Criticality of Investments and Organisational Centralisation: Econometric Evidence from Drinking Water Services in France

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Abstract

The recent literature on the coherence between institutions and technology in network industries considers infrastructures as large technical systems. As such, in order to safeguard infrastructure performance, their technical integrity must be guaranteed. Core transactions, i.e. transactions involving highly specific and critical assets, therefore need to be aligned with suitable modes of organisation. Decentralisation of decision rights on critical assets can lead to high coordination costs. The results of an econometric test within the French drinking water sector support the idea that the existence of critical assets is linked to modes of organisation where decision rights on these assets are highly centralised. As a policy implication, local authorities should not only think in terms of public or private provision of water services, but also in terms of distribution of decision rights and possible coordination problems, especially in lease contracts, if their knowledge of the underground network is low.

Key words: Decentralisation, decision rights, modes of organisation, public-private partnership, water sector, critical assets, transaction costs, coordination, econometrics

1. Introduction

This paper studies the idea that critical investments in infrastructures, like underground networks, require centralised modes of organisation and offers an econometric application to the French drinking water sector. The reasoning used is close to the make-or-buy question in transaction costs economics and to the role of asset specificity for vertical integration (Coase, 1937, Williamson, 1985, Joskow, 1988). Transaction costs economics teaches that the presence of specific assets in association with uncertainty raises the risks of opportunistic behaviour. This is why modes of organisation will tend towards integration or long-term contracts, which provide more suitable coordination mechanisms like authority or contractual instruments to resolve such problems. This paper borrows from these ideas but considers several of their aspects from a different perspective. These differences arise out of the proximity of the argumentation with a new strand of literature, namely the literature on the role of coherence between technological characteristics and institutional arrangements in network industries (Finger et al., 2005, Ménard, 2009, Künneke et al., 2010, Crettenand and Finger, 2013). Substantively, attention must be given to three points.

Firstly, this paper considers infrastructures as large technical systems, thus stressing the importance of technology. Infrastructures consist of various strongly complementary technical components. An example of such complementarity can be given by water distribution networks which combine pipes, pumps, valves and more. The technical integrity of the overall system must be secured so as not to endanger the functioning of the service (Künneke et al., 2010, p. 495). The consideration of technology is missing in the traditional make-or-buy literature.

Secondly, whereas the literature on vertical integration underlines the decisive role of asset specificity in the choice of governance structures (Williamson, 1983, Riordan and Williamson, 1985), emphasis here is placed on so-called critical assets (Künneke et al., 2010, p. 496). In doing so, the fundamentality and indispensability of these assets for the technical integrity of the system is underlined. In the distribution of drinking water, one might think of pipes. The underground transmission and distribution networks are particularly critical to the provision of drinking water services. They will also form part of the focus of this paper.

Thirdly, it is not enquired whether water services should be provided through public or private management in order to perform well as in the classical make-or-buy literature. This is justified in the light of recent indications that ownership might not be the key issue for infrastructure performance (Ménard and Peeroo, 2011, p. 321). Rather, the focus lies on the

(de-)centralisation of decision rights on critical assets, and more particularly, the analysis of whether these decision rights are concentrated in a single organisation or dispersed, i.e. distributed among the entities constituting a hybrid governance structure. This approach highlights potential coordination problems resulting from the splitting and sharing of decision rights (Ménard, 2013, pp. 149 f., 163 f.). The question is therefore in what cases do decision rights need to be centralised and when can they be more decentralised?

Although the still very young literature on coherence has already brought forward a considerable amount of empirical analyses, namely in the form of case studies (Künneke and Finger, 2007, Crettenand, 2012, Perennes, 2013, Scholten, 2013), no econometric test has been proposed until now. In fact, the mainly qualitative nature of the framework has been identified as a weakness and the need for more quantitative measurement has been expressed (Crettenand and Finger, 2013, p. 125). It is hoped that this first attempt will contribute to the development of further ideas in order to promote the operationalisation of the coherence framework in the economic literature on infrastructures.

This paper is structured as follows. Section 1 introduces the coherence framework and defines several key concepts such as core transactions. These core transactions involve critical assets and need to be aligned with suitable governance structures in order to guarantee the technical reliability of the infrastructure. Thereafter, the paper's approach to the decentralisation of the decision rights is elaborated upon, together with a proposed explanation of the ensuing coordination problems. A proposition is put forward according to which the existence of critical assets calls for more organisational centralisation. Section 2 then presents the data set for the French drinking water sector and the econometrical model. Variables are defined in order to measure the degree of decentralisation of modes of organisation and the criticality of assets. Particular attention is paid to the underground networks of water systems. Section 3 produces the results of several econometric tests which provide support for the initial idea that the criticality of assets might be a determinant of the degree of centralisation in the chosen mode of organisation. The final section concludes and also proposes possible extensions of this work.

