is needed for either of the stylized regulatory traditions (the English and the French policy). Section 2 sets out the framework of an integrated water management according to the European approach. Section 3 presents a microeconomic model that comprises both an economic and an environmental sector to be regulated. To keep the model simple we confine our analysis to the sewerage sector. Various results show that coordination is required even in a world of symmetric information. Almost all regulatory mechanisms put into practice[6] need some modification to assure an efficient allocation of economic and environmental resources. Nevertheless, the French approach of auctioning service rights (section 4) and the English policy of yardstick competition (section 5) do better than the traditional approach of relating prices to average costs as practised in Germany (section 6).

[3]See e.g. Byatt [5] and Roche and Johannés [18].

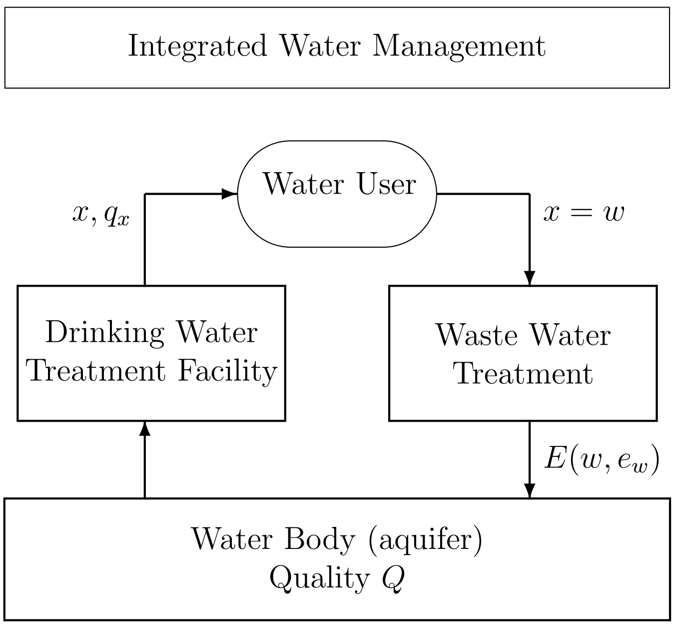
[4]See Article 9 of the EU–Directive.

[5]For a survey see Estache and Martimort [8].

[6]In this paper we do not deal with optimal mechanisms as developed in the more advanced literature. See e.g. Martimort [13] or the recent overview of Armstrong and Sappington [1].

2 Integrated water management: the resource based approach

Let us start with the European Directive of Water. Article 1 defines the purpose of this Directive. Inter alia it should[7] *"promote sustainable water use based on long–term protection of available water resources"*. Hence, for environmental economists a resource based approach is required to define the task of an integrated water management. By its very nature, the concept of sustainability refers to a dynamically stable cycle of water supply and wastewater discharges[8]. The following scheme (**??**) displays the main features of this cycle. Users demand potable water x of a certain quality q_x. Due to the law of mass conservation,[9] water will be discharged to a waste water treatment plant. The black water $w = x$ is purified, leaving e_w pollutants per unit[10]. The processed waste water is returned to the water body. The effects of the purified waste water on the aquifer is captured by $a(n)$ (over)simplified stream–quality model. The change[11] of water quality Q depends upon the quality of the aquifer itself and upon the volume and the quality of the waste water.



Here the function $E(w, e_w)$ denotes the discharge function. The task of an integrated water management approach is to maximize total social welfare of the people living in the the respective watershed. Following the common approach adopted by resource economists, the objective function will be a variant of discounted utility over an

[7] See European water Directive [9].

[8] See for example the water cycle as depicted in a well known book on the economics of water resources by Spulber and Sabbaghi [21].

[9] We disregard leakage and evaporation.

[10] We confine the analysis to one type of pollutant.

