REGULATING NATURAL MONOPOLIES: THE CASE OF DRINKING WATER IN FRANCE

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INTRODUCTION

The water industry is typically a network industry. However, this industry has special features because water of good quality is essential for the existence of human life. Matters of ethics and efficiency are therefore inextricably linked together and raise a number of fundamental, ethical, and practical questions for society.[1] In this paper, we look at how the topic of drinking water management relates to the traditional analysis of natural monopoly regulation and argue that regulating natural monopolies, which involve irreversible environmental and public health risks, changes the usual regulating schemes in such a way that risk coverage and insurance premiums must be incorporated in the analysis. We emphasize the essential nature of water and its quality because of their implications for human health and the environment. In this context, water and its quality engage the regulator's liability as well as that of the monopolist. We show that this complicates the case of no-risk regulation, where the objectives of regulation are limited to ensuring that water services are offered at a proper price and that the firms allowed to benefit from the monopoly are those that are the most efficient in using it.

The paper is organized as follows. In Section 2, we define the characteristics of drinking water management and the nature of the natural monopoly, and develop the role of the risk and uncertainty that face regulators and managers. In Section 3, we use the French case to illustrate the problem and present a methodology for solving it. Section 4 concludes.

REGULATION OF THE DRINKING WATER SECTOR

Drinking Water a Social and Specific Good: Public or Private?

Is water a public good? From an economic point of view, many of its characteristics would tend to put "water" in the private commodity category. Indeed, it can be infinitely divided, stored, privately owned, and sold on a market, etc. Hence, because of these features it may be considered as a private good. For instance, in many countries water is sold as a commodity by individuals, and the bottled-water industry is growing.[2] However, in most of the developed countries water resources are considered as a public good and governments reserve the right to establish institutions for allocating all water within their boundaries[3]. From a purely ethical standpoint, every person does have a right to fresh water access and no consumer may be excluded because of price. All this having been said, it appears that the jury is still out on the definitive verdict of whether water should be classed as a public or a private good. In the following paragraph, we use the concept of quality to help make the choice.

Consider the principle of equity in the right to life. This principle and the essential nature of water rules out discrimination, and consequently, the same quality of water should be available to everyone in a given geographical area. Hence, the public good characteristics of water are mainly associated with the necessity to keep drinking water as pure and accessible as possible. J.S. Mill made the case for water as a public good when he wrote:

> "*the case to which the water-supply of towns bears most analogy, are such as the making of roads and bridges, the paving, lighting, and cleansing of streets. The nearest analogy of all is the drainage of towns, with which the supply of water has a natural connection. Of all these operations it may reasonably be affirmed to be the duty of Government, not necessarily to perform them itself, but to ensure their being adequately performed. I do not say that it ought not to be lawful to build a house without proper drainage and proper water-supply; but assuredly every one who owns or builds a house in a town should have the means of effectual drainage and water-supply put in his power, at the smallest practicable expense* (J.S. Mill p.434)."

With this in mind, water appears to be a public good with private features in its distribution. These are the characteristics of a natural monopoly.

Drinking Water as a Natural Monopoly

Our definition of a natural monopoly is closely related to that of Baumol et al. (1977):

> *"By natural monopoly we mean an industry whose cost function is such that no combination of several firms can produce an industry output vector as cheap as it can be provided by a single supplier."*

Applied to water management, water utilities are monopolies not only because of the economic advantages related to scale economies but also because of the economic advantages related to technical considerations that prevent competition between several providers in a given area. The management of a pipe network, the related heavy investments, the supply and the treatment of water, and sometimes the sewage plants necessitate a monopoly. The monopoly is more a result of conditions related to the management and maintenance of a unique infrastructure of pipes and plant than it is with economies of scale. It is difficult to imagine competition in the management and maintenance of this infrastructure. This leads us to consider the irreversibility of the investments in the field of water supply.[4]

Regulating Natural Monopolies Under Risk

More than a century ago, John Stuart Mill observed that the

> *"water supply of London may be provided in three ways: by trading companies, as at present; by a functionary or a board of functionaries appointed by Government; or by some local or municipal authority (J.S. Mill (1851 p.433)."*

Since these early times, the debate has changed very little except that, nowadays, nobody would willingly empower a board of civil servants to manage a local public utility. Hence, the debate is not whether the water supply should be privately or publicly managed, but rather how to manage regulation efficiently.