2. Criticality of assets and the need for alignment with organisational structures

The founding article on the coherence framework (Finger et al., 2005) parted from the observation that infrastructure reform was mainly considered a matter of institutional change,

leaving aside the technological aspects of network industries[1]. This failure to acknowledge the technological requirements of infrastructure in liberalisation measures, according to the authors, was an explanation for cases of system failures like blackouts in the electricity sector and accidents in the railway sector. In its static approach, the central idea of the coherence framework is that the technological characteristics of infrastructure require an alignment with matching modes of organisation in order to guarantee the technical reliability of the system (Künneke and Finger, 2007, p. 327). Missing alignment lowers performance (Künneke et al., 2010, p. 504)[2]. With regard to the water sector, Ménard (2009, p. 87) describes these challenges as follows: "[…] economists too often neglect the physical specificity of water systems. Laws of turbulence impose tight coordination in the network and its subsystems, between production and distribution on the one hand, and between primary and secondary networks on the other hand. It also requires coordination with maintenance services in order to control systemic effects of leaks".

The coherence framework subsequently considered how to determine the criticality of the technological aspects of infrastructures and proposed two perspectives (Künneke et al., 2010, pp. 496 ff.). A first way is to look at critical assets, i.e. assets that are fundamental for the functioning of the system (for instance pumping stations in water). A second way is to identify critical technical functions that must be performed in order to safeguard the technical performance of the system. The problem of load balancing, i.e. the balancing of the production and consumption of electricity at any given moment of time, provides an example (ibid., p. 495). The second issue is what the authors subsequently focused on, by using a control engineering perspective. This paper explores the first notion and investigates organisational needs arising from the presence of critical assets. Closely linked to the existence of these critical assets is the idea of "core transactions".

2.1. Core transactions and the need for coordination

Ménard (2009, p. 89) defines core transactions as being "[…] essential to maintain the integrity of technical functions while keeping the system economically viable". An example for such a core transaction is the replacement of a deteriorated pipe. The integrity of the water distribution network is critical for the functioning of the infrastructure. By contrast, "peripheral

[1] Crettenand and Finger (2013) review the coherence literature since its starting point in 2005.
[2] Crettenand and Finger (2013, p. 108) point out that performance is a multi-faceted concept which accommodates many aspects (technical, operational, social, economic and environmental) in the question of coherence between technology and institutions.

transactions" like metering or collecting bills are not critical for the technical integrity of the system. These examples illustrate that transactions differ in their criticality. Critical transactions are essential to safeguard the technical and economic integrity of the system. Therefore, there is a necessity for alignment between the chosen mode of organisation and the characteristics of the core transactions (ibid.).

A helpful way to understand the criticality of a transaction is by considering the urgency of the situation, i.e. within which timeframe the issue must be addressed[3]. Maintenance works for instance are more critical than collecting bills, yet less urgent and ergo less critical than the renewal of desolate parts of the network. Some transactions might not be critical immediately but become more critical in time. Set aside such dynamics, a static perspective, as applied in this paper, implies that transactions differ in their criticality. Ménard (ibid.) points out that these critical transactions are closely related to the existence of highly specific assets. In other words, at least in the short run, the issue of criticality concerns critical, specific assets. Critical assets, such as pumping stations or pipelines in water, are essential for the operability and reliability of the system[4]. Leaks, if not substantial, can be less critical in the short-term but if they reach 40 % as in certain cases in France (Conseil Général de Seine et Marne, 2012, p. 7), their repair becomes a highly critical and urgent issue because they endanger the functioning of the infrastructure. First of all, the pressure in the network can be highly reduced. This affects the distribution of drinking water to users who, when opening the tap, will find the water flow reduced. Next to that, the pressure losses might enable the intrusion of contaminating agents through the leak openings into the drinking water within the network, thereby generating health risks (Hunaidi, 2000, p. 1). In addition, if not attended to, these water losses through leaks might involve high economic costs not only in form of unpaid water (cost of raw water including its treatment and transmission) but also in form of eroding and breaking pipes and damages to the foundations of roads and buildings (ibid.). Hence, leaks have the potential of jeopardizing the technical reliability and economic viability of the water infrastructure so that their repair might become a highly critical transaction.

Associated to critical assets are problems of uncertainty and opportunistic behaviour (Ménard, 2009, p. 90, Künneke et al., 2010, p. 501). One cause for uncertainty in water infrastructures is related to water technology, which involves underground water distribution

[3] In that respect Künneke et al. (2010, p. 498) elaborate on the necessary “speed of adjustment”.
[4] As a further criterion for identifying the criticality of transactions Künneke et al. (2010, p. 498) propose the geographical scope of the transaction: does it concern the entire system or only part(s) of it?

networks. Uncertainty is high if the operating entity does not have knowledge over the network, e.g. the position of valves that section the network or the state of the pipelines. In order to reduce this uncertainty, inspection works on the network are needed. These inspection works constitute therefore a further transaction of a certain criticality for water services, a criticality which increases in time[5]. Following the reasoning of transaction cost economics, there is a need to align the characteristics of critical transactions with suitable modes of organisation in order to reduce problems resulting from uncertainty and opportunistic behaviour.