[11] Time derivatives are denoted by a dot.

infinite time horizon. To avoid an extended discussion about the suitability of this approach[12], and also for the sake of simplicity, we confine our analysis to a static model that captures the characteristics in a steady state[13]. The objective function might look like this:

$$W(\cdot) = \int_0^x p(v)dv - C(x, q_x, Q, c) - K(w, e_w, k) - R(c) - P(k) \tag{1}$$

Here the function $K(w, e_w, k)$ denotes the costs of waste water treatment. In addition, we have introduced the efficiency variables c and k that reduce operating costs $C(\cdot)$ and $K(\cdot)$ respectively. $R(c)$ and $P(k)$ are the respective fixed costs associated with these measures given any level of efficiency c. These costs are assumed to vary with respect to the parameters c and k in the following way:

$$R'(c) < 0, R''(c) > 0 \tag{2}$$

and

$$P'(k) < 0, P''(p) > 0. \tag{3}$$

The costs will decrease at an increasing rate.
The stream–quality interaction is described by an absorbtion function

$$\dot{Q} = H(Q) - E(w, e_w). \tag{4}$$

The quality of the aquifer evolves according to this differential equation where $H(\cdot)$ is logistical and the discharge function E is assumed to be

$$E = we_w. \tag{5}$$

If the watershed is in an ecological equilibrium the sustainability condition

$$\dot{Q} \Rightarrow H(\bar{Q}) = E(w, q_w) \tag{6}$$

applies.
We skip the task of optimizing (1) and characterizing the optimal allocation with regard to quantities and qualities. Instead, we follow a more institutional approach and try to analyze what kind of regulatory mechanisms can serve as an institutional design to meet the provisions of the EU Water Directive. We want to find out how regulatory authorities have to be coordinated. To keep the model as simple as possible, we confine the analysis to the sewerage system. All our results can be extended to the whole economic–ecological system displayed in figure (**??**).

[12] A discussion of the neoclassical approach with regard to intergenerational equity can be find in Perman, Ma and Common [16].

[13] To be precise, this is only true if the discount rate is very low or equal to zero.

3 Regulation of the waste–water treatment sector

Let us start with the inverse demand function

$$p(x), \quad p'(x) < 0 \tag{7}$$

which represents the water user as a waste water discharger[14].
The environmental regulation is introduced as a price–standard policy(PSA[15]), i.e total effluents per period are exogenously fixed by:

$$xe \leq \bar{E} = H(\bar{Q}), \tag{8}$$

where $\bar{Q}$ is an exogenous quality standard for the aquifer.
The black water[16] from users is purified, which leads to operating costs

$$C(x, e, c) = xC(c, e) \quad \text{with} \quad \frac{\partial C(\cdot)}{\partial c} > 0 \quad \text{and} \quad \frac{\partial C(\cdot)}{\partial e} < 0. \tag{9}$$

Notice that the cost function is assumed to be linear in x. The parameter $c > 0$ denotes the inefficiency of the purification process. Thus, the cost of purification increases in the amount of purified water and is higher, the more inefficient the technology is. The cost decreases in the amount of pollutants left in the water.
To compare the performance of various regulation schemes, we first have to define the optimal allocation. The social welfare function is given by

$$\int_0^x p(v)dv - xC(c, e) - R(c) \tag{10}$$

The social welfare function is maximized under the constraint that $E - ex \geq 0$. The first best allocation $\{x^*, c^*, e^*\}$ derived from this program can be characterized by the first order conditions

$$p(x) - C(\cdot) - \lambda e = 0, \tag{11}$$

$$-\frac{\partial C(\cdot)}{\partial c}x - R'(c) = 0, \tag{12}$$

$$-\frac{\partial C(\cdot)}{\partial e}x - \lambda x = 0. \tag{13}$$

The first order conditions prescribe to set the marginal rate of substitution between the quantity of purified water and the amount of pollutants left in the water equal to the rate of substitution between on a iso–emission line.[17]:
In what follows, we analyze various types of regulatory mechanisms. We begin with the French system of auctioning service rights known as franchise bidding. We then turn to the English yardstick competition and, finally, we look at the German cost related price regulation.

