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The Networked City: Managing Power and Water Utilities in Portugal, 1850s-1920s

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This paper explores the evolution of power and water systems in Portugal throughout the period of urban infrastructure modernization. The network characteristics of electricity, gas, and sanitary equipment are emphasized, not only in its economic and technical characteristics, but also in its impact on management, regulation, and initial installation. Regulatory issues and conflicts between private entrepreneurs and public authorities are particularly emphasized. Sometimes they provided the path to municipalization. Otherwise, the outcome of these conflicts enhanced regulatory mechanisms and long-term relationships between public and private institutions. The analysis of agency problems and the theory of contracts are used as the main theoretical devices to explain the outcome of these relationships.

The motivation for this paper comes from the economics literature on network utilities, which emphasizes high sunk costs, asset specificity, classic natural monopoly issues, and the need for coordination throughout all the parts of the system to maintain its efficiency.[1] The latter characteristic is the one most closely related to the network feature assumed by urban utilities.

Our aim in this paper is to explore the impact of these characteristics on the evolution and management of gas, electricity, and water systems between 1850 and 1920. This period was selected for several reasons. First, it was during these decades that the urban infrastructure was modernized, gas and water supply systems began, and later reached maturity. The same was true of electricity at the end of the nineteenth

[1] David M. Newbery, *Privatization, Restructuring and Regulation of Network Utilities* (Cambridge, Mass., 2000).

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century. This period is also relevant to issues related to the private and public management of public services. In mid-nineteenth-century Portugal, private management was considered the normal way to deal with the provision of goods and services; the supply of water, gas, and, later, electricity did not divert from this assumption and practice. Limited-life franchises, which gave private entrepreneurs a local monopoly, prevailed as the organizational solution to running these networked industries. However, private companies' performance and problems related to the private provision of local services led to consideration of public management as a possible alternative. Therefore, we will explore the network characteristics of the supply of water, gas, and electricity in an attempt to illuminate the central issues related to their establishment, evolution, and management.

This paper reflects the two different research paths undertaken by the authors.[2] The first path is dedicated to water supply and the sanitary equipment connected with sewers. The second path deals with gas and electricity supply. The association of these utilities derives from the fact that public lighting was the common ground linking municipal authorities with the companies operating in the sector.

A Typical Case of Positive Externalities: The Development of Sanitary Equipment Throughout the Second Half of the Nineteenth Century

The Sanitary Revolution. In the second half of the nineteenth century, a sanitary revolution was underway across Europe and North America. This was a movement aimed at cleaning up the cities through the provision of purer water supplies and better sewage disposal, and through the paving of streets and control of the urban layout of cities.[3] This sanitary

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[2] The bibliographical references exemplify the research on water supply and sewer systems undertaken by Álvaro Ferreira da Silva. Ana Cardoso de Matos has been working on gas and electricity supply. We are starting a common research project on urban infrastructures in Portugal.

[3] Gordon E. Cherry, "Public Policy and the Morphology of Western Cities: The Example of Britain in the Nineteenth and Twentieth Centuries" in *The Rise and Fall of Great Cities: Aspects of Urbanization in the Western World*, ed. Richard Lawton (London, 1989), 32-44; Jean-Pierre Goubert, "The Development of Water and Sewerage Systems in France, 1850-1950" in *Technology and the Rise of the Networked City in Europe and America*, ed. Joel A. Tarr and Gabriel Dupuy (Philadelphia, Pa., 1988), 116-136; Anne Hardy "Smallpox in London: Factors in the Decline of the Disease in the Nineteenth Century," *Medical History* 27 (1983): 111-138; John von Simson, "Water Supply and Sewerage in Berlin, London and Paris: Developments in the 19th Century," in Hans Juergen Teuteberg, *Urbanisierung im 19. und 20. Jahrhundert: Historische und Geographische Aspekte*, ed. Hans Juergen (Koeln, 1983), 428-439; Anthony Sutcliffe, "Environmental Control and Planning in European Capitals, 1850-1914:

revolution was responsible for changing the conditions of city life. Several changes in the way water was distributed and consumed, as well as other transformations in the removal of human and animal waste from the city, set off a new and healthier urban environment, responsible for a dramatic decrease in mortality rates in urban areas.[4]

The organization of water supply and sewers based on networks supported the technological innovations in sanitation.[5] We define modern water supply as water provision based on a network system that relies on centralized, piped water, substituting for water sold in containers or manually carried from a local street fountain. The introduction of modern waterworks marks a movement away from reliance on a localized and labor-intensive water-supply process towards a more capital-intensive system, organized in a network, and automated.

The same is true with the sewer system. Traditionally, human waste disposal was based on cesspools and privy vaults. From time to time, scavengers contracted by the cities cleaned the privies and took away the waste to rural areas, because of its potential use as manure. This process was labor-intensive and inefficient, creating both aesthetic nuisances and health problems. At the beginning of the nineteenth century, cities with sewers usually employed them for storm-water drainage rather than

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London, Paris and Berlin," in *Growth and Transformation of the Modern City*, ed. Ingrid Hammarström and Thomas Hall (Stockholm, 1979), 71-88; Joel A. Tarr, "Building the Urban Infrastructure in the Nineteenth Century: An Introduction," *Essays in Public Works History* 14 (December, 1985): 61-85; Anthony S. Wohl, *Endangered Lives: Public Health in Victorian Britain* (London, 1983).

[4] Jeffrey K. Stine and Joel A. Tarr, "At the Intersection of Histories: Technology and the Environment," *Technology and Culture* 39 (4, 1998): 601-640; Richard A. Easterlin, "How Beneficent is the Market? A Look at the Modern History of Mortality," *European Review of Economic History* 3 (December, 1999): 257-294. For the argument concerning the technological character of this sanitary revolution see Álvaro Ferreira da Silva, "Running for Money: Municipal Trade in Lisbon (1860-1910)" in *Comparative Aspects of Urban Infrastructure in the 19th and 20th Centuries: Technology, Finance and Regulation*, ed. Andrea Giuntini, Peter Hertner, and Gregorio Núñez (forthcoming).

[5] For further references concerning these networked utilities see Jean-Pierre Goubert, "The Development of Water and Sewerage Systems in France, 1850-1950" in *Technology and the Rise of the Networked City in Europe and America*, ed. Joel A. Tarr and Gabriel Dupuy (Philadelphia, Pa., 1988), 116-136; Joel A. Tarr, "Water and Wastes: A Retrospective Assessment of Wastewater Technology in the United States, 1800-1932," *Technology and Culture* 25 (25, 1984): 226-264; Joel A. Tarr, "Building the Urban Infrastructure in the Nineteenth Century: An Introduction," *Essays in Public Works History* 14 (December, 1985): 61-85; Joel A. Tarr and Josef W. Konvitz, "Patterns in the Development of the Urban Infrastructure," *American Urbanism: A Historiographical Review*, ed. Howard Gillette Jr. and Zane L. Miller (New York, 1987), 195-226.

human waste removal. In many cases, local ordinances even prohibited the placing of human waste in these storm sewers.[6] In contrast, the water carriage system of waste removal introduced an automated, centralized, and capital-intensive system to solve sanitary problems created by the old human waste disposal methods. The major technological innovation behind this system was the use of water as a draining and cleansing agent, in order to remove solid waste from the toilet flush and the sewer pipes. In addition, there were several changes in the design of the pipes and the network, to assist this automated cleaning. By covering the whole city with a network of oval-shaped sewer pipes and adapting the slope of the pipes to the topography, it was possible to remove water and solid waste.

Both the water supply infrastructure and the new sewer system associated with this technological revolution in sanitation had some peculiar characteristics. They had to be considered systems in their own right and this network characteristic meant that coordination throughout all the parts of the system was essential for its efficiency (systemic and site-specific characteristic). These networks had to be planned much further in advance than the actual demand when they were created (prospective characteristic). Finally, the crucial element that revolutionized sanitation throughout the second half of the nineteenth century was the interrelationship of the modern water supply and the solution to the waste disposal problem through a modern sewer system (interrelation of technological systems).

It was a nineteenth-century assumption that private enterprise was the best solution for running modern waterworks. This assumption was backed by contemporary economics and supported by public opinion. Private enterprise was considered more efficient for dealing with agency problems within the firm. However, supplying water is not like other businesses. First, the very nature of the technological system involved is such that the large amount of capital invested in waterworks (aqueducts, dams, pipes, and reservoirs) is a perfect example of an economic activity where sunk costs are very high. These high sunk costs are associated with assets that are specific to water supply and would be difficult to transfer to another economic activity. Waterworks such as aqueducts or pipes laid under the streets are of no use for any other purpose. The specificity of the investment, the high sums of capital involved, and the concentration of the economic activity in the supply of only one good, prevents an easy exit from the industry or strategic decisions regarding enlarging the scope of the business. As a network utility, partial investment in any portion of the network only makes sense and is effective if the performance and organization of the whole system is efficient. Modern water supply is a

6 As was the case in Lisbon at the time, see Álvaro Ferreira da Silva, *Crescimento urbano, regulação e oportunidades empresariais, Lisboa 1860-1930* [Urban Growth, Regulation and Business Opportunities, Lisbon 1860-1930] (Ph.D. diss. European University Institute, Florence, 1997).

classic case of a natural monopoly, where a single firm can satisfy the entire market demand at lower total cost than any other combination of firms.[7] The network itself is an obvious case where duplication raises the total cost of supplying a market. Therefore, a single firm providing a good or a service might be tempted to abuse its position in the market. Finally, there are positive externalities associated with water provision. From the point of view of nineteenth-century sanitary problems, continuous and abundant water consumption was essential for dealing with urban health problems.

However, the superiority of private management in dealing with water supply was taken for granted for most of the nineteenth century. Public administration had to provide order, fight fires, and maintain public spaces, but it could not intervene in other initiatives. Private enterprise was seen as the proper institutional form for dealing with the modernization of the water supply. The provision of water to the cities was not considered fundamentally different from other economic activities, since there were several contractual conditions that had to be agreed upon to deal with the specificities of the business.[8]

Therefore, by the mid-nineteenth-century, private operation under a limited franchise monopoly constituted the prevalent institutional alternative. It owed much to the contemporary experience of railroad construction and operation, as well as to the theoretical principles associated with the work of Edwin Chadwick. He differentiated traditional market competition, "competition within the field," which assumed a large number of firms competing in the market, from "competition for the field," which was based on competition between several bidders to have the exclusive right to supply water to the entire local market.[9] This competitive bidding process would in some way replicate the social efficiency of "competition within the market."

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[7] William W. Sharkey, *The Theory of Natural Monopoly* (Cambridge, U.K., 1982).

[8] "Parliament did not regard water supply as in any way different from normal speculative ventures, and relied on the workings of market forces and the potential of competition to safeguard the public interest," writes Malcolm E. Falkus when discussing the situation in England in the first half of the nineteenth century; see Falkus, "The Development of Municipal Trading in the Nineteenth Century," *Business History* 19 (2, 1977): 140. Robert Millward also emphasizes that in the same period water and gas supply were treated as ordinary goods by the administration and public opinion, and "private enterprise was seen as the proper institutional form." See Robert Millward, "Emergence of Gas and Water Monopolies in Nineteenth-century Britain: Contested Markets and Public Control," in *New Perspectives on the Late Victorian Economy: Essays in Quantitative Economic History*, ed. James Foreman-Peck (Cambridge, U.K., 1991), 99.

[9] Harold Demsetz, "Why Regulate Utilities?," *Journal of Law & Economics* 11 (April, 1968): 55-65; Robert B. Ekelund and Robert F. Hébert, *A History of Economic Theory and Method* (New York, 1990).

However, the efficiency of such proposals depends ultimately on the design of the contracts, the power of vested interests, the behavior of the judiciary towards litigation between administration and private enterprises, and information on the industry. The design of these private enterprise contracts to regulate the water supply involves several features stressed by institutional economics in the relations between principal and agent. Bounded rationality and the costs of acquiring and processing information were certainly present in planning the work and investment needed to supply a certain quantity of water or in forecasts of future population evolution. This was common to both the administration and the private utility.

Opportunistic behavior might also be present. A private enterprise will attempt to deliver services that are more profitable rather than more efficient, choosing either higher or lower quality or cost, depending on the incentives it faces. The regulator opportunistically takes advantage of the costly investment in sunk and specific assets to threaten the enterprise, reneging on contractual clauses or trying to renegotiate contracts, so that the utility fears it may become a hostage of the regulator.

This summary of the characteristics of the modern urban water supply infrastructure illustrates the reasons why public regulation was needed and why public supply later became a realistic solution to the problems associated with the provision of such a good.