The French system of water management is a case in point. The relevant regulatory level is essentially municipal, and three main types of water management are at work at the municipal level. The first type, called the "Régie Municipale," is a system of direct management involving the Mayor and its Council where the municipality is in charge of the whole management system (plants, pipe-network, etc.). The second type, a sort of "Super Régie Municipale," gathers the resources of several municipalities to form an association of communes. The third type is a delegation system whereby the municipality or the "Super Régie Municipale," allows a private firm to manage the allocation and the treatment of fresh water and sewage. In France, quantitatively, the delegation system is by far the most popular.

In a delegation contract, the municipality temporarily cedes its management powers to a private firm. The delegation can be total or partial, but it is always temporary and long term for a period of up to thirty years. Full privatization of the water supply, as in the United Kingdom for example, is prohibited. At the contract's maturity, control reverts to the municipality, which may choose to renew delegation with the existing firm or a competitor, or to assume direct management itself. Thus, the procedure appears competitive. However, because of several factors linked to the oligopolistic nature of the water management market in general and to the French institutional framework in particular, there is no effective competition and the delegated firms are able to extract excessive profits at the expense of the community of consumers.

When natural monopolies face environmental or health risks, as do drinking water utilities, the risks are more than simple uncertainty about sales levels and income losses. They involve the liability of the regulator for environmental and health damages and the necessity for him to incorporate them accurately in his strategy. Thus, it appears intuitively that these regulation rules should be different from those of the generally accepted natural monopoly theory where the stakes are limited to the levels of supply and demand. Hence, the very notion of regulation is changed, and coordination and incentives under risk become central concepts. Boyer and Robert (1997), for instance, estimate that the electricity industry should be regulated as a natural monopoly because of the important potential economies of scale present in the network activities. Where drinking water is concerned, the inefficiency is not related to foregone economies of scale, but rather to the risk of irreversible damage to both the environment and public health.

Incorporating Risk in the Regulation Scheme: The French Case

Efficient regulation means that from an economic and institutional standpoint rules are defined so that the outcome of the system is equivalent to the outcome of competition. Because space is lacking, these points will not be developed here but the important aspects of the discussion can be found in Boyer and Robert (1997), Waterson (1988), Laffont and Tirole (1993). Where the role of risk is concerned, two major issues are at work.[5] The first one relates to damage liability and the contractual relationship between principal and agent. The second relates to the appropriate pricing rule, given the risks associated with both income and damages. Because French law explicitly recognizes the role of damage liability, we use the French case to illustrate these points.

The Regulator and Damage Liability

The role of damage liability in the French system of water management can be summarized as follows: According to French law, the municipalities are in charge of water resource management, including protection of the water supply, river management, and pollution control. In this framework, the mayor is personally liable for any damage due to negligence on his part. The liability is civil, to the extent of all his worldly belongings, as well as criminal and is transferred to the municipality itself if damages exceed the total value of the mayor's net worth. Mayors have been prohibited by law from using the municipality to insure themselves against this particular risk. Furthermore, there is a high level of uncertainty about how negligence will be defined by the individual courts. All this puts the mayor in a precarious position. By delegating authority to a private firm, the mayor can eliminate his personal liability, which is transferred to the delegated firm. Given the uncertainty surrounding the traditional measure of protective cover, delegation has consequently become popular with mayors and municipalities as an effective instrument in eliminating their negligence liability. Herein lies the seed of a costly conflict of interest between the personal welfare of the mayor and the well being of the community. It is clear that the conflict of interest arises from the damage liability associated with managing the water supply.

Clark and Mondello (2000a) have shown that this problem can be analyzed in the context of insurance theory where the cost of the mayor's guarantee can be priced as the value of an insurance policy W

$$W(x(t)) = \left[\frac{fr}{(r-a)(r+r-a)} + \frac{l}{(r+r-a)}\right]x(t) \qquad (1)$$

where x represents the loss level in the case of a catastrophe due to negligence and follows geometric Brownian motion

$$dx(t) = a\,x(t)dt + s\,x(t)dz(t) \qquad (2)$$

r is the riskless rate, a is the rate of growth of the potential loss, s is its standard deviation, dz is a standard Wiener process with zero mean and variance equal to dt and l, f, r with $l < f$ are intensity parameters of Poisson processes representing respectively the arrival rate for losses at the low socially mandated precautionary level (low technical and quality standards), the arrival rate for losses at the high socially mandated precautionary level (high technical and quality standards), and the probability per unit of time of passing from the low to the high level.