Different modes of organising water services involve different instruments for coordination. An integrated firm uses authority to coordinate whereas hybrids use contracts[6]. Usually, these options mean, for the water sector, that water services range from public management to full privatisation[7] with Public-Private Partnerships (PPPs) in between. Depending of the type of PPP, the private partner is more or less involved in the provision of water services. In what follows, these modes of organisation are analysed as to their decentralisation of decision rights.

2.2. Decentralisation of decision rights and coordination problems

The analysis of the distribution of decision rights between entities involved in the provision of water services is a helpful way to examine the issue of coordination problems. Although the remainder of this paper considers modes of organisation from the perspective of decision rights, there is an important difference in relation to the approach of the property rights theory as represented by Grossman and Hart (1986) and Hart and Moore (1990). These authors present the general idea that *ex post* problems in contracts can be circumvented if property rights are well assigned *ex ante*. Our approach however borrows from transaction costs economics the idea that any contractual arrangement contains the risk of *ex post* adaptation problems[8].

Ménard (2010) suggests decision rights as a way to classify hybrid modes of organisation. According to Baker et al. (2008) each mode of organisation has a way to allocate property, decision and revenue rights. Some decision rights are transferable by contract. With regard to water utilities, the authority for decision-making is transferred from the public to the private

[5] Ménard (2009, pp. 89 f.) identifies additional sources of uncertainties relating to core transactions, such as the physical environment involving a varying quality of water or agricultural or industrial activities polluting water resources.

[6] The market which uses the price mechanism for coordination does not play a significant role in the water sector which is usually organised in local monopolies.

[7] This option is in fact very rare in the water sector and has no significance in France. Examples are England and Wales or Chile.

[8] Joskow (2005) provides a helpful comparison between property rights theory and "classical" transaction cost economics.

entity. In order to study the intra-organisational allocation of decision rights, Jensen and Meckling (2009) propose to consider the different project-stages of the PPP. In an analogy to this approach, water services can be broken down according to different domains of action. Depending on the mode of organisation, the decision rights for the various domains are allocated between the public and the private entity, or – in the case of direct public management – are completely in the hand of the public party. Boyer et al. (2001, pp. 4 ff.) provide a list of the distinct activities in the provision of drinking water services. The authors name finance, planning and design, construction, renovation (i.e. long-term investments), maintenance (i.e. short-term investments), operation of the infrastructure, and finally collecting and billing.

As already mentioned, the extent to which decision rights are decentralised determines the importance of coordination issues. In the case that all decision rights are held by one party, corresponding to full public management or full privatisation, no coordination issues arise[9]. However, as soon as another party gets involved in one or more of the above listed activities, coordination issues arise. In the French context, this case corresponds to the situation where the local public authority delegates at least part of the services to a private operator. Ménard (2004, pp. 359 f.) elaborates on the potential coordination issues and notes the need for adaptation, namely to adjust flexibly to unforeseen situations, for control of the actions of the contracting partner, and for safeguards in order to prevent opportunistic behaviour.

Coordination implies costs. Gulati and Singh (1998, p. 781) define these coordination costs as "[…] the anticipated organizational complexity of decomposing tasks among partners along with ongoing coordination of activities to be completed jointly or individually across organizational boundaries and the related extent of communication and decisions that would be necessary". Coordination costs increase with the complexity of the transaction at stake and the extent of asset specificity (Ménard, 2004, p. 350). This description fits with the characteristics of core transactions and critical assets in the water sector. Faced with the risk of opportunistic behaviour, in order to economise these coordination costs, contractual agreements are replaced by quasi-integrated solutions (ibid., p. 355). Hence, the degree of centralisation required to coordinate partners determines the chosen mode of organisation (ibid., p. 357). This is why we can expect to find centralisation of decision rights when the need for critical assets increases.

[9] Ménard (2013, pp 161 f.) points out that strictly speaking all decision rights are never united in the hand of a single party, because there are always laws, regulation and so forth that constrain possible actions.