Water Supply in Portugal in the Early Twentieth Century. At the beginning of the last century, most Portuguese towns with more than 5000 inhabitants were without a modern water supply system.[10] Only 17 percent of these towns had a piped water supply and for some of them the water supply was of inferior quality.[11] For instance, in Setúbal and

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[10] This overview of water supply is based on the *Inquerito de salubridade das povoações mais importantes de Portugal* [Inquiry Into the Sanitation of the Most Important Towns in Portugal] (Lisboa, 1903), a large and detailed source of information on water supply and sewage disposal across Portugal at the beginning of the twentieth century based on a survey distributed to towns in 1901. The information on cities with modern water supply presented in this source was supplemented by data from local studies and the survey published in 1935: *Inquérito sobre o saneamento de aguas e saneamento das sedes de concelho* [Inquiry on Water Supply and Sanitation of the Towns Head of Municipalities], Ministério das Obras Públicas e Comunicações, 1935. Because data from both surveys are not entirely consistent, information provided by local studies was used to identify cities and towns with modernized water supply. Matosinhos was not considered to be independent from Oporto in the Montenegro survey, and the same criterion was used in Table 1.

[11] As a reference, this number might be compared with the situation in England in 1914: of 1,130 boroughs and other urban districts outside London, only 2.6 percent were without piped supplies; see John Hassan, *A History of Water in Modern England and Wales* (Manchester, U.K., 1998), 22. The proportion of

Santarém water quality was poor, and even in Oporto, the second largest city, water provision was polluted by dirty leaks. Nevertheless, in towns where the water supply had not been modernized the quality was even more appalling.[12]

If we look at the urban hierarchy, most of the largest Portuguese cities did not have a modern water supply. At the top of the urban network, Lisbon and Oporto (with 356,000 and 168,000 inhabitants, respectively) had piped water provided by private companies. However, the third largest city, Braga, with 22,000 inhabitants, had a traditional water supply, based on fountains and springs, without piped water to households. The fourth largest Portuguese city, Setúbal, with 19,000 inhabitants, relied on a private company to provide households piped water. With the exception of Coimbra (with 16,000 inhabitants), all the other major cities had a traditional water supply.

The quantity of water provided by fountains in the cities without modern water systems was not much less than the amount provided in the few cities where the system had been modernized. For instance, fountains and springs supplied Braga. However, the water volume per capita was not much lower than in Setúbal, the city immediately below it in the urban hierarchy, which had a private, piped water supply.[13] Other cities at the top of the urban hierarchy relying on a traditional water supply illustrate this comparison even better. All of these received more than 45 liters per inhabitant each day, which was more than what was provided by the private company in Oporto, where the daily water supplied per inhabitant was around 40 liters. In the case of Évora, whose population did not grow very much after the early modern period, the second longest aqueduct built in Portugal provided a record 196 liters per day of water, twice the per capita water supply in Lisbon at the time.[14] Nevertheless, it was the modern waterworks in the Portuguese capital that had the largest water supply per capita of all eleven cities and towns with a piped water supply.

There are several institutional options for managing a modern water supply. The first is public management and ownership of the waterworks and the whole infrastructure. The second is public ownership

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boroughs with piped water in Portugal for the same year (1914) would give a very different result: only 27 (less than 11 percent) of the Portuguese towns, which were heads of municipal districts, had piped supplies (see Table 2).

[12] For the towns listed in the survey, 36 percent described the water consumed by the population as bad. In some cases it was very polluted, constituting a serious health problem.

[13] In Braga, daily water supply per capita was 25 liters, and in Setúbal, 28 liters.

[14] The *Aqueduto da Água da Prata* was built in the seventeenth century. The longest aqueduct was built in Lisbon throughout the first half of the eighteenth century. For a description of Évora's aqueduct see Maria Filomena Mourato Monteiro, *O Aqueduto da Água da Prata em Évora* [The *Água da Prata*'s Acqueduct in Évora] (Masters thesis, Universidade de Évora, 1995).

of the infrastructure, with a limited-life franchise monopoly granted to a private company. The third possibility is entirely in the private sector, with a private company as the owner of the waterworks and operator of the supply to the households. There is a fourth option, which is typically the case for a traditional water supply based on personal and small-scale provision: individuals or communities own the springs and wells and organize a water supply to either their own household and premises, or to a small neighborhood.

TABLE 1
Water supply at the beginning of the twentieth century

Modern Water Supply and Urban Network	
Cities with more than 10,000 inhabitants	9
Cities with more than 10,000 inhabitants with modern water supply	4
Towns with more than 5,000 inhabitants	41
Towns with more than 5,000 inhabitants with modern water supply	7
Total number of towns with modern water supply	9
Institutional Options to Manage Water Supply	
Towns with private concession	
Towns with municipal supply and private concession	3
Towns with municipal supply	2
Water Provided in Towns with Modern Water Supply (lhd)	
< 30 liters	4
30-60 liters	2
100 liters	1
“Plentiful supply”	2
Water Quality and Quantity for All Towns in the 1901 Survey	
Water supply with good quality	110
Water supply with deficient quality	62
Water supply in small quantities	23

Source: see note 7.
lhd = liters per head per day

At the beginning of the twentieth century, the nine Portuguese towns with modern water provision relied mainly on private management, with or without infrastructure ownership. Only two, Santarém and Coimbra, had water provision managed by local authorities. The main difference among these nine towns was the level of monopoly. In three situations private operators coexisted with a public supply. In these cases, pre-existing waterworks (aqueducts, pipes, reservoirs, springs, and fountains) were maintained by the municipality rather than integrated into the infrastructure managed by the private company. This pre-existing

infrastructure continued to be publicly run to supply fountains where water could be collected free of charge.

TABLE 2
Periods of installation of piped supplies in Portuguese towns, heads of municipalities (Mainland, 1935)

Time Period	# of Boroughs with Piped Supplies	% of Boroughs with Piped Supplies
Before 1901	12	12.5
1901-1910	7	7.3
1911-1920	10	10.4
1921-1930	38	39.6
1931-1935	29	30.2
Total	96	100.0
Total # of boroughs	252	38.1

Source: see note 10.

A typical example of this situation was the second largest Portuguese city, Oporto. Water supply was contracted out to a private company, the *Companhia das Águas do Porto*, owned by the French *Compagnie Générale des Eaux pour l'Étranger*, but the municipality did not give up the existing city waterworks, managed by the local authorities. Public pipes, aqueducts, reservoirs, and fountains remained under city control and the water was used both for municipal services consumption and for providing the population with public fountains. Only provision of piped water to households by Oporto city council was forbidden.[15] After the 1920s, with respect to municipal control over the water supply, both public and private infrastructures were consolidated under unified management.

The 1901 survey covered 183 Portuguese towns; the proportion that had modernized their water supply was 5 percent. By the mid-1930s, the situation had improved. However, by European standards the availability of modern waterworks was still very rare, as is shown in Table 2. Both water quantity and quality provided to households by modern waterworks were deficient at the beginning of the twentieth century.

[15] Contract between the Portuguese government and the *Compagnie Générale des Eaux pour l'Étranger* signed on 22 April 1882.

Designing the Regulatory Framework for Networked Water Supply. Private management's superiority in dealing with the water supply was taken for granted for most of the nineteenth century. When the modern water supply became a political issue in Portugal, however, the arguments in favor of private management were much less insightful. The governance model was absent from consideration in the options for modernizing the water supply even in Lisbon, which anticipated and modeled technical and organizational solutions for other Portuguese towns.[16] The first governmental proposal tendering bids to provide piped water to Lisbon stated the importance of supplying water "in the same fashion used in other European cities, where private companies are responsible for the introduction of new and modern habits in personal hygiene."[17] This reference to institutional arrangements used abroad was the only justification for proposing an end to public management of the Lisbon waterworks, which had begun with the construction of the eighteenth-century aqueduct.[18]

Further discussion of the water supply to Lisbon, mainly concerning the conflict between the municipality and the private company that gained the franchise monopoly in 1856, added another argument to

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[16] The first detailed presentation of the solutions for improving the water supply to Lisbon was made by Pedro José Pézerat, *Dados e estudos para um projecto de abastecimento de agoas e sua distribuição em Lisboa, mandados confeccionar e publicar pela Camara Municipal da mesma cidade* [Data and Studies for a Water Supply Project to the City of Lisbon] (Lisbon, 1855). There was no reference to the organizational form for water supply, even though the implicit solution was public administration. The same was true of the discussion between two members of the city council published in Augusto de Carvalho, *Reflexões acerca do abastecimento de agoas e sua distribuição na capital* [Reflections on Water Supply and Distribution in the Capital City], Lisbon, 1853 or in the technical report made by Carlos Ribeiro, *Considerações geraes sobre a grande conserva d'aguas projectada na Ribeira de Carenque mandadas publicar pela Camara Municipal de Lisboa* [General Considerations on the Dam Projected to the *Ribeira de Carenque*, Published by the Municipal Council of Lisbon] (Lisbon, 1854).

[17] Preamble to the 22 Dec. 1852 Decree.

[18] This aqueduct, which even today is visible in Lisbon's landscape, was begun in 1731 and was built over the course of a century. Its water reached the city in 1748, but the infrastructure of additional public works did not end until 1835. At the time, the municipality substituted the state administrative body that was running the construction and the operation since the beginning of the works in 1731, establishing the first experience of municipal management. See Jorge das Neves Larcher, *Memória histórica sobre o abastecimento de água a Lisboa até ao reinado de D. João V* [Historical Memoir on Water Supply during the Reign of D. João V] (Lisbon, 1937); Augusto Pinto de Miranda Montenegro, *Memoria sobre as aguas de Lisboa* [Memoir on the Water in Lisbon] (Lisbon, 1895); Luís Leite Pinto, *Subsídios para a história do abastecimento de água à cidade de Lisboa* [Subsidies into the History of Water Supply in Lisbon] (Lisbon, 1973).

justify private management. The financial burden on the public administration was very heavy, thus the capital needed to carry out the modernization of the water supply would have to be raised by private investors. The granting of a license to a private company, which could raise capital by issuing shares to the public, appeared to offer the best prospect of improving water supplies, given the capital-intensive nature of the modern waterworks.[19]

However, the production details associated with water supply, the high sunk costs, and the specific requirements of waterworks led potential private entrepreneurs to secure their property rights against opportunistic behavior from the administrative body that granted the franchise. From the point of view of private investors, several dangers might be anticipated to arise. These can be summarized in two areas. The first was the need to reward such a large, specialized investment. As this was a new business needing time to mature, concerns about capital return were inevitable. The administrative guarantee of a minimum rate of return on the investment could have been a solution to this problem, as was common in private railway companies. Another might have been an extension of the term of the limited franchise monopoly, in order to secure property rights and allow formulation of long-term strategies. The second area is related to the fact that the municipality was the water company's most important customer. Thus, the company feared it might become a hostage of the local administration or of decisions made by the central government. As the specificity of assets prevented an exit from the business, there were strong incentives to make very detailed contracts, attempting to cover any possible situation that might lead the firm into a hostage situation.

From the consumer's point of view, private management of the water supply also had several shortcomings in need of contractual regulation. The fact that a firm held a monopoly increased the possibility of it abusing its market position by raising prices or lowering service standards. The aim of introducing a modern water supply system was to increase the quantity and quality of water supplied, particularly given the importance of the need to improve sanitary conditions. Therefore, private water suppliers had to address this general goal and do the work needed to bring larger quantities of water into the city and make the service available to the entire population.

The regulatory framework approved for the water supply in Lisbon between 1852 and 1867 is important for two reasons. First, it provided the principles that other cities would copy. Second, analysis of the framework reveals the weaknesses of the regulatory apparatus and possible reasons

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[19] For a more extensive examination of the Lisbon water supply, see Álvaro Ferreira da Silva, "The Peculiar Customer: Conflicts of Power and the Modern Water Supply System in Lisbon," in *Réseaux techniques et réseaux de pouvoir dans les villes européennes (XIXe siècle-début XXe siècle*), ed. Denis Bocquet (Rome, forthcoming).

for the recurrent conflicts between the private company and the public administration.