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[14]Notice that due to the law of mass conservation $x = w$.

[15]The price–standard approach has been introduced by Baumol and Oates as a policy alternative to the traditional welfare theoretical concept. See Baumol and Oates [4].

[16]We disregard the possibility of source control, i.e. the splitting of waste water into grey and black water as proposed in the water science. See for this interesting approach Otterpohl, Grottker and Lange [15].

[17]Despite the fact that the environmental constraint is not quasi–concave, the first order conditions characterize the global optimum due to the curvature properties of welfare function and the constraint.

4 Franchise bidding

To keep the model simple and to focus on the interaction between environmental and economic regulation, we assume that all competitors are identical. Relaxing this assumption leads into the theory of auctions and bidding mechanisms.[18]. Moreover, to assure a simple analytical framework, fixed costs are set to zero[19] Assuming that local authorities want to maximize consumer surplus, franchise bidding can be modelled as Bertrand–competition. This is because the maximum of consumer surplus is achieved by setting the lowest price p. The profit function facing competitor i is given by

$$G(p_i, e_i) = \begin{cases} px(p_i) - xC(c,e) & \text{if } p_i < p_j \forall\ j \neq i, \\ \dfrac{px(p_i)}{m} - \dfrac{xC(c,e)}{m} & \text{if } p_i = p_j \text{ and } p_k > p_i \forall\ k \neq i, j \\ 0 & \text{if } \exists\, p_j < p_i. \end{cases} \tag{14}$$

Here m denotes the number of firms j charging the same price as firm i. So $1/m$ denotes the probability that one of the firms making the lowest bid will be successful. She chooses $\{p_i, e_i\}$ such that profits are maximized and the environmental constraint $xe \leq \bar{E}$ is satisfied. This leads to the symmetric Bertrand–equilibrium

$$p^{fb} = C(\cdot) \quad \text{and} \quad x(p^{fb})e^{fb} = \bar{E}. \tag{15}$$

Result 1 *The franchise bidding procedure leads to a suboptimal allocation.*

The equilibrium is characterized by to much water being used ($x^{fb} > x^*$) and to much purification being carried out ($e^{fb} < e^*$). Of course, this results from the strong competition for the auctioned rights, which in turn leads to a low supply price and hence a high water consumption. In order to meet the environmental constraint, purification has to be intensified.

The bidding procedure can be supplemented by an environmental tax that might yield optimality. Now, the modified profit function for a franchise bidding procedure is:

$$G(p_i, e_i) = \begin{cases} px(p_i) - xC(c,e) - \tau x_i & \text{if } p_i < ep_j, \forall\ j \neq i \\ \dfrac{px(p_i)}{m} - \dfrac{xC(c,e)}{m} - \dfrac{\tau x_i}{m} & \text{if } p_i = p_j \\ & \text{and} \quad p_k > p_i \forall\ i, j \neq k \\ 0 & \text{if } \exists\ p_j > p_i. \end{cases} \tag{16}$$

The next result states that, if the waste water charge τ is set equal to the optimal shadow price of the command program (17), then optimality can be achieved.

[18] In the context of public procurement see Laffont and Tirole [12] where an optimal auction design is introduced for an indivisible project of a fixed size. In the present context, Hansen [10] seems to be more suitable. There, the qualtity supplied is endogenous. If the cost parameter c is uniformly distributed, one can show that a first price sealed bid action leads to the highest expected consumer surplus. See Wolfstetter [23, p.236,237].

[19] Of course, this is a heroic assumption which has to be discarded in a more thorough analysis of franchise contracting in the case of a natural monopoly.

Result 2 (supplemented franchise bidding) *The modified franchise bidding procedure leads to an optimal allocation.*

We proceed by pointing out the major problems of implementing environmental regulation into a franchise bidding system.

1. Charges have to be fixed in advance. Hence the usual trial and error process used by the PSA cannot be applied since bidding will not be repeated every period.