The idea behind the precautionary levels is that with a given infrastructure and technology, lower minimum technical standards will lead to fewer accidents being judged by the courts as caused by negligence. Thus, $l < f$. The reason that passage from one level to another is modeled as a random process with r as the instantaneous probability of change is because there is no national standard setting board in France. Consequently, individual courts are free to decide for themselves what the minimum precautionary level (technical and quality standard) should be. As might be expected in the land of 50 million notoriously independent thinkers, the minimum precautionary level can and does vary from court to court.

Equation (1) measures the cost of the agency conflict between mayor and community as the value of an insurance policy that covers all losses due to negligence when there is a doubt about how negligence will be defined. The uncertainty about how negligence will be defined is embodied in the two socially mandated precautionary levels. Thus, equation (1) says that the value of the insurance policy covering a low risk that might become a high risk is equal to the present value of expected cash flows resulting from losses discounted at the riskless rate increased by a risk premium r, the probability that the change in riskiness will actually occur. Thus, it values the personal liability of the mayor when there is a possible change in the risk level. This is the price (agency cost) that the Community would have to pay to cover the mayor's risk as a means of eliminating the agency conflict and inducing him to make the water management choice that is in the best interest of the Community. When formulating a pricing policy, the regulator cannot ignore this cost.

The Formulation of an Optimal Pricing Policy When Income is Stochastic

In the formulation of an optimal pricing policy, it is important to know whether the contractual relationship between the firm and the regulator is reversible. The problem of delegation irreversibility is tied to economic rents and is a consequence of the public authorities negotiating disadvantage in the face of the cartelized water management firms. It can be described as follows. In a delegation contract, a municipality temporarily cedes its management powers to a private firm. In

France, the law allows partial or total delegation of water management, but not a full privatization of the water supply as in the United Kingdom. The contract is long term, it is determined by an auction, and it provides for the ongoing opportunity to renegotiate prices and terms. At the contract's maturity, the municipality retains control of the delegation allocation and may choose among competitors or even revoke delegation in favor of direct management. [6]

Changing this situation through legislation is not feasible in the foreseeable future since it would require a major overhaul of the French governance system with significant effects far outside the realm of water management. Furthermore, in spite of the municipalities' inherent disadvantage, this same system pushes them to opt increasingly for delegation. First of all, the technology of monitoring the safety of the existing pipe network is fully controlled by a de facto cartel of a small number of large, specialized companies that monopolize the market and limit the municipalities' access.[7] Secondly, the required competencies for water management have become more and more specific thereby making it difficult and costly for the municipalities to find and retain qualified personnel. Finally, and most importantly, because of a quirk in the French administrative organization there is the above mentioned problem of the mayor's personal liability in the case of damage when the court judges that the harm was caused by negligence. The result of all this is that once a municipality has opted for delegation, the decision is, for all practical purposes, irreversible. In the absence of reversibility, regulation and the formulation of an optimal pricing policy come to the fore.

Several pricing rules may be used as regulation tools. Among the more theoretically advanced, the most popular are Ramsey-Boiteux and the efficient component pricing rule (EPCR). Armstrong et al. (1994), (1995), (1996), (1998) analyze profit-maximizing nonlinear pricing by a firm that is subject to price cap regulation where they consider the two main forms of regulatory constraint: (1) a cap on the firm's average revenue, and (2) a constraint that the firm must continue to offer each consumer the option of buying at the uniform price. Optimal nonlinear price schedules in these regimes are shown to have simple characterizations that are related to the nonlinear tariffs that an unregulated monopolist would charge. These authors show that of the regulatory regimes, the firm prefers the average revenue constraint to the option constraint and likes uniform pricing least. Unfortunately, these theoretical approaches suffer from some informational difficulties summarized by Boyer and Robert (1997 p.13):

> *"They are very complex in realistic cases and they are open to manipulation, to regulatory capture and to predatory behavior because of this complexity and because of the fact that there is so much uncertainty or imprecision in the estimates of the basic parameters or basic variables you have to obtain and know to apply them and because of the fact that generically, the information structure on costs and demands is incomplete."*

Furthermore, they are not dynamic and they fail to incorporate compensation for the uncertainty (risk) surrounding the monopolist's income as well as the risk associated with damage liability, which for the French case, is the cost of the agency conflict.