Some principles reappeared in other contracts: compulsory purchase powers similar to the railroad companies'; exemption from import duties and any tax until the capital invested had reached a net profit of 5 percent; the need for administrative approval for all waterworks.[20] The definition of property rights was also common to other situations in the nineteenth century and adapted the traditional principles and terminology peculiar to copyhold land tenancy. The public administration was the "direct owner" (*proprietário directo*) of all the waterworks, old (the *Aqueduto das Águas Livres*, for instance) and newly constructed. The private company received, for the period of the concession, the "useful property" (*domínio útil*) of all the waterworks and springs. At the end of the contract, the "useful property" would become consolidated with the "direct property." In some other concessions (Oporto, Cascais, Barcelos), the municipality continued to run the pre-existing infrastructure, which in most cases, in addition to the water sources only included some reservoirs, pipes, and fountains. The private company had a monopoly on the responsible for providing piped water. However, at the end of the contract the waterworks constructed and managed by the company would be incorporated into the public domain.

Table 3 includes a summary of the main clauses set down in contracts and contests, beginning with the first tendering bid in order to provide water to the city (1852)[21] and ending with the second franchise monopoly granted to the *Companhia das Águas de Lisboa* (1867), a contract which provided most of the regulatory framework for Lisbon until 1932 and acted as a model for water provision by private enterprises in other cities.[22] A small number of clauses have been selected to facilitate the comparison and to illustrate the main aspects regulated by the contracts.

The main conclusion that can be drawn from this process is the tentative approach used to design a regulatory framework for water

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[20] See for instance the rules for Oporto's water supply contest (12 Aug. 1880) and the contract signed between the government and the concessionaire for Oporto water supply on 22 March 1882. Both the clauses for tendering bids and the contract reproduced most of the rules of the Lisbon contracts, mainly the one signed in 1867.

[21] Another contest to provide water to the city was announced in 1849. See Montenegro, *Memoria...*,. However, it did not set any conditions for potential competitors. This contest had no bidders.

[22] Other addenda to the 1867 contract were signed between 1867 and 1932. However, they changed or clarified only a few clauses of the first contract. A summary of the legislation concerning water supply in Lisbon was published in *Boletim da Comissão de Fiscalização das Obras de Abastecimento de Água à Cidade de Lisboa* [Bulletin of the Committee for the Surveillance of the Water Supply Works in the City of Lisbon], 1937, 11.

supply. The contrast between the 1852 and the 1855 contests is particularly striking.[23] The former presented hardly any contractual conditions for the competitive bidders. It set only the time span for the concession and the volume of water to be provided.

The provisional contract with Duarte Meddlicott, which served as the basis for the 1855 contest, constitutes a turning point in water supply regulation through concession contracts. It has not been possible to trace the negotiations between the public administration and these entrepreneurs. Nevertheless, it seems that the foreign entrepreneurs brought to Portugal conditions from other countries' water supply contracts that had been absent from the previous contests because of the government's inexperience with these types of agreements.

For the first time, this provisional contract and, simultaneously, the directive for the bidding process, represented the main items included in all other contracts throughout the second half of the nineteenth century. It even included a clause (omitted from the Table 3 summary) precluding opportunistic behavior by the franchised enterprise: during the last five years of the contract, the municipality had to control any attempts made by the firm to lower its standard of service; the firm had to act in conformity.

Moreover, both the 1855 contest clause and the 1856 contract included price regulation as an alternative to rate of return regulation, which was explicitly rejected in both documents.[24] As an alternative, it stipulated both the maximum price for water sold by the company and the minimum volume of water the company had to provide to the capital city. Thus, the regulatory method was price regulation combined with a predetermined standard of service.

This regulatory method was maintained throughout the period. The setting of a maximum price was an attempt to prevent the enterprise from exploiting its market position. The standard of service addressed the positive externalities associated with water supply as an industry. In 1898, municipal participation in company profits was added to simple price regulation. The company equally shared net profits with the city when dividends were more than 6 percent, an example of price regulation method with profit sharing. This new contract also changed the tariff policy of the company by introducing regressive tariffs and a fixed minimum consumption threshold.

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[23] The 1849 contest is absent from this analysis; the law allowing the government to open the contest did not set any conditions at all, not the volume of water to be provided, nor the duration of the concession.

[24] On the different methods of regulation, see W. Kip Viscusi et al., *Economics of Regulation and Anti-Trust* (Lexington, Mass, 1992).

TABLE 3
Main conditions in different contracts or contests to provide water to Lisbon (1852-1867)

	1852	**1855**	**1858**	**1867**
Time span for the concession	20 years	80 years	80 years	99 years
Time span for public takeover with indemnity		50 years	50 years	45 years
Total quantity of water, lhd	14.3 l	34.5 l	55.7 l	100 l
Water provided to the municipality for free		All the water needed with the exception of the water for cleaning the sewers	All the water needed with the exception of the water for cleaning the sewers	1/3 of the volume supplied by the company
Consumer base		Piping into the households not compulsory	Piping into the households not compulsory	Compulsory piping into the households after 1872
Evolution of water supply		Per capita water charges must increase at the same rate as the population	Per capita water charges must increase at the same rate as the population	
Public provision for the population		The number of public fountains cannot be increased	The number of public fountains cannot be increased	The number of public fountains cannot be increased

Sources: Contracts and bidding clauses for the following years:
1852: Conditions for a tendering bid in order to supply water to Lisbon (22 December).
1855: Provisional contract with the Duarte Meddlicott group. The clauses in this provisional contract provided the base for the new tendering bid (13 August).
1858: Contract with the *Companhia das Águas de Lisboa*, which won the 1855 contest (29 September).

1867: New contract with the *Companhia das Águas de Lisboa*, after the 1864 crisis between the company and the administration (27 April).
lhd = Litres per head per day. The calculation of lhd for 1852, 1855 and 1858 used the population of Lisbon in the respective year.

The 1867 contract marked the second turning point in the contractual regulation of the water business. It represented an attempt by the Portuguese company to both secure the contract it had gained 11 years earlier and to achieve a sustainable demand. The minimum quantity of water per head per day increased more than 60 percent. The implicit assumption was that the need to increase water supply was in the distant future. Moreover, such an increase in the previous minimum threshold constituted a strong argument for securing the concession, after the 1864-1867 crisis in relations between the municipality and the company.[25] In this context, the clause requiring the water supply to increase at the same rate as the population disappeared between 1858 and 1867. It was an important change and left the administration without a contractual device to control company performance over the long-term.

The other major contractual change, in attempting to secure the concession, was the new quota for administrative use. The contract dramatically increased the volume of water to be made available to the local administration and removed the exception for public use of the water supply, the water needed for sewer cleaning. Because the 1858 contract was never put into effect, due to its interruption in 1864, the water volume in excess of the municipal quota that could be used for cleaning the sewers was never calculated. Increasing the municipal quota, without exceptions, was an interesting clause for the administration, because cleaning sewer pipes was one of the most important municipal purposes for the water the city council received.[26] This became the source of many clashes between the concessionaire and the administration during the following decades, until 1932.

Another innovation in the 1867 contract was compulsory piping as a way to shape and maintain a solid consumer base. It was also a rule in the first contract with the Oporto concessionaire in 1882. From the perspective of the company, this clause could be considered the corollary of price regulation. Because government did not guarantee the rate of

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[25] Álvaro Ferreira da Silva, "The Peculiar Customer: Conflicts of Power and the Modern Water Supply System Lisbon," in *Réseaux techniques et réseaux de pouvoir dans les villes européennes (XIXe siècle-début XXe siècle*), ed. Denis Bocquet (Rome, 2002).

[26] Water for cleaning sewer pipes was so badly needed that the 1898 contract allowed the city council to break the company's monopoly of water provision. The municipality was able to get water from the Tagus River and carry it by special pipes to clean the sewers.

return, enlarging the consumer base by administrative rather than market means was critical to the company, especially in light of the waterworks' large investments to collect water from Alviela. However, without a tariff to encourage consumers' adherence, this administrative measure would have been of little use in enlarging the consumer base.[27] A new policy with the partial objective of a minimum level of consumption and regressive tariffs was not introduced in a contract revision until 1898. However, following the arrival of the Alviela water in Lisbon in 1885, which produced a relative excess in water supply, the tariff policy was not adjusted to respond to this supply.

TABLE 4
Consumers and private consumption in Lisbon (1870-1914)

Periods	Consumers		Water Consumption		Consumers' lhd
	N	Growth (%)	m^3	Growth (%)	
1870-1874	7,665	-	-	-	-
1875-1879	13,097	71	-	-	-
1880-1884	23,689	81	1,391,961[a]	-	35.8 [a]
1885-1889	33,727	42	1,619,911	16	29.2
1890-1894	40,290	19	1,723,766	6	26.0
1895-1899	42,617	6	1,788,761	4	25.6
1900-1904	47,911	12	2,178,960	22	27.7
1905-1909	56,506	18	2,940,965	35	31.7
1910-1914	65,422	16	3,341,468	14	31.1

Notes: lhd = liters per head per day. Consumers' lhd takes into account only the company's consumers, not the entire population of Lisbon (thus, it measures only the water privately consumed, not public uses). Compare with Table 6, column 3, in which all the water (public and private) and the entire population of the city are considered to calculate the water per capita.

[a] 1883 and 1884

[27] The 1867 contract stipulated compulsory piping, but household tenants were not obliged to become customers and consume piped water. Residents could continue to rely on public fountains and on free sources of water.

The evolution of consumers and private consumption in Lisbon reflects the company's tariff policy (see Table 4). The number of consumers increased significantly throughout the years 1870-1894, particularly after the 1880 approval of the compulsory piping regulation. Water consumption did not show similar growth rates during the same period, as is well illustrated in the evolution of consumption per head among the company customers (see Table 4, last column).[28] The levels of water consumption per head per day not only were very low, but steadily decreased until the end of the century. This trend changed after the approval of the new tariff in 1898, suggesting that the water price policy did not produce the consumption expansion strategy on which the administrative decision to introduce compulsory piping was based.

Finally, the 1867 contract also introduced a new institutional arrangement for providing current regulation over the company's operation. The 1855 provisional contract, clauses for the contest, and the 1856 contract all stipulated that the government and the municipality should have two representatives on the company's board of directors. The large municipal assets (previous waterworks belonging to the *Aqueduto das Águas Livres*) given in tenure to the *Companhia das Águas* justified the presence of these representatives on the board. In 1867, an independent body was created, a committee of control whose members were appointed by the government and the municipality, the function of which was to survey company activities. An arbitration committee was established to deal with disputes between regulator and company.

Agency Problems in Water Management and Regulation: The Municipalization Threat. Contracts and the other regulatory devices did not prevent conflicts between the concessionaire and administration, mainly with the local city council. The 1858 contract was very detailed compared with the governmental terms of reference for the 1852 contest. The 1867 contract was even more comprehensive. However, all of these contracts were discussed for years, a situation repeated for the contract signed between the municipality of Oporto and the French concessionaire for water supply to the second largest Portuguese city.[29] Limited rationality from economic agents prevents anticipating every possible situation that might occur in relations between the company and its customers, or the company and the administration. The perfect contract, regulating the private company concession, and securing business

[28] Unfortunately, the company's accounts did not give details on private consumption before 1880, preventing comparison between consumers and consumption at the beginning of the series.

[29] In the case of Lisbon the decision concerning the 1855 bid became public in 1856, but the contract was signed in 1858. The new contract, in 1867, ended a long process of negotiation begun in 1865. The Oporto contest was decided in 1880, but the contract was signed in 1882.

expectations in a new industry as well as consumers' prospects, was beyond their reach.

Some issues provided a motive for recurrent disputes between the administration and the private concessionaires for water supply in Lisbon and Oporto. One of the most important and frequent of these was the companies' non-observance of the works project stipulated in the contract and in further agreements. This failure to comply with previous agreements affected the companies' ability to supply the quantity of water stipulated in the contract and within the agreed deadlines. In Lisbon, this was the reason for the government's decision to break off the contract with the concessionaire in 1864, as well as for crises in 1888 and the 1920s.[30] In Oporto, the delayed signing of the contract in 1882 was due to the renegotiation of some of the clauses that provided the basis for the 1880 contest. Later, the 1882 contract was also renegotiated to accommodate some demands from the company. The volume of water supplied was far below the threshold of 100 liters per head per day, proposed as the basis for bidding. Furthermore, insufficient numbers of the steam engines necessary for taking the water to the company's reservoirs to be distributed by the network had been acquired.[31]

Another source of conflict was the need for companies to enlarge their consumer base. In Lisbon an attempt was made to do this through was the aforementioned compulsory piping of households. The dispute between the city council and its opposition, the *Associação Comercial de Lisboa* (a business association), was fierce, and a great debate ensued in the newspapers and the Parliament. In Oporto, the 1882 contract also contained an obligation to link households to the company's main pipes. It stipulated that when the construction of the modern waterworks was complete and the company began supplying water to the pipes, a law to enforce mandatory water piping for all houses whose revenue was higher than a certain threshold should be approved, with installation costs to be paid for by the owners. The company ended construction of the waterworks in 1886, and requested the contractual clause be applied, thus making water piping compulsory.[32] Conflict with the population, business associations, and opinion makers followed, just as it had in Lisbon.