2. As only one firm finally is granted the franchise, a discharge permit market cannot be established after the bidding process. However, an ex ante market for discharge permits could be introduced. But this would give rise to incentive problems by the firms competing for the franchise as they would quote prices for the permits strategically. These problems of strategic behaviour can only be solved by using a truth revealing mechanism.

3. Regulating intensities (here: e) does not solve the problems (The German waste water charge rate depends on toxicity of the water discharged). In our model, fixing e leads to the same inefficient allocation as in the case of fixing the standard $\bar{E}$.

5 Yardstick regulation

We modify the model in order to make it compatible with the setting introduced by Shleifer[20] in order to to derive the yardstick competition mechanism. Let us begin with the command allocation as a reference case.[20]

$$\int_p^\infty x(v)dv + (px(p) - xC(c,e) - R(c) + \lambda[E - ex(p)]. \tag{17}$$

The first best allocation $\{x^*, c^*, e^*\}$ can be derived from the first order conditions (11), (12) and (13).

Result 3 *The standard yardstick competition is not optimal.*

PROOF: The standard yardstick competition formulas are:

$$\bar{p}_i = \frac{1}{N-1}\sum_{j\neq i} C(c_j, e_j), \tag{18}$$

$$\bar{R}_i = \frac{1}{N-1}\sum_{j\neq i} R_j, \tag{19}$$

where $\bar{R}_i$ indicates lump sum transfers covering fix costs.

[20] For simplicity, we omit indices i indicating demand and supply at different localities.

Inserting (18)and (19) into the profit function of a local monopoly i yields:

$$px(\bar{p}_i) - x(\bar{p}_i)C(c_i, e_i) - R(c_i) + \bar{R}_i. \tag{20}$$

Maximizing (20) with respect to $\{c_i, e_i\}$ under the constraint $E \leq e_i x(p_i)$ yields the first order conditions

$$\frac{\partial C(c_i, e_i)}{\partial c_i} x(\bar{p}_i) - R'(c_i) = 0, \tag{21}$$

$$\frac{\partial C(c_i, e_i)}{\partial e_i} x(\bar{p}_i) - \lambda x(\bar{p}_i) = 0. \tag{22}$$

In the basic model, Shleifer assumes symmetry (identical firms). Hence the Nash equilibrium $\{e^{yst}, c^{yst}\}$ is given by (21), (22) and the pricing rule (18). The respective quantity x^{yst} can be derived from the inverse demand function. Note that the equilibrium exhibits dominant strategies, which show the robustness of the mechanism. Comparing the optimal allocation conditions (**??**)–(**??**) with (21), (22) and the pricing rule (18), it is obvious that the allocations differ.
Again, we observe to much water consumption and too high a quality of purified waste water. The missallocation is due to a missing shadow price of the environmental constraint in the pricing rule (18). Hence, modifying this rule can remedy the failure. The following pricing rule will be called modified yardstick competition.

$$\bar{p}_i = \frac{1}{N-1} \sum_{j \neq i} C(c_i, e_i) + \tau, \tag{23}$$

$$\bar{R}_i = \frac{1}{N-1} \sum_{j \neq i} R_j, \tag{24}$$

where $\tau = \lambda^* e_i^*$, i.e. the tax rate is equal to the monetarized environmental impact multiplied by the emission intensity of output.
The modified yardstick competition works under different types of environmental policy. We can imagine assuring the local environmental constraint either by command and control or by price incentives (taxes or certificates). Let us assume that the local environmental standard is secured by a firm specific level standard $\bar{E}$ (i.e. command and control policy) . Under the MYC–rule the firm maximizes

$$(\bar{p}_i - \tau)x(\bar{p}_i) - x_i(\bar{p}_i)C(e_i, c_i) - R(c_i) + \bar{R}_i + \lambda[\bar{E} - e_i x(p_i)] \tag{25}$$

with respect to $\{e_i, c_i\}$.