These shortcomings can be overcome with the tools of stochastic calculus and the techniques developed in real option theory. To make the pricing problem dynamic we let the monopolist's income "*y*" vary stochastically through time in geometric Brownian motion

$$dy(t) = a_y y(t)dt + s_y y(t)dz_y(t) \tag{3}$$

where a_y represents the expected growth rate of income, s_y is the standard deviation of the growth rate, and dz_y is a standard Wiener process with zero mean and variance equal to dt.

The regulatory problem is to determine the cap price that includes the potential risk damages that are captured in equation (1). Clark and Mondello (forthcoming November 2000b) provide a solution when the potential risk damages are treated as an annual operating cost. To find the solution they ask the question, "At what level of income *y* would it be optimal for the municipality to revoke delegation and manage the drinking water supply itself?" To incorporate the potential damage liability, they let c represent operating costs, including the insurance premium for liability coverage. As we mentioned above, this liability is unlimited and in the case of negligence engages the personal responsibility for the mayor-municipality in the case of direct management and for the firm in the case of delegation. In the absence of market imperfections where both municipality and the firm have equal access to technology and expertise, the liability is the same for both. From equation (1) we know the value of the liability is equal to *W*. Since the liability is perpetual we calculate its operating cost as a perpetual annuity *l* in the formula $l/r = W$ or $l = rW$. Thus, the cost of the damage liability is subsummed in the cost side of the investment's cash flows. Finally, assume that within the output capacity of the investment operating costs are constant.[8]

The required risk adjusted rate of return on $y(t)$ can be found by applying the CAPM directly to $y(t)$.[9] The required rate of return will be given by

$$m = r + l\, s\, r_{x,m} \tag{4}$$

where r is the riskless rate of interest, l is the market price of risk, $r_{y,m}$ is the correlation coefficient of the percentage change in $y(t)$ with the market rate of return and $m > a$. Let $m - a = d > 0$, which can be interpreted as a dividend or convenience yield derived from actually owning the investment.

The value of the investment project, $F(y(t))$, can then be found by setting up a hedge portfolio with a long position of one unit of the investment and a short position in $F'(y(t))$ units of $y(t)$. Using standard methods in stochastic calculus gives the following differential equation:

$$\frac{s^2}{2} F''(y(t))y(t)^2 + (r-d)F'(y(t))y(t) - rF(y(t)) = 0 \tag{8}$$

The solution to (8) is:

$$F = B_1 y(t)^{g_1} + B_2 y(t)^{g_2} \tag{9}$$

Using the boundary conditions in the Appendix gives:

$$F = B_1 x(t)^{g_1} \tag{10}$$

where $g_{1,2} = \dfrac{-(r-d-\frac{s^2}{2}) \pm \sqrt{(r-d-\frac{s^2}{2})^2 + 2s^2 r}}{s^2}$ are the roots to the quadratic equation in g,

$$B_1 = \frac{(g_1 - 1)^{g_1 - 1}\left[\frac{c}{r} + I\right]^{1-g_1}}{(dg_1)^{g_1}}$$

and

$$y^* = \frac{g_1}{g_1 - 1} d\left[\frac{c}{r} + I\right] \tag{11}$$

Equation (11) gives the maximum income level or the cap price for the monopolist. Beyond this point, it is in the interest of the municipality to revoke delegation and resume direct management. From (11) it is clear that damage liability raises the minimum price above what it would otherwise be ($\partial y^*/\partial c > 0$).

The foregoing solution to the regulator's problem is intuitively appealing with practical advantages. The intuition is that the optimal price is where the interests of the municipality are just equal to the interests of the monopolist and that the associated interests are determined by objective economic considerations that include the damage liability. The practical advantage is that if the revocation threat is credible, the monopolist will have an incentive to auto-regulate himself in order to avoid losing his contract.