2.3. Coordination problems in French water contracts

In France, the provision of water services falls under the responsibility of the local public authorities. These authorities take the form of either a single municipality or of an intercommunal association. The local public authority has to organise the production, treatment and distribution of drinking water and has to decide whether to provide these services on its own or with the participation of a private firm. The involvement of the private firm is more or less intense, according to the chosen mode of organisation. At one end of the spectrum is direct public management ("***régie"***) under which the local public authority offers all services by itself. At the other end of the spectrum are concession contracts ("*concessions*") where the private firm is not only responsible for the operation and management but also for all types of investments, short-term or long-term. Various intermediate forms exist such as service contracts ("*régie avec prestation de services*") under which the local public authority resorts to a private operator for one or more specific tasks (e.g. cleaning or meter reading) and to different types of management contracts[10] ("*gérance*" and "*régié intéressée*") where the private firm operates and manages the services but does not invest in the infrastructure. Representing over 80 % of contracts, lease contracts ("*affermage*") are the most common contractual arrangements in France (Euromarket, 2004, p. 29). They are in-between management contracts and concessions insofar as the private firm makes short-term, but not long-term, investments. The long-term, and thereby more heavy, investments remain the responsibility of the local public authority.

In the case of lease contracts, the decision rights on investments are shared between the public and the private party. Therefore, certain issues relating to coordination may arise. Concretely, the private firm operates the utility and hence the distribution network. At the same time, the private firm is not responsible for investments in the network since this falls under the long-term investments which remain under the responsibility of the local authority. In parlance of the coherence framework there is a lack of alignment between a critical transaction and the mode of organisation that governs this transaction. The lease contract attributes the decision rights on the operation of the network to the private firm but not the decision rights on the corresponding investments, because the replacement of desolate parts of the network remains under the responsibility of the local authority. This discrepancy between the right to operate and the investment obligations possibly results in a high level of uncertainty governing the transactions linked to the renewal of the network. The source of this uncertainty lies in the

[10] These contracts differ in the way the operator is remunerated and therefore obey to different incentive schemes.

feature of water technology to use underground pipelines. The local authority cannot directly observe the state of the network. Rather, it relies on information provided by the private operator. The private firm operates and maintains the network which means that it has knowledge of the state of the critical assets, primarily pipes, but also valves and sometimes pumps, and collects data on them[11]. The local authority does not hold this information and is dependent on the private operator to obtain it. Hence, the operator must transmit its private information to the municipality so that the municipality can efficiently renew the ailing sections of the network, i.e. renew where it is necessary and not renew where it is not. This necessity for transmission of information requires a regular dialogue between the private firm and the local authority. It thus helps to illustrate the need for coordination between the public and the private party in core transactions linked to critical assets.

Such coordination is costly. *Ex ante*, the public authority has to try to include clauses in the lease contract that guarantee the transmission of the operator's private information to the public authority. *Ex post*, the public authority has to find means to direct and to control the transmission of information. Additionally, coordination is costly because the *ex ante* distribution of decision rights is not always clear in the initial contract. Lease contracts may differ with regard to the sharing of financial and operating risks (Martimort and Sand-Zantman, 2006, p. 764). These differences also have consequences on the distribution of decision rights in relation to investments. In addition to the initial contract negotiations, renegotiations in the later stages of the contract are common. It is apparent that the resulting coordination costs in the presence of critical assets might be very high in lease contracts. In other words, the need for investment in critical assets in combination with a governance structure where decision rights on these assets are split between the local authority and the private operator might result in very high coordination costs. Where investments concern critical assets, the public authority might prefer to choose a mode of organisation where decision rights on these critical assets are mode centralised in order to economise these coordination costs. This is a way of lowering the need for coordination between several parties and therefore a way to reduce coordination costs.

These considerations lead to the formulation of the following proposition:

[11] Attention is drawn to the fact that, just as in lease arrangements, in management contracts ("*gérance*" and "*régie intéressée*") the private firm operates the network, too. Although the private operator does not make maintenance investments, it nevertheless gains knowledge on the state of the network through its operation (Martimort and Sand-Zantman, 2006, p. 764). In that way, coordination issues as described in the following sections may also arise, although, in presence of management contracts, to a lesser extent.

Proposition. The higher the need for critical assets in the provision of drinking water services, the higher the probability of observing modes of organisation where decision rights are highly centralised.

3. Data and methodology

Two databases have been considered for testing the proposition on the role of criticality of assets for the centralisation of decision rights: firstly, a database from the French Environment Institute (*IFEN*) and the French Ministry for Health (*DGS*) which contains information on the water services of 5000 municipalities in 2001 and secondly, an annually published database by the French National Office for Water and Aquatic Environments (*ONEMA*) containing information on about 14,000 water services in 2009. Both databases have their advantages and disadvantages. The *IFEN* database contained, after deleting missing and erroneous values and outliers, 3,650 observations. However, the information on investments was much less refined than in the *ONEMA* database. The original *ONEMA* database contains around 14,000 observations which are reduced to 410 after elimination of missing, extreme and erroneous values. Hopefully there will be a development towards more complete databases in the