Result 4 *The modified yardstick competition is optimal and meets the environmental standard.*

PROOF: Similar to (3).

Remark 1 *Optimal environmental regulation and price setting cannot be separated. Hence, integrated waste water management is required, which entails either a coordinated price and environmental policy of separated regulatory authorities or its merging.*

PROOF: The assertion follows from the interdependence of the optimal setting of x, c, e according to the command program (17). The setting of τ requires the knowledge of λ^* and e^*. This in turn requires the knowledge of how tight the environmental constraint is. Since the environmental constraint depends on the quantity $x(\bar{p}_i)$, the environmental authority has to know how the pricing rule of the price controlling authority works. Conversely, the price regulating authority has to observe emissions and has to know the optimal shadow price.

6 Cost related regulation

Up until now, we have analyzed regulation mechanisms with good efficiency performance. Cost related regulation schemes are known to be flawed by bad performance with respect to efficiency. For instance, cost–plus regulation may lead to waste expenses. Rate–of return regulation entails overcapitalization (the so called Averch–Johnson–effect).

This section deals with the question of how to include environmental quality standards in an otherwise inefficient price regulation framework. This question is of some importance since many countries in Europe still apply cost–related regulation schemes, especially in the water sector (e.g. Germany, Spain, Italy). We confine our analysis to the RoR–regulation which is prevalent in Germany. Here, prices of public water enterprizes are constrained by average costs which allow for calculated capital costs based on a statutory rate of return[21].

It is a well known result from the literature that a rate of return regulation leads to a missallocation of resources. In particular, we observe overcapitalization, which is dubbed the Averch–Johnson–effect[22] Here, the literature makes a distinction between the so called level effect and the overutilisation on the margin[23]. The level effect refers to a overproduction, i.e. as an output level beyond the optimal allocation (from a welfare point of view). The overcapitalization refers to an overutilisation of capital for producing a given output, i.e. an input allocation which is not cost minimizing.

It is more difficult to define an efficient environmental policy in an otherwise inefficient regulation setting. The main question is whether environmental policy should serve as an additional means to cure or at least mitigate the bad performance of the price regulation scheme. Some economists believe that environmental policy, e.g.

[21] To be more precise, in some German federal states annual capital costs are calculated by a capital–recovery factor utilizing the allowed rate of interest.

[22] See Averch and Johnson [2]. For a brief description see Crew and Kleindorfer [6]. A detailed analysis can be found in Bailey [3].

[23] See e.g. Sheshinski [19].

water quality policy, can be be utilized as an additional means of achieving overall efficiency[24].
In this paper we adhere to the opinion that water quality regulation and the corresponding policy tools should not serve as an additional means of mitigating missallocations due to distortive price regulations. The main reason for this policy approach is the belief that environmental policy will be overloaded by tasks which should be solved at the origin (principle of causation).
We are now going to work out in more detail how to shape environmental policy within an inefficient regulatory setting.
The monopolist's profits (local waste water treatment facility) under an environmental standard are defined by

$$G = p(x)x - xC(c, e) - R(c) + \lambda[\bar{E} - ex(p)]. \tag{26}$$

The Cournot–allocation $\{x^C, e^C, c^C\}$ solves the equations

$$p(x) + p'(x)x - C(\cdot) - \lambda e = 0, \tag{27}$$

$$\frac{\partial C(\cdot)}{\partial c}x - R'(c) = 0, \tag{28}$$

$$\frac{\partial C(\cdot)}{\partial e}x - \lambda x = 0. \tag{29}$$

Of course, the environmental constraint is also met.
Alternatively, we could have considered the case of a price based approach. In this case the price, e.g., a waste water charge, should be equal to the shadow price of $\bar{E}$, i.e. the charge rate τ should be set equal to λ^C.
The RoR–regulation places an upper bound on the monopolist's profits by relating the cash flow to the allowed interest payment on capital. Formally,

$$p(x)x - xC(c, e) \leq \rho R(c), \tag{30}$$

where $\rho > 1$ is a inflating factor which assures that the allowed rate of return is above the market interest rate. Inserting this constraint into the program (26) leads to the allocation of a RoR–regulated monopolist. This allocation is called constrained efficient.