CONCLUSION

In this paper, we have shown how the topic of drinking water management relates to the traditional analysis of natural monopoly regulation. We argue that from a purely ethical standpoint, the essential nature of water for human existence and welfare makes equal access a right and that water is, indeed, a natural monopoly. However, regulating natural monopolies, which involve irreversible environmental and public health risks, changes the usual regulating schemes in such a way that damage liability must be included in the analysis. Using the French case as an example because French legislation explicitly recognizes the damage liability associated with water management, we show that the damage liability can be measured as the value of an insurance policy associated with any and all losses due to negligence on the part of the regulator or his delegated manager. Using real options pricing techniques, we then show how an optimal pricing policy can be determined and how the damage liability can be integrated into the analysis. As intuition would have it, it turns out that the damage liability raises the cap price.

APPENDIX 1

The first boundary condition is

$$F(0) = 0 \tag{1A}$$

which implies that $B_2 = 0$.

The second boundary condition depends on income and the cost of exercise. There will be a value of $y(t)$, noted $y*$, where it will be optimal for the commune to exercise its option. At this point it will receive the value of the investment *V* less the cost *I* of exercising the option. This cost includes the technology costs, recruiting costs, investment costs and indemnities that must be paid if the municipality wants to renew direct management. Thus, the value matching

$$F(y*) = V(y*) - I \tag{2A}$$

where *V* is the present value of the investment's cash flows and I is the exercise price, i.e. the cost of revoking delegation. The smooth pasting condition that makes it possible to find $y*$ jointly with $F(y(t))$ is:

$$F'(y*) = V'(y*) \tag{3A}$$

Solving (2A) and (3A) simultaneously gives the solution in the text.

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END NOTES

[1] The BottledWaterWebTM Copyright 1999 Best Cellar Communications, a division of Best Cellar LLC recalls that "In 1993 a waterborne outbreak of Cryptosporidum in Milwaukee caused an estimated 400,000 residents to become ill with flu-like symptoms and a number of deaths to those that were immune impaired. Later that year a failure of Washington D.C.'s filtration process caused elevated turbidity and an increase in diarrhea illness in residents of Washington D.C. Water quality varies from city to city, street to street, and tap to tap. Even the water from one tap can change from day to day depending on water treatment techniques and blending of different sources. Other inconsistencies in tap water come from chlorinating, which kills bacteria in water but can produce trihalomethanes (THMs) when it interacts with organic matter in water. THMs have been found to be carcinogenic. From toxic dumps leaking into the aquifers to agricultural pesticides turning up in our faucets, our taps are under constant attack. Even the very delivery system that brings our tap water from the reservoir to our glass has been found to contain lead, copper, radon and a potpourri of other contaminants that can cause everything from severe headaches to cancer."

[2] In poor countries for instance, drinking water is privately supplied by individuals in little tanks and prices are settled on the distribution time, the quantity, etc.

[3] See for instance Spulber and Sabbaghi (1994 chap.9).

[4] To a full treatment of the natural monopoly question see for instance Boyer and Ali (1997)

[5] That does not mean that in the water industry, relationships between agents are restricted to only two contractual ones (see for instance the relationships between stockholders and manager, employees and manager etc) as for usual firms.

[6] Although the procedure appears equitable and competitive, in fact, as the Cour des Comptes concluded in its report of January 1997, because of the French governance tradition that is extremely exacting with respect to the municipalities' duties and obligations and that also allows de facto cartelisation, fair competition is seldom achieved.

[7] In France, for example, La Compagnie Generale des eaux, the Lyonnaise des Eaux-Dumez, and the SAUR linked to the Bouygues Group are the main leaders that also control a large network of subsidiaries.

[8] This assumption implies that either there is a single given technology or that technology changes affect water quality but not cost. Technology and changes in technology, while important in a more general context, are only peripheral to the problem at hand. Furthermore, the great majority of operating costs in water management accrue to depreciation, which is fixed or has a fixed schedule, and skilled labor. Because of social legislation that eliminates temporary layoffs and the specialized skills required for water management that make temps a limited commodity, labor costs are also fixed for all practical purposes. Thus, variable operating costs are a small percentage of total operating costs. Consequently, the assumption of constant operating costs is not too unrealistic. Since this assumption simplifies the mathematics and makes the model more intuitively appealing, we have much to gain and little to lose by it.

[9] In France $y(t)$ is directly observable in so far as water companies are required by law to furnish the authorities with regular, detailed information on quantities and prices. If $y(t)$ were not directly observable, a spanning asset could be substituted. An alternative method in the absence of a reliable spanning asset is to assume risk neutrality.