The third cause of conflict between the administration and private operators was the amount of water available for municipal use. In every contract, there was a clause stipulating that the municipal council should receive a certain amount of water for free. Any excess would be charged at

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[30] Even before signing the contract in 1858, the company attempted to drop some of the waterworks provided for in the conditions for the 1856 contest. This was the main reason for the delay in the signing of the 1858 contract.

[31] The municipality and the company agreed to this change to the previous contract in August 1887.

[32] It was approved by the municipal council in May 1886 and immediately applied.

a reduced price (as a rule, half the average tariff to private consumers). The Lisbon case represented the greatest difficulties, as the municipality of Oporto had access to its own water supplies.[33] The situation concerning disagreements about the amount that should be paid for public consumption beyond the volume of water supplied for free started to deteriorate in the 1880s, due to with the accumulation of several years of municipal debts. The municipality contested the charge for this excess water, saying that the company was trying to force the city council to pay for its own inability to enlarge private consumption and its entrepreneurial inefficiency. It also argued that the margin for leaks and the resulting water loss, which artificially expanded public consumption, was higher in Lisbon than in any other city.[34]

It is difficult to disentangle the truth from the arguments presented by the company and the local administration. In fact, the municipality occupied the most important place in the water consumption structure and its position did not change much throughout the period under consideration (see Table 5). Thus, it is true that the company showed poor performance in enlarging private consumption, transforming the local and central administrations into the main revenue sources for the private company. The local administration's position as a consumer might be compared with the situation in England, at the beginning of the period displayed in Table 5; in 1882 in forty-eight leading provincial towns only 6.3 percent of the water was supplied for public use, compared with 60.3 percent delivered to domestic households, and 33.4 percent used by industry and trade.[35]

Finally, contracts with such a long time-span (almost a century) had to move in line with population growth and increase in accordance with the demand dictated by new patterns of comfort. Scientific discoveries, proposing new methods to guarantee drinking-water quality and protection against threats to its purity, also influenced regulator-utility relations. Gradually, the credibility of bacteriological water analysis increased and chemical methods became less important in guaranteeing water quality.[36] Increasingly, the bacteriological analysis methodology was

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[33] However, when municipal consumption increased, the Oporto municipality asked that the amount of water to be provided by the company for municipal uses be renegotiated (new contract in 1901).

[34] In fact, the municipality stressed that the losses due to water leaks were only 10 percent of the water supplied to Lisbon, when in other countries the proportion was 20-30 percent; see *Actas das Sessões da CML* [Proceedings of the Municipal Council's sessions], 21 July 1919, p. 131.

[35] J. A. Hassan, "The Growth and Impact of the British Water Industry in the Nineteenth Century," *Economic History Review* 38 (Nov. 1985): 542.

[36] For the development of bacteriology in medicine and its effects on disease control see Jean-Nöel Biraben, "Pasteur, Pasteurization and Medicine" in *The Decline of Mortality in Europe,* ed. Roger Schofield, David S. Reher, and Alain Bideau (Oxford, U.K., 1991); J. Mokyr and R. Stein, "Science, Health and

acknowledged as crucial to certifying water purity.[37] In Lisbon, on the occasion of typhoid outbreaks in 1907, water quality was implicated as a possible cause of the many deaths. Infiltrations in water pipes coming from cesspools and old sewer pipes were responsible for the spread of such water-borne outbreaks.[38] Pressures on the utility to modernize its quality-control methods became a new source of conflict.

TABLE 5
Companhia das Águas de Lisboa
Public consumption of water (cubic meters), 1883-1914

	Total Consumption	Public Consumption			
		Total	% of Total Consumption	Municipal	% of Total Consumption
1883-1884	5,948,572	4,556,611	77		
1885-1889	8,635,995	6,976,318	81		
1890-1894	8,460,427	6,558,216	78	5,209,761	62
1895-1899	8,369,300	6,466,056	77	5,028,442	60
1900-1904	9,547,789	7,261,195	76	5,750,331	60
1905-1909	11,971,270	8,966,992	75	7,186,552	60
1910-1914	13,239,006	9,836,152	74	7,703,909	58

Source: Álvaro Ferreira da Silva, “The peculiar customer: conflicts of power and the modern water supply system Lisbon,” in Denis Bocquet

Household Technology: The Effect of the Pasteur Revolution on Consumer Demand” in *The Economics of New Goods* (Chicago, 1997); G. Rosen, *A History of Public Health*, ed. T. F. Bresnahan and R. J. Gordon (New York, 1958); C.-E. A. Winslow, *The Conquest of Epidemic Disease* (Princeton, N.J., 1943).

[37] Christopher Hamlin, “Edwin Chadwick and the engineers, 1842-1854: the Systems and Anti-Systems in the Pipe-and-Brick Sewers War,” *Technology and Culture* 33 (Oct. 1992): 680-709; John Hassan, *A History of Water in Modern England and Wales* (Manchester, U.K., 1998).

[38] In 1913, a new typhoid outbreak led to the very first proposal for the creation of bacteriological purification stations. In addition, a new program for waterworks to improve the quantity and quality of water provision was considered. In Oporto, the 1903 typhoid outbreak raised the same concerns over water quality.

(ed.), *Réseaux techniques et réseaux de pouvoir dans les villes européennes (XIXe siècle-début XXe siècle*), (Rome, 2002).

In addition, urban growth constituted a threat to water supply per capita levels in the first phase of waterworks modernization. The problem was particularly acute in Oporto, where the first concession only provided about 40 liters per head per day. From the start, this was a very small volume of water compared with international standards and technical opinion at the time.[39] In Lisbon, the volume of water followed the population increase (see Table 6, column on consumption lhd). However, it did not reach the contractual minimum threshold level of 100 liters per head per day, and was also well behind other cities at the time; the average consumption was over 150 liters per capita in English, French, and German cities.[40] Italian cities, such as Rome, Florence, Turin, and Milan had private consumption in 1908 above 110 liters per capita per day.[41] It must be noted that those ratios included all the water consumed in the city of Lisbon, including industrial and municipal uses. If private consumption were isolated, then the average consumption per head per day would fall to less than 30 liters, when considering the level of consumption in 1900 (see Table 4).[42] These were very low levels of consumption, particularly because they include only the company's private customers, who were mostly well-off city residents.

These issues were responsible for systematic conflicts between the concessionaire and the administration. The case of Lisbon provides a clear

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[39] In 1864, Henry Gavand estimated 40 liters per head per day to be the minimum level, not including the water needed by the local administration, which would double this estimate. See Henry Gavand, *Estudo sobre o abastecimento d'agua da cidade do Porto* [Study on the Water Supply to the City of Oporto] (Lisbon, 1864). At the end of the nineteenth century Montenegro cited several estimates, proposing an average consumption per head of more than 140 liters (see Montenegro, *Memoria...*,). In 1913, in the United States water consumption per head per day at the household level, aside from industrial or public use, was 60 liters per day, for a household with 2 taps, one water closet, and one bath.

[40] Marjatta Hietala, *Services and Urbanization at the Turn of the Century: The Diffusion of Innovations* (Helsinki, 1987), 101 and 201-202; Jean-Pierre Goubert, "The Development of Water and Sewerage Systems in France, 1850-1950" in *Technology and the Rise of the Networked City in Europe and America*, ed. Joel A. Tarr and Gabriel Dupuy (Philadelphia, Pa., 1988).

[41] A. Raddi, "Il consumo ed il prezzo dell'acqua potabile in alcune città italiane," in *Revista di ingegneria sanitaria*, n. 23 (1912).

[42] This calculation included only private consumers, not public consumption or the large proportion of the Lisbon population who did not have piped supplies, as is evident in Table 5. It was well below the levels of consumption proposed by Gavand 40 years earlier; see Gavand, *Estudo...* (Lisbon, 1864).

example of the problems and has been discussed in detail elsewhere.[43] It also represents the first time possible municipalization of the water supply was considered.

TABLE 6
Consumers, consumption, share prices, and financial ratios of the water company (1870-1919)

	Consumers as % of City Households	Consumption per capita (lhd)	Share Price Index (1877=100)	Financial Autonomy	Solvency Ratio
1870-1879	6.2	-	94	0.887	7.624
1880-1889	47.1	88.4	157	0.594	1.462
1890-1899	57.3	74.5	161	0.434	0.766
1900-1909	63.7	74.1	402	0.408	0.702
1910-1919	65.5	74.5	318	0.426	0.679

lhd = liters per head per day
Financial Autonomy = Capital/Total Assets
Solvency Ratio = Capital/Liabilities

In 1866-67, there was a great debate on the best way to manage the Lisbon water supply. Two years earlier, the government had denounced the private company contract and granted the municipality of Lisbon administration of the waterworks. However, the private company (*Companhia das Águas de Lisboa*) did not accept the solution, invoked property rights in order to preserve the franchise monopoly, and proposed a new contract to the government. Nevertheless, the city council supported its position for municipalization with arguments from the technical committee, appointed by the government in 1863 to analyze the water supply situation and propose the best solution.[44]

The technical committee favored municipalization. First, water provision was presented as being closely related to the drainage and sewer system. Both contributed to the improvement of sanitary and health

[43] Álvaro Ferreira da Silva, "The Peculiar Customer: Conflicts of Power and the Modern Water Supply System in Lisbon," in *Réseaux techniques et réseaux de pouvoir dans les villes européennes (XIXe siècle-début XXe siècle*), ed. Denis Bocquet (Rome, forthcoming).

[44] Municipal petition to the government, 21 March 1866, *Archivo Municipal*, 1866, pp. 2623-2626.

conditions, and work on either system needed to be planned in tandem.[45] Water supply could be a profitable business, enabling improvements in the sewer system through use of revenues from providing water to homes. Second, a need as fundamental as the water supply should not be managed by a private monopoly. The positive externalities associated with water supply and the common fears that private concessionaires would abuse their market position were emphasized. The technical committee believed only public management would simultaneously ensure moderation in price, quality of service, and extended social coverage. It was the only way "to promote greater consumption, indispensable to the improvement of public sanitation, to the creation of better hygienic habits and to the expansion of industries."[46]

The municipal administration's position had several weak points. The first was technical.[47] Even if it was undeniable that efficient water provision would benefit urban sanitation, the principle of water-carriage for waste drainage was not included in the plan to modernize the sewer system. Only the 1880 technical committee proposals for the modernization of the sewers conclusively advanced this solution. It must be remembered that in 1871, Bernardino António Gomes, a distinguished doctor and hygiene expert, favored a different solution based on traditional manual removal.[48] In the 1860s, every waste removal proposal addressed to the municipality advocated manual cleaning of privies and cesspools, and proposed pipes only for the draining of rain runoff and residual home water. Therefore, the defense of the water-carriage system as a new technology to deal with sewage problems was not considered as a possible solution at that time. In other urban contexts, it provided

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[45] "The issues related with cleaning and drainage, as well as with water provision are so closely linked that they cannot be considered in isolation, both because they both contribute to improving sanitary conditions, and because the work to be done in the sewage system or in the water provision should follow the same plan" [Municipal Petition to the Government], *Archivo Municipal*, 1866, p. 2623.

[46] Ibid., 2624. Based on the technical committee position, the municipal administration wrote a petition to the government supporting municipalization. The municipal petition ended with the demand that the city council be given the management of Lisbon water provision, and went on to ask for permission to contract a loan in order to finance the work needed to modernize the water supply.

[47] The financial and organizational problems will not be discussed here. For a longer explanation see Álvaro Ferreira da Silva, "Running for Money: Municipal Trade in Lisbon (1860-1910)," in *Comparative Aspects of Urban Infrastructure in the 19th and 20th Centuries: Technology, Finance and Regulation*, ed, Andrea Giuntini, Peter Hertner, and Gregorio Núñez (forthcoming).

[48] Bernardino António Gomes, *O Esgôto, a Limpeza e o Abastecimento das Aguas em Lisboa* [The Sewers, the Cleaning and Water Supply in Lisbon] (Lisbon, 1871).

arguments for the municipalization of water, but it did not influence the government or public opinion in Lisbon.

The reasons that led to a call for municipalization in other urban contexts, such as the extreme sanitary problems or the refusal of private monopolies to run water supply service, were present in the Portuguese capital. However, the new sewer technology based on the water carriage system was not adopted, and did not constitute an added, compelling reason for municipalization. Furthermore, the municipality's financial resources were insufficient for the large investment needed to promote the modernization of the water supply.