Definition 1 *An allocation $\{x^{ceff}, e^{ceff}, c^{ceff}\}$ is called constrained efficient if it maximizes (26) subject to (30). It is characterized by the first order conditions*

$$(1 - \mu)[p(x) + p'(x)x - C(\cdot) - \lambda e = 0, \tag{31}$$

$$-(1 - \mu)\frac{\partial C(\cdot)}{\partial c}x + (\mu\rho - 1)R'(c) = 0, \tag{32}$$

$$(1 - \mu)\frac{\partial C(\cdot)}{\partial e}x - \lambda x = 0. \tag{33}$$

[24]This strand of reasoning is mainly prevalent in the literature on environmental policy in oligopolistic markets or in markets dominated by monopolies. See e.g. Requate [17].

Here, μ denotes the Lagrange multiplier associated with the rate of return constraint. Of course, this allocation is not optimal in the sense of program (10). Comparing this allocation to the optimal values, we find the regulated firm purifies too much waste water to too high a degree. Moreover, operating costs are too low and capital costs $R(c)$ are too high[25].

Usually, environmental authorities do not constrain total effluents into a local water body. Instead, they restrict the intensity of pollutants, say per cubic meter (the variable e). It is well known from the literature that this kind of regulation produces missallocations[26].

Therefore, we focus on policies that utilize prices, say an effluent charge on the total effluents discharged. From the price–standard approach we know that this kind of policy works quite well. The informational requirements are low, and enforcement problems are negligible. The local water authority must be able to observe the total of effluents released by the waste water treatment facility. In addition, she must be allowed to adjust the charge rate step by step so as to guarantee a certain effluent standard. Given this, this type of price driven regulation exhibits good efficiency properties.

Nevertheless, some degree of coordination between the price regulating schemes and environmental policy is needed. Otherwise, even constrained efficiency cannot be reached. This can be shown in the framework of our simple microeconomic model of a regulated waste water treatment facility. Let us introduce a waste water charge rate τ. Then total waste water charges are τxe. Further, let us assume that the charges collected may be partly or totally refunded on an lump sum base. Then, the total expenses of the regulated firms are

$$T = \tau ex - S, \tag{34}$$

where S indicates a lump sum repayment.

Since effluent charges cause expenses and thus reduce profits, they can be included into the profit constraint

$$p(x)x - xC(c, e) - \beta T \leq \rho R(c), \tag{35}$$

where $\beta \in \{0, 1\}$ is a factor indicating whether policy induced expenses are chargeable ($\beta = 1$) or not ($\beta = 0$). If one adheres to the pollutant pay principle, waste charges will be passed on to the customers, i.e. ($\beta = 1$).

Profits of the local waste water treatment plant are

$$G = p(x)x - xC(c, e) - R(c) - \tau[xe - S], \tag{36}$$

which will be maximized subject to the price/profit constraint (35). The first order conditions with respect to $\{x, c, e\}$ are

$$(1 - \mu)[p(x) + p'(x)x - C(\cdot)] - (1 - \mu\beta)\tau e = 0, \tag{37}$$

[25] These results can be derived by comparing the optimality conditions (11) – (13) and (31)-(33).

[26] Helfand [11] shows in a simple microeconomic production model how intensity regulation induces incentives to overproduce. More recently, see McKitrick [14].

$$-(1-\mu)\frac{\partial C(\cdot)}{\partial c}x + (\mu\rho - 1)R'(c) = 0, \tag{38}$$

$$(1-\mu)\frac{\partial C(\cdot)}{\partial e}x - \tau x(1-\mu\beta) = 0. \tag{39}$$

Result 5 (Efficient waste water charge rate) *The waste water charge rate replicating the constraint efficient allocation* $\{x^{ceff}, e^{ceff}, c^{ceff}\}$ *must be set according to the following rule:*

$$\tau^{PSA} = \frac{\lambda^{ceff}}{1-\mu\beta}. \tag{40}$$

If $\beta = 1$*, i.e. if the waste water charges can be passed on to consumers, then*

$$\tau^{PSA} > \lambda^{ceff}, \tag{41}$$

i.e. the charge rate must be set above the shadow price of the effluent constraint.