Even after the definitive concession of the water supply to the *Companhia das Águas de Lisboa* in 1867, there were two other occasions before the end of the nineteenth century that municipalization could have provided the solution to improving water provision. The first occasion was in 1872 when the company presented its project of "private piping regulation," obliging all new buildings to be connected to the water network. Because the 1867 contract stipulated compulsory connection to the water network, government non-compliance would have required substantial compensation to the company. However, the reasons preventing municipalization in 1866-1867 (the lack of municipal funds and the absence of the water-carriage principle in proposals for the modernization of the sewer system) persisted in 1872.

The second occasion for municipalization occurred in 1887, following the report of a committee appointed to settle three points of a dispute between the public administration and the private concessionaire: the late approval of the "private piping regulation," which caused a shortfall in the company's expected revenues; disagreement about the amount of public consumption that the company should be paid for; and conflict concerning the responsibility of the concessionaire for the failure to provide 100 liters of water per head per day. The final report of the committee suggested that the contract be revoked and municipalization be introduced. In spite of opposition from a majority of the city council and republican propaganda against the private concession, the government backed down when faced with a legal dispute with the company and the amount of compensation that shareholders would have to be paid.[49] The price tag of municipalization precipitated a compromise. Throughout the 1880s, the company had consolidated its economic position, enlarged the number of consumers (via the compulsory connection to the water network), become profitable, and witnessed a strong rise in its share

[49] As the company's shares almost doubled between 1882 and 1883, increasing the company's value, municipalization became more expensive. On the evolution of share prices see Table 6 and Álvaro Ferreira da Silva, "The Peculiar Customer: Conflicts of Power and the Modern Water Supply System Lisbon," in *Réseaux techniques et réseaux de pouvoir dans les villes européennes (XIXe siècle-début XXe siècle*), ed. Denis Bocquet (Rome, 2002), Figure 1.

value.[50] In addition, any attack against a company with many shareholders would prejudice the State's reputation in the financial markets. A resort to debt, a structural characteristic of the Portuguese financial system in the second half of the nineteenth century, was the only means of financing the public budget deficit.[51] Therefore, the State's position was tenuous. The late 1880s were particularly difficult for the Portuguese State, as well as for the municipal council, due to the deteriorating financial situation that led to the 1891-1892 bankruptcy and abandonment of the gold standard.

Summing up, it would be an exaggeration to say that municipalization was omnipresent in the relations between the local city council and the water company. However, it haunted periods of harsher conflict, becoming a menace. These conflicts between the administration and the water company emphasize the limitation of contracts and the existing regulatory framework. Periodic revision of contracts adjusts regulatory agreements to changing circumstances or unexpected outcomes.

The relations between company and regulator also reveal opportunistic behavior on both sides. The situation related to municipal consumption is a clear example of this issue, well identified in regulation theory. This was amplified by the peculiar characteristic of the municipality of Lisbon, that is, its importance as a customer, which intensified opportunistic behavior from the regulator's side.

Systems Integration and Municipalization. To recapitulate, the state of economic knowledge in the nineteenth century, as well as public opinion, emphasized the superiority of private enterprise for modernizing waterworks and supplying water to the cities. It was assumed that private enterprise was the most appropriate institutional form for dealing with the supply of goods and services that were private by definition (that is, it is possible to prevent some individual from using or consuming a certain good or service). Private agents can better solve the inevitable agency problems associated with the management of hierarchal relationships within the firm.

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[50] See Table 6. da Silva, "The Peculiar Customer" and Álvaro Ferreira da Silva, "Público e privado na modernização das infra-estruturas: o abastecimento de água a Lisboa no século XIX," [Public and Private in the Modernization of Urban Infrastructures: Water Supply into Lisbon in the Nineteenth Century] *Urbanismo e Infra-estruturas Urbanas*, XVIII Encontro da Associação Portuguesa de História Económica e Social (Lisbon, 1998), present a more detailed analysis of the firm's performance in the 1880s.

[51] J. B. de Macedo, Álvaro Ferreira da Silva and Rita Martins Sousa, "War, Taxes and Gold: The Inheritance of the Real," in *Transferring Wealth and Power from the Old to the New World: Monetary and Fiscal Institutions in the 17th through the 19th Centuries*, ed. Michael D. Bordo and Roberto Cortés-Conde (Cambridge, U.K., 2001), .

In order to deal with positive externalities, natural monopoly issues, give guarantees to private entrepreneurs with high volumes of sunk capital invested, and simultaneously maintain the social benefits of competition, a new institutional form developed: competition to win the franchise monopoly for provision of some good or service. This solution, largely practiced in urban infrastructures, relies heavily on the efficiency of contracts as regulatory devices to deal with the peculiarities of this kind of industry. Modern water supply systems and the Portuguese experience in the second half of the nineteenth century exemplify this situation.

However, problems of agency were not solely dependent on relations within the firm. Once the franchised firm had a monopoly granted by public authorities and contractual clauses governing its operation, another problem of agency arose from the relationship between the utility and the administration. The franchised firm and the regulator had different goals and the solution for problems of agency between them involved high transaction costs, namely dealing with bounded rationality, opportunistic behavior, and specificity of assets.

We can analyze the contracts and conflicts of power between regulator and franchised firm in the case of the Lisbon water supply from this perspective. The main contractual documents regulating the franchise monopoly reveal a tentative, trial and error approach, and the influence of foreign models. They also disclose the concerns of regulator and utility. Price regulation, without any administrative means to reward sunk costs, came face to face with difficulties in giving any incentives to the enterprise other than the long-term franchise contract. Compulsory piping (in the 1867 contract) was the answer to this dilemma, using this administrative constraint to amplify the consumer base, rather than relying entirely on market mechanisms to gain an investment return on the large waterworks in the 1870s. However, until 1898 the price policy of the *Companhia das Águas de Lisboa* did not promote higher levels of consumption.

The issues responsible for conflicts of power between the private company supplying the service and the public administration may be summarized in four main areas: the quantity and quality of the water provided; the day-to-day operation of the company; the positive externalities arising from an efficient water supply; and the importance of the municipality as a customer.

The positive externalities resulting from an efficient water supply were exceptionally important in nineteenth-century cities. The significance of water for proper urban sanitary conditions was recognized as a crucial issue at the time. The decisive element that revolutionized sanitation throughout the second half of the nineteenth century was the interrelationship between a modern water supply and the solution of waste disposal through a modern sewer system.

Water played a critical role in the solution of the nineteenth century sanitation question. Abundant and universal provision of water was needed to introduce new technology in sewerage: the water carriage

system of waste disposal. If water were not provided in sufficient quantities, filth would accumulate in the sewer pipes, counteracting the benefits derived from the automated process of waste disposal. Without piped water to most households, sanitation technology based on a centralized system would be inefficient, presenting a clear case of market failure and externalities related to water provision.

The impact of the modern sewer system in the rise of water consumption is even clearer when we look at the distribution of water consumption by domestic use (see Table 7). A water-closet increased domestic water consumption by almost one third; thus, shortcomings of the water supply limited the spread of a modern waste carriage system.[52] Where this system proliferated without an adequate water supply "the result was a public health crisis and the circumstances which contributed to the growth of those two classic water-borne disease, cholera and typhoid."[53]

TABLE 7
Distribution of household water consumption
by different fittings (1913)

	lhd	**%**
One kitchen tap	20.9	35.0
Additional tap	4.2	7.0
One water-closet	19.0	31.8
One bath	15.6	26.2
Total consumption	59.7	100.0

Source: Adapted from John Hassan, *A History of Water in Modern England and Wales* (Manchester, U.K., 1998), Table 2.1
lhd = liters per head per day

In addition, even without an integrated modern sewer system in operation, the existing municipal sewers in Lisbon needed increasing water supplies, as the rapid growth of municipal consumption demonstrates (Table 5). This was one of the primary reasons why the municipality was the main company customer throughout the period considered here.

With extended social coverage and improved water supply, the city would become healthier, as recognized in the 1864 report of the technical committee appointed to assess water company service in Lisbon. Private

[52] Anthony S. Wohl, *Endangered Lives: Public Health in Victorian Britain* (London, 1983).
[53] John Hassan, *A History of Water in Modern England and Wales* (Manchester, U.K., 1998).

water supply was judged to be inefficient in addressing the social and health aspects related to the strict relationship between water and the sanitary conditions of the city.

All these reasons pushed the municipality to take over the water supply. Positive externalities from the consumption side are the most important motive in other contexts.[54] When there are positive externalities at the consumption level and extraordinary transaction costs, incentives are high to municipalize the water supply to internalize these externalities. In Lisbon in the latter half of the nineteenth century, regulatory devices were imperfect and there were recurrent conflicts between regulator and utility. Contemporary observers emphasized the positive externalities that would arise from an improved water supply and in view of the appalling conditions of urban sanitation and low water consumption levels.

Moreover, just as systems integration between the water supply and the sewer system was critical to a revolution in nineteenth-century sanitation, there was another incentive to municipalization. Vertical integration between both systems, consolidated under municipal management, occurs with municipalization of the water supply. Theoretically, vertical integration becomes an alternative when transactions demand specific investments and there are high costs associated with servicing contracts. As a result, technical interdependency between sewerage and water supply, coupled with high transaction costs associated with regulation, was a strong incentive to consolidating management in one entity: the public administration.

In the case of Lisbon, another reason emerges. The recurrent bitter disputes between the water company and the municipality, which were virulent at times, were the result of their peculiar relationship. The local administration was by far the company's largest customer, as well as its main debtor, which forever poisoned their relationship. Calculating the actual amount of water consumed by the administration above the assigned quantity was a permanent source of controversy. As a result of this peculiar relationship between client/regulator and utility, there was a powerful motivation for the municipality to take control away from the private company. Aside from any public health reason that might arise from better, cheaper, and extended water provision, efforts to control the water supply can best be explained as an attempt to centralize administration of a service whose main consumer was the city council.

However, the Lisbon water supply was not municipalized in the latter half of the nineteenth century. To reiterate, financial problems associated with the very limited municipal revenues, and technical issues

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[54] Silva, "The Peculiar Customer"; Robert Millward, "Privatisation in Historical Perspective: the UK water industry," in *Money, Trade and Payments: Essays in Honour of D. J. Coppock*, ed. David Cobham, Richard Harrington, and George Zis (Manchester, U.K., 1989); Hassan, "The Growth and Impact of the British Water Industry."

related to the underdevelopment of the modern sewer system, were the main reasons the municipalization did not occur.

The economic impact of the First World War, together with quantity and quality complaints about the water supply, launched another wave of municipalization. At the end of the 1910s, the private water companies in Lisbon and Oporto that remained from the nineteenth century franchise water supply companies faced mounting energy costs[55] and wage demands from employees[56] in a situation of political and social unrest. Tariff increases were banned by contract, unless authorized by the government. Administrative decisions on the revision of water tariffs demanded hard and long negotiations, with short-lived governments. With escalating prices the financial position of the companies weakened and investment in waterworks vanished.[57]

The *Companhia das Águas do Porto* was municipalized in 1927, after a long process that began in 1920 with the creation of a committee to analyze water supply conditions in Oporto. The municipality paid an indemnity of 3,500 *contos de réis* to the company to take over the waterworks.

In Lisbon, the process was very similar, but it did not end in municipalization. The reasons for this different outcome are discussed elsewhere. The high cost of the indemnity to consolidate the franchise monopoly before the end of the contract was one of the reasons.[58] The other reason was the difference in water supply situations in Oporto and Lisbon. The situation in the second largest Portuguese city was worse in terms of both the quantity and the quality of water provided. The French company invested very little in waterworks and its response to the difficulties generated by the war was to lower the quality of the service provided. In addition, the *Companhia das Águas de Lisboa* had a large numbers of stakeholders (almost all Portuguese).

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[55] As a result of the wartime crisis in the provision of strategic goods, the price of coal increased as it, too, became scarce. At the end of the 1910s, Portugal suffered a large currency devaluation, which aggravated the cost of imported goods. At the time, the water companies tried to find substitutes for coal, which was used by the steam engines that carried the water, using gas or firewood. Some of Lisbon's reservoirs also substituted electric power for steam power.

[56] In 1917 and 1919, two strikes paralyzed the company in Lisbon. The first one involved the intervention of military forces to protect the premises and equipment. In 1920, the Oporto water company also had to face workers' wage demands.

[57] By 1924, the price index had increased 24 times since the First World War began, with annual inflation rates in double figures. For instance, in 1920 the inflation rate was 73% and in 1921, 57%.

[58] The arbitration committee fixed the indemnity at almost 21,000 *contos de réis* (*Actas das Sessões da CML*, 14 Feb. 1926) Considering the high cost of municipalization, the city council decided to give up the contractual possibility of taking over the company before the end of the contract.

The Lisbon water supply problem was not only technical (the need to increase water volume and prevent bacteriological contamination), but also financial (the financially weakened private company needed to secure the capital for large investments). The solution was an original one: private property rights were maintained, but a tight regulatory framework emerged, which took all authority away from the *Companhia das Águas de Lisboa* concerning share dividends, new works, and financial organization.[59] The attitude of the new authoritarian regime was characteristic of its typical position with regard to private enterprise: it attempted to create a barrier between the past and the future, honoring property rights, but introducing changes that transformed actual institutional operations (in this case, of the Lisbon water company) of those experiencing intervention.[60] As an illustration of the new regime's nature and disposition, the negotiation for a new contract was presented by the Public Works Minister as follows: if the company accepted the contract clauses completely and unconditionally, it would continue as concessionaire; should it fail to accept them, the State would act on its right to rescind the franchise.

Networks of Power: The Development of Gas and Electricity in Portugal

Introduction of Gas Supply. The creation of gas networks in Portugal was initiated in the mid-nineteenth century: Lisbon in 1848, Oporto in 1855, and Coimbra in 1856. However, gas networks did not spread to other cities until the 1880s, when several foreign gas companies tried to win new markets. Thus, only foreign enterprises tried to obtain franchise contracts in Portuguese cities during this period of expansion. The large investments needed to build a gas plant and to install the network explain this time-lag in the spread of the gas supply to smaller cities. Market considerations explain why the largest cities were the first to be served by the new power technology.

A city's gas supply monopoly was associated with the contract to provide public lighting throughout the municipality. This constituted a crucial step in ensuring an early consumer base, before the use of gas for domestic and industrial uses became widespread. As in the case of water supply, gas companies also tried to obtain long time periods for exclusive operation, in order to support the high sunk costs.

In Lisbon gas production and distribution was first assigned to the *Companhia Lisbonense de Iluminação a Gás*. After 1887, the public lighting franchise contract was won by the *Companhia Gás de Lisboa*, the

[59] The 1932 contract, which introduced major changes in the regulatory framework, will not be analyzed here.

[60] After 1926, there was a military coup that ended the democratic Republic. A non-parliamentary regime (the *Estado Novo*) emerged, which lasted for 48 years.

capital of which was mainly held by the *Société Éclairage du Centre* (Belgium), which won the bid, and by two former candidates for the franchise, Léon de Somzée (Brussels) and Kohn Reinach and Company (Paris).[61] The *Companhia Lisbonense de Iluminação a Gás* competed with the new *Companhia Gás de Lisboa* to supply domestic and industrial consumers. This peculiar situation ended in 1891 when both companies merged to form the *Companhias Reunidas de Gás e Electricidade* (CRGE).

When the new gas franchise contract was signed in 1887, electricity was already a possible competitor for street lighting. Therefore, the municipality pledged not to launch any other technology for lighting during the first 10 years, in order to secure the investments the company had to make in order to modernize the gas network. The duration of the franchise contract was also extended from 30 to 60 years in 1891. Gas for public lighting was sold below the general tariff and was to decrease at the same rate as the increase in the number of domestic consumers. Once private consumption reached 17 million cubic meters, gas for public lighting would be supplied free of charge.

In Oporto its former concessionaire, Hardy Hislop, transferred the franchise contract to the *Companhia Portuense de Iluminação a Gás*.[62] In 1889, a new contract was made with the *Companhia Gás do Porto*, which continued to manage the service until its municipalization in 1920.

Difficulties in the Creation of Gas Networks. There were differences in the creation and development of the Lisbon and Oporto gas networks. Although the steep slopes characteristic of both cities created installation difficulties, in the early years the Oporto gas company faced greater troubles than its Lisbon counterpart, owing to its plant location. In addition, the market's response to the introduction of gas was also different in both cities.

In Lisbon, gas plants were located in Boavista and in Belém, near the Tagus River, in industrial districts within the city, and not far away from the residential areas. In fact, the gas plant of the *Companhia Lisbonense de Iluminação a Gás*, built in 1848, was established downtown, near the Tagus River and the port. This facilitated the circulation of gas to upper areas of the city without using much pressure. The proximity to the river made it easier to import coal from England and allowed the smoke being emitted from the gas plant to be directed to the

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[61] See Alice M. Martins, Campos Martins e Coelho, and Adriano Pinto, "A fábrica de gás de Belém: os projectos e os processos de produção no final do séc XIX" [The Gas Factory in Belém: Projects and Production Processes at the End of the Nineteenth Century], *Arqueologia & Indústria*, 1988 .

[62] "A contract agreed between Hardy Hislop and the Board of the *Companhia Portuense de Iluminação a Gaz* on 16 August 1854," AHMP-Casa do Infante. Documentos Originais. Obra Pública. 5751-1975, vol. 3 doc. 7.

river, reducing pollution in residential areas.[63] The location of the new *Sociedade Gás de Lisboa* gas factory, built in 1887, was also near the river. However, none of these factories in Lisbon were very distant from residential districts and all remained close to Lisbon's industrial areas.

In contrast, the contract between the municipality of Oporto and Hardy Hislop specified that the gas plant should be constructed beyond the city limits, at a location with few inhabitants, on a plot of land provided by the city council. In order to evaluate the costs associated with the installation of gas plumbing into the city, Hardy Hislop asked the engineer Geddie Pearse to produce a city map and prepare a report on the technical and economic viability of the venture. This report provides an interesting account of the kind of technical and economic problems associated with setting up the gas networks.[64] Pearse believed that the place chosen by the municipality had several inconveniences. First, the topographical characteristics of the plant site required significant work to level the soil. Second, it would be difficult to ship coal to the plant, despite its location near the river. Finally, the long distance from the city center would impose severe costs because the company would have to construct all the piping needed to serve the main residential areas. Eventually Hardy Hislop decided to build the gas plant on the land provided by the municipality. In the ensuing decades, the decision regarding the gas plant location and mistakes in the installation of both the plant and the piping regularly affected the gas supply. Furthermore, the periodic flows of the Douro interrupted gas production. The work to correct previous errors had a very negative financial impact.

In Lisbon, it was the topography that made gas supply difficult. The city's many hills and the fact that the residential nucleus was spread over a wide area meant the need to construct a large network. Moreover, the hills prevented stable gas pressure from being maintained in different areas, which led to diversity in the intensity of the lighting available.

Payment for public lighting took into account the number of street lamps installed. Therefore, the average distance between each street lamp affected the revenue of the companies. As was mentioned in the 1856-1857 *Companhia Lisbonense de Iluminação a Gás* annual report, in Paris there was a street lamp for every 25 linear meters of gas piping. In Lisbon,

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[63] Considering these advantages, the directors of the *Companhia Lisbonense de Iluminação a Gás* were against any proposal to transfer the factory to the outskirts of the city. See *Relatório da Comissão eleita em 28 de Julho de 1858 pela Assembleia Geral da Companhia Lisbonense de Iluminação a Gaz para examinar o relatório e as contas da direcção do ano económico de 1857 a 1858* [Report from the Board elected in 28th July 1858 by the *Companhia Lisbonense de Iluminação a Gaz* shareholders assembly, to examine the Board's report and accounts for the year 1857-1858] (Lisbon, 1858), 18.

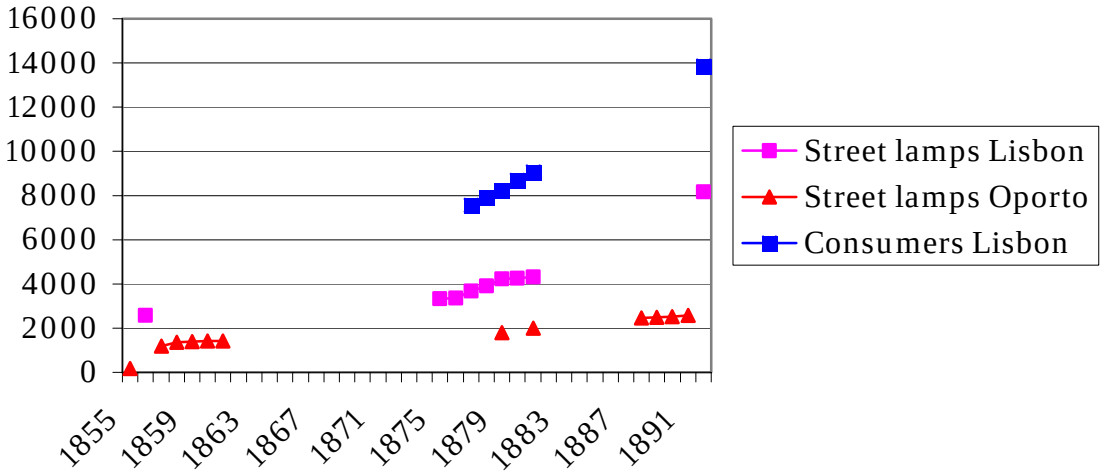
[64] AHCMP—Casa do Infante. Documentos Originais—Obras Públicas. Papéis a avulsos sobre a iluminação a gás [Papers on Gas Lighting].

however, there was only a street lamp every 54 meters. In Oporto, the distance between the street lamps was more than 45 meters.

Several difficulties were also encountered during gas pipe installation. Initially the pipes used in Lisbon had to be constantly renewed, owing to their rapid deterioration. Thus, in 1876-1877 the old pipes had to be replaced. The opportunity was used to install larger pipes in the main line distributions.

The installation of street lamps occurred at a different rhythm in Lisbon and Oporto (see Figure 1). In the largest city, the amount of street lighting increased at a regular pace during the second half of the nineteenth century. Even when the population of the city grew at a higher rate in the 1880s,[65] public lighting was able to follow urban expansion. Meanwhile, in the city of Oporto at the beginning of the franchise contract, there was an initial installation of street lighting in the commercial and residential districts but public lighting did not expand at the same rhythm as population growth. The disparity in the evolution of the ratio between street lamps and the population (Table 8) is the consequence of this different rhythm of growth experienced by both cities.

FIGURE 1
Street lamps in Lisbon and Oporto and consumers in Lisbon



[65] The 1880s experienced one of the largest rates of growth in the history of the Portuguese capital city. Álvaro Ferreira da Silva "A evolução da rede urbana portuguesa (1801-1940)" [The evolution of the Portuguese Urban Network"] in *Análise Social*, 1997, 143-144: 779-814.

TABLE 8
Ratio between the number of street lamps and the population in Lisbon and Oporto, in percent

Years	Lisbon	Oporto
1857	1.26	0.21
1878	1.72	1.70
1891	2.74	1.81

The piping for gas distribution inside buildings was the owners' responsibility. The company supported the costs of construction up to the entrance into the building. When the buildings were grouped together and located near the main pipe, installation costs were not very high. However, when they were situated very far from the main pipe, extending piping was an expensive operation, the cost of which might not be compensated by the revenue received from future consumption. Therefore, the Oporto gas company started to finance piping installation to buildings that were not more than 50 meters away from the main pipe. Otherwise, the owners had to bear the installation costs. This meant that economies of contiguity were very important in these networks, assuming relevance similar to economies of scale in other industries. The spread of the urban population and the scattering of wealthy areas across the city were important factors in rising installation costs.

Public-Private Conflicts and Regulation. The governador civil (regional representative of the central government), the municipalities, and the Public Health Committee regulated the operation of the gas companies. The municipalities had power to control and inspect the companies: the planning and installation of the network, the gas production equipment, the street lamps, and the quality of the energy supplied. This regulation evolved over the years, following the technological evolution of the industry and growth of the consumer base.

This regulatory practice was the source of recurrent conflicts between the gas companies and the municipalities. Sometimes the conflicts were aggravated by the city councils' financial difficulties when they were unable to pay for the gas consumed for public purposes (lighting the streets or public buildings). The Lisbon and Oporto municipalities tried to expand the area illuminated by gas lighting without incurring further expenditure by requiring less energy be provided to street lamps and that they should be lit at half power during nights with a full moon.

Most conflicts between the municipalities and the gas companies arose from consumers' complaints concerning leakages across the network. In the case of Lisbon, one of the first measures taken by the

CRGE after assuming responsibility for gas distribution was to begin work on the piping network "in order to, as quickly as possible, reduce the very large losses it had owing to the bad conditions of the network."[66]

The work undertaken on the network was another source of conflict, not only with the municipalities but also with the companies responsible for water supply. The area below ground, which was crossed by gas, water, and sewer pipes, required urban planning and a specialized cartography of the network infrastructure. This was rarely followed and the work carried out by water companies, gas companies, or intervention by the municipal services in the sewers affected the piping networks. In addition, the street surface was affected by the gas companies' work, causing public concern and provoking conflict with the city council.

Gas tariffs were another source of disagreement. Gas franchise contracts specified prices for gas sold to private consumers and municipalities. Therefore, the companies could not raise the tariffs without the municipality's prior consent. In periods of economic crisis, gas consumption declined, affecting the companies' revenue. When the price of imported coal increased to high levels, the gas companies tried to increase tariffs to reflect this, but they faced strong opposition from the municipalities.

Gas consumed by the municipalities had a lower tariff than that for private consumption. In addition, when private consumers reached certain thresholds the companies had to provide gas for public lighting for free. This was also a source of recurrent conflicts between companies and municipalities, aggravated by the municipal debt to the gas concessionaires. The contracts for public lighting, which at the beginning of the network installation were important in providing a financial guarantee to private enterprise, began to seem unprofitable to the companies.[67]

Consolidation of the Gas Network. Private consumption was low, due to the mild climate, which demanded little central heating, and the population's low per-capita income. Nevertheless, at the end of the nineteenth century private and public consumption increased both in Lisbon and in Oporto. Figures 2 and 3 present the available evidence on the evolution of consumption and consumers in both cities. It is interesting to note that private consumption was higher than public consumption, the inverse of water provision at the time.

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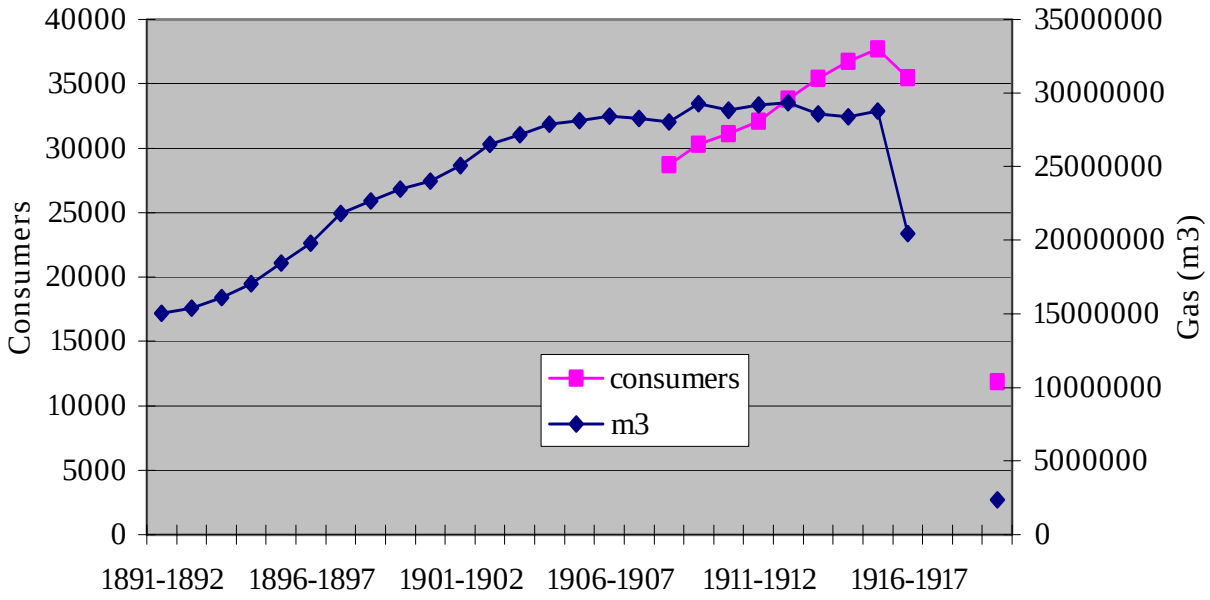
[66] *Relatório do Conselho de administração da CRGE 1891/1892* [Report from CRGE's Board], 10.

[67] This aspect is stressed in the 1885 annual report of the *Companhia Lisbonense de Iluminação a Gás. Relatório da Direcção e Parecer do Conselho Fiscal: Gerência de 1885* Report from the Board and advice from the Financial Committee] *Companhia Lisbonense de Iluminação a Gás* (Lisbon, 1886), 12.

FIGURE 2
Gas consumed in Lisbon (1891-1920)



Source: Anuários Estatísticos da Câmara Municipal do Porto (Oporto's Municipal Council Statistical Yearbook) 1889-1893.

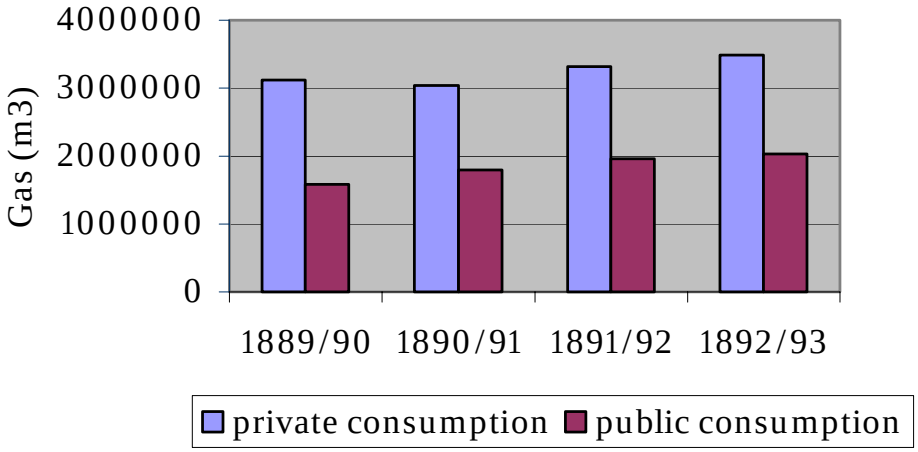
The increase in private consumption may be explained by the spread of gas cookers. To promote this sort of domestic appliance, the CRGE created a shop where it exhibited cookers, other domestic appliances, and industrial equipment. It also began to loan, sell on credit, and assist domestic consumers with this type of equipment.[68] In addition, the gas consumed for industrial uses had lower tariffs to increase its application as a power source. In both cities, the rise in gas consumption required the installation of new gas plants by the beginning of the twentieth century.[69]

At the end of the first decade of the twentieth century, gas consumed in Lisbon stabilized, after several years of remarkable rise. The substitution of gas engines by industrial engines powered by electricity was the main reason for this. After the beginning of the First World War, an increase in the price of coal led to a decline in consumption. A rise in production costs was responsible for serious losses and the company

[68] *Relatório do Conselho de administração da CRGE-1892-1893* [Report from the CRGE Board], 6.
[69] *Relatório do Conselho de administração da CRGE-1904-1905* [Report from the CRGE Board].

decided to suspend gas supply in 1918.[70] The replacement of gas with electrical power for street lighting was the main result.

FIGURE 3
Gas consumed in Oporto



Electricity as a Power Alternative for Private and Public Consumption. At the end of the nineteenth century, cities such as Vila Real, Braga, and Lisbon decided to adopt electric public lighting. In the early twentieth century, other cities followed their example, although in several towns the electricity option was complicated by contracts with gas companies for public lighting. For electricity companies, investing in providing energy merely for private consumption was risky as there was no guarantee that private consumption would support such a business venture. Thus, only a few electricity-producing companies were set up in urban centers where there were prior contracts for provision of public lighting. In Évora, for example, although a company was set up in 1905 to supply electricity only to private consumers, it struggled to obtain the public lighting contract, and finally succeeding 1917.

In the early twentieth century, electricity was introduced in several towns at the initiative of industrial firms that started using power engines and tried to gain maximum profits by producing electricity for public lighting. A somewhat paradoxical situation emerged: small towns, sometimes located very far away from larger cities and with low levels of per capita income, benefited from an early introduction of electricity.[71]

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[70] *Relatório do Conselho de administração da CRG, 1917-1918* [Report from the CRGE Board].

[71] This was the case of Elvas, Reguengos de Monsaraz, Estremoz, Penalva do Castelo and Famalicão, where the use of electricity for industrial purposes was later extended to lighting.

Municipal authorities followed two distinct paths in the creation of electricity networks.[72] In some cases, city councils granted franchise contracts, similar to those for water or gas provision. In such situations, although local authorities had the power to grant such rights, central government approval was required and there were strict legal limitations on the conditions under which councils could approve franchise contracts.[73] In other cases, municipalities were directly involved in setting up and operating electric power production plants.

Throughout the 1920s, there were several developments in the process of granting franchise contracts for the production and distribution of electricity. One of the first regionally-based companies to produce hydroelectric energy, *União Eléctrica Nacional*, founded in 1919 and operating a power station in the Douro region, supplied several towns in the region.[74]

TABLE 9
Number of municipalities with electricity

Years	Municipalities	% of municipalities
1918	41	14.9
1923	63	22.9
1928	146	53.2
1933	214	78.8
1938	244	89.0
1945	254	92.0

Source: Maximiano Apolinário, "A indústria da energia eléctrica em Portugal" [The Electric Power Industry in Portugal], in *Revista de Obras Públicas e Minas*, 583-588 (Lisbon, 1918), *Estatísticas das Instalações Eléctricas* [Electrical Installations Statistics].

During the Dictatorship period, the policy of centralization initiated in 1926 was also applied to the electricity supply, although technical aspects were a determining factor. The provision of hydroelectric power was only feasible if it served more than one municipality. Therefore, in

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[72] See Jaime Alberto do Couto Ferreira and João José Monteiro Figueira, *A electrificação do centro de Portugal no século XX* [The Electrification in Central Portugal during the Twentieth Century] (s/l, 2001), 20-24.

[73] In 1912, the *Regulamento das concessões de licenças para o estabelecimento e exploração de instalações eléctricas* [Regulations for the Granting of Licenses for the Establishment and Operation of Electric Power Stations] was introduced and remained in force until 1936.

[74] Owned by the *Empresa Electra del Lima* Company.

1927 legislation was passed enabling the government to take the initiative for fostering the formation of regional organizations for the construction or operation of one or more networks for the distribution of electricity.[75]

By 1934, 79 percent of district capitals had electricity for private and public lighting; municipalities operated 51 percent. This does not mean, however, that the electricity distribution network covered all towns, much less that it applied to the various urban centers in each district. In addition, in urban centers that benefited from electric lighting, the level of private consumption was extremely low: much lower than the average consumption for Europe.

The private consumption of electricity only began to rise when regressive tariffs were introduced, beginning in the 1930s. The 5th Congress of the International Union of Producers and Distributors of Electric Energy (UNIPEDE) held in 1934 in Zurich and Lausanne, doubtless contributed to the adoption of such pricing policies. The engineer, Ferreira Dias, who attended the congress as the Portuguese representative, affirmed that at the meeting "without concealing its doubts and reticence as regards the novelty of such pricing (which has still not disappeared completely), the organisation accepted the new pricing system."[76] In Portugal, European pricing (graded charging for different types of use) was only introduced in 1937.

When electricity became an alternative to gas for public lighting, the *Companhia do Gás do Porto* tried to obtain the concession to supply it. In the contract signed with the Oporto city council on February 7, 1894 the company agreed to supply electric power to the city. In an attempt to fulfill this obligation, the company bought a power station from another company, the *Companhia Luz Eléctrica*, which provided electricity to a small network of consumers. However, the size of the power station, as well as the dimensions of the network remained insufficient to provide public lightning. The company's financial condition worsened the situation by preventing the construction of a new power station and network or even the expansion of the former power station. This project was successively postponed, even though the municipality reiterated that the contract should be fulfilled. The solution would be the creation of a new enterprise, the *Sociedade de Energia Eléctrica do Porto*, which brought together new foreign and domestic capital, as had the CRGE, the company providing gas and electricity to Lisbon at the time.

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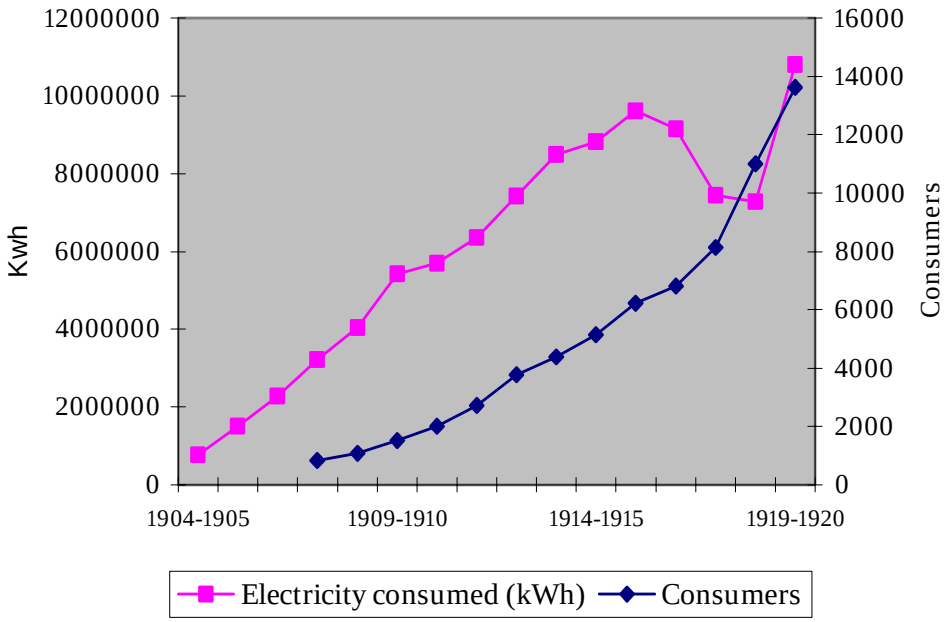
[75] Decree 14.772, of 22 Dec. 1927.

[76] J. N. Ferreira Dias, *Linha de Rumo I e II e outros escritos económicos 1926-1962*, Tomo II, Lisbon: Banco de Portugal, 1998, 207.

FIGURE 5
Electricity consumed in Lisbon



In Lisbon, the *Companhia Reunidas de Gás e Electricidade* was the result of a merger between two enterprises previously in operation. It continued to run the central power station in *Avenida da Liberdade*, where, in 1892, there were 37 arc lamps.[77] The capacity of this power station was insufficient to significantly increase the electricity network. The construction of a more extensive network required a much greater investment and there had already been a major investment in the gas network. In order to support this effort, the Municipal Council promised to maintain lighting based on gas for at least 10 more years. In addition, the concession for electricity exploitation by the CRGE was extended for 30 years.[78]

As the CRGE exploited gas and electricity, there was no competition between alternative systems for lighting. Therefore, there was not much pressure on the company to lower the prices, as was the case in other cities where such competition did exist. In the same way, monopolistic exploitation of the Lisbon electricity network kept away competition from other electricity enterprises.[79]

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[77] *Relatório do Conselho de administração da CRGE-1892/93* [Report from the CRGE's Board], 8.
[78] Condition 5 of the contract between the City Council and the CRGE (Lisbon, 1898), 5.
[79] The situation in other Iberian cities, like Madrid or Barcelona, was radically different.

However, even if economic competition was not a determining factor in lowering electricity prices in Lisbon, the contracts between the municipality and the company regulated prices and conditions for supplying gas and electricity to the city. The defense of public interest and against any tendency to suffer the consequences of the monopolistic position of the company over the market were the principles behind this regulation, in the same way as was the case for the water supply. In order to guarantee that the city would not be in the dark (and suffer the inconvenience and threats to security that would pose), the municipality required the company to maintain gas lighting as a reserve network.[80] This situation demanded parallel investments in gas and electricity networks for public lighting and negatively affected the expansion of the electric street lighting compared with the use of electricity in industry and at home.

The capacity of the old power station in *Avenida da Liberdade* was not enough to significantly increase the electricity network. Therefore, a new power station was constructed in *Boavista*, which began operations in 1903. During the following years, electricity consumption surpassed the company's predictions, necessitating the installation of two other 1,500 c/v units. The rise in consumption was the result of lower tariffs.[81] In 1906, electricity consumed increased 41 percent over the previous year, largely due to its use in industrial engines, which grew by 220 percent.[82] Until then, the use of new energy sources in industry had not affected the company's gas revenues, because the engines substituted were mainly steam engines. However, in 1908 several industrial engines using gas were replaced by electrical ones, which caused a 198,695 cubic meter reduction in gas sales. At the same time, electricity consumption for industrial power increased from 200,000 Kwh in 1906 to more than 1,100,000 Kwh in 1908.[83] In the following years, there was a rise in both electricity consumption and the number of consumers (see Figure 5). Electricity consumed grew at a faster rate than the number of consumers, indicating that the power was largely employed for industrial uses. The increase in electricity consumption required construction of a new power station, the

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[80] See the 5th condition in the *Contracto para a Nova Illuminação a Luz Electrica de diversas ruas, praças e avenidas celebrado com a Sociedade Companhias Reunidas Gaz e Electricidade em 25 de Fevereiro de 1905* [Contract for New Lighting in Several Streets, Squares and Avenues Celebrated with the *Sociedade Companhias Reunidas Gaz e Electricidade* 25 Feb. 1905) (Lisbon, 1907), 5.

[81] *Relatório do Conselho de administração da CRGE-1905/1906* [Report from the CRGE Board], 6.

[82] *Relatório do Conselho de administração da CRGE-1907-1908* [Report from the CRGE Board], 5-6.

[83] *Relatório do Conselho de administração da CRGE-1907-1908* [Report from the CRGE Board], 6.

Central Tejo, the first phase of construction of which was finished in 1911. The war prevented further power station expansion, and work resumed only after the end of conflict.

After 1915, there was a decrease in electricity consumption, even though the number of consumers was rising. This was due to problems with the coal supply, which led the company to ask consumers to reduce their power consumption. An increase in tariffs also explains the reduction in per capita consumption. It was only after the end of the First World War that the coal supply was back to normal and electricity consumption reached its full potential.

Electricity replaced gas for public lighting, but at a slower pace. In 1905, the CRGE signed a contract with the municipality of Lisbon to substitute 177 street lamps powered by gas.[84] The large investments the company had made in renewing the gas network for public lighting at the end of the nineteenth century explain this slow move to substituting electricity. In 1908, the number of electric street lamps rose to 293.[85] During 1917-1918, the war was responsible for a dramatic change. The company suspended gas supply for public lighting and replaced it with electrical energy and, in some cases, oil.

The increase in electricity consumption required the construction of a new power station, the Central Tejo, the first phase of construction of which was finished in 1911. The war prevented the expansion of the power station, and work only resumed after the end of conflict.

In Oporto, electricity supply began in 1909, when the power station *Central do Ouro* was finished. In 1912, the number of consumers reached 1,250. Of these consumers, 100 used electricity as a source of industrial power and for lighting. In the following years, the number of consumers increased and by 1917 reached 4,303.

A study of the companies' installation of electrical cables provides an interesting comparison of the electrical power networks in operation in both cities (Table 10). The electrical power network was more extensive in Lisbon, as was the case in the street lighting comparison. In Oporto, the electricity supply was restricted to the city's central districts. The city council recognized this situation after municipalization, but its financial difficulties prevented any further expansion until the mid-1920s.

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[84] See condition 5th in the *Contracto para a Nova Illuminação a Luz Electrica de diversas ruas, praças e avenidas celebrado com a Sociedade Companhias Reunidas Gaz e Electricidade em 25 de Fevereiro de 1905* [Contract for New Lighting in Several streets, Squares and Avenues Celebrated with the *Sociedade Companhias Reunidas Gaz e Electricidade* in 25 Feb. 1905] (Lisbon, 1907), 5.

[85] Câmara Municipal de Lisboa, *Contracto de 28 de Novembro de 1908 com a Sociedade Companhias Reunidas de Gaz e Electricidade* (Lisbon, 1911), 5.

TABLE 10
Ratio between the linear meters of electrical cables and the population in Lisbon and Oporto, in percent

Years	Lisbon	Oporto
1911	62.87	17.68
1920	89.44	38.51

The municipalization of the Oporto electricity supply cannot be separated from the municipalization of the gas supply, owing to the close relationship between the companies operating these services. The First World War aggravated the losses of the *Companhia do Gás*. The rise in coal prices caused severe irregularities in gas supply, particularly for public lighting. After 1915, the municipality considered municipalization, but that did not occur until 1917, when the decision was made to also extend the public takeover to the *Sociedade de Energia Eléctrica do Porto*. This decision led to vigorous complaints by this enterprise, which argued that it should continue to operate normally. The municipality claimed that the transfer of the concession for electric public lighting between the two companies in 1907 was approved on the condition that the responsibility for public lighting would lie with the *Companhia do Gás* and would be associated either with the gas or the electricity supply.

When the municipality began to run the *Central do Ouro*, the installation and engines could not provide the electricity needed to supply the city. Therefore, the city council asked for help from the *Companhia de Carris de Ferro do Porto* (an urban public transport operator) in order to ensure the supply of electricity to part of the city.[86] Once they alleviated the pressure on the *Central do Ouro*, it was possible to repair the generators and resume regular electricity supply.

In 1919, the war was over and the municipality hoped that the provision of gas and electricity would provide some profits, in order to compensate for prior investments, improve services, and extend the network. However, against all expectations, there was a deficit in 1919, a situation that continued until 1922. This deficit was partially caused by the fact that the tariffs for gas and electricity lagged behind inflation. However, the joint provision of gas and electricity brought together different costs related to the provision of the two services. Gas always produced losses. In contrast, the electricity supply was profitable, which produced a balance in the joint cost of the supply.

In Lisbon, municipalization did not occur. The gas and electricity company suffered losses and had poor financial performance during the

[86] Câmara Municipal do Porto, *Parecer do Delegado Municipal, Director technico da Exploração sobre a Exploração futura dos mesmos serviços*, ob. cit., 5.

war period. However, the CRGE was not municipalized, a situation similar to that of the water company operating in the capital city.

Conclusion

These modern utilities had common characteristics associated with network infrastructures, namely the systemic approach used in designing, operating, and expanding them. High sunk costs and asset specificity were other shared features of these investments. There were also issues related to their operation as natural monopolies or the positive externalities resulting from their use and expansion.

Therefore, there were also common themes behind the conflicts that caused local and state authorities to oppose private companies' provision of water, gas, and electricity. Contractual design, tariffs, and the increased pressure on the streets constitute the primary reasons for the controversy. The first two points are directly related to the regulatory framework that was tentatively erected during the period. The last point highlights another common issue linking all these utilities. In fact, the new nineteenth-century urban infrastructures (gas, electricity, sanitation, and transport) all shared the use of public resources such as roads. This source of conflict derives from the trend towards rising and intense pressure on the city streets, not only as a means of circulation, but because the cables, pipes, or tubes necessary for the operation of the new urban infrastructures were placed under the pavement.[87]

There were also some notable differences. One of them concerned barriers to entry, which were less important for gas and electricity supply than in water supply. The gas and electricity operations in Lisbon and Oporto created other enterprises that tendered bids for the franchise contract when it came to an end. The introduction of electricity provided competition with gas companies for public lighting, something that did not occur in the case of the water supply. Moreover, the technologies used for electricity production and distribution in the late nineteenth century provided limited economies of scale. The low voltages of the direct current systems restricted the size of the area that could be served by a central station. In addition, the direct current voltage used by companies during the 1880s and early 1890s could not easily be stepped up or down to match consumers' requirements. Therefore, different types of users could segment the market (traction, incandescent lights for private lighting, or arc lights for street lighting).

The conflicts also seem to have been less fierce in the case of gas and electricity than for the water supply. Two reasons may explain this difference. One of them is related to the easier contractual design

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[87] François Bédarida and Anthony R. Sutcliffe , "The street in the structure and life of the city: reflections on nineteenth-century London and Paris" in *Modern industrial city. History, policy and survival,* ed. Brice M. Stave (Beverly Hills, 1981).

associated with the provision of one public good, street lighting, compared with the bundle of externalities connected with sanitation involved in supplying water. Measuring output and monitoring quality was easier in the case of lighting, compared with water provision. The number of lamps operating on a given night, the number that remained unlit, and the quality of the illumination could be easily controlled on a day-to-day basis. The quality of water and its provision to private consumers was less easily monitored. Another reason for the more intense clashes between municipalities and water companies involves the greater positive externalities associated with water supply, as well as its close relationship to the sewer network, which constitutes a single system, modern sanitation. We have emphasized the importance of this interrelationship as one of the reasons for conflicts between water companies and municipalities.

The probability of becoming municipalized was not associated with the type of utility. Local conditions (political, financial, and business) seem to have been more important than the type of utility. Oporto municipalized all the modern networks we have addressed. In Lisbon, however, water, gas, and electricity companies remained private for a long time. In the case of water supply, the difficulties faced by the company were enormous, but it escaped municipalization.