Proof: First, observe from (38) that an interior solution requires $\mu < 1$.
Inserting the constrained optimal allocation $\{x^{ceff}, e^{ceff}, c^{ceff}\}$ into (37) and (39), respectively, and comparing with (31) and (33) yields

$$\lambda^{ceff} e^{ceff} = \tau e^{ceff}(1-\mu\beta), \tag{42}$$

which proofs the assertion.
What are the conclusions from this result?

1. If the environmental authority sticks to a tax policy, then the efficient rate must be set above the shadow price of the environmental standard.

2. The efficient charge rate can be found by a trial and error process. Hence, the authorities need not know the efficient shadow price.

From a practical point of view, our result 5 is of little importance if only a local monopolist is under environmental regulation.
If the charge rate is set at a level such that the local environmental standard is met, then the tax–based environmental policy will be constrained efficient. However, this result does not extend to the case of a whole industry discharging effluents. Consider the case of a water body where many dischargers are located. Some of these are direct dischargers that introduce pollutants into the water. Examples are industrial dischargers or agricultural sources. An environmental authority sets a local effluent standard and allocates effluent rights according to the price standard approach. For instance, it has been proposed to allocate water rights by means of effluent trading[27] As a result of trading, an equilibrium permit price will be established the value of which is equal to the marginal abatement costs of each discharger. It is well known that the resulting allocation is efficient[28].

[27] A fully elaborated framework has been developed by EPA. See EPA [7]. Markets for water rights along a river are analyzed by Weber [22].
[28] See e.g. Baumol and Oates [4].

7 Discussion

This paper has examined the working of various regulation schemes adopted in the European water industry under quality provisions. Starting from a price–standard–approach we have shown that the regulation of environmental standards and the price regulation of water providers or waste water facilities cannot be separated. In the case of franchise bidding and yardstick competition the strong competitive elements within these mechanisms lead to low prices and hence high water consumption for drinking water as well as waste water. To meet the environmental standard, firms have to intensify water treatment. As a result, the model predicts too much water consumption and too much water purification. The inefficient allocation can be avoided if the regulation devices are modified. This requires adding a price for the environment that reflects the environmental constraint. The crucial policy implication is that economic and environmental regulation have to be considered simultaneously. To induce economic efficiency and to guarantee an environmental target requires an integrated regulation approach. The price regulation mechanism must include an environmental price which, in turn, can only be fixed if the regulation authority can anticipate total emissions as a result of both regulatory instruments. Since we cannot assume that the regulatory authorities have sufficient knowledge of the demand function, the cost functions and the emission function, the question remains how to fix the proper tax rate. Future research should take up this information problem and search for a solution. A first step to solve this problem is to use the well known trial–and–error process of the price–standard–approach to find the proper tax rate by a sequential procedure of adjusting the environmental price. But this might introduce a strategic dimension into the regulation process. If firms know the reaction function of the environmental authority they may exploit this knowledge strategically. As a result, the modified price regulation schemes proposed here might lead to an inefficient allocation.

Cost related price regulation rules play an important role within (continental) Europe. Hence, we also have analyzed their working in terms of quantity–quality–allocation despite of their well known inefficiency. To work out the specific inefficiency due to the separate regulation of prices and of environmental quality we have introduced the concept of constrained efficiency which takes the inefficiency due to the cost related regulation schemes as given. Then we show that a second best effluent charge must exceed the charge of the price–standard–approach. Here again, it is shown that a regulation approach separating price regulation and environmental regulation leads to additional inefficiencies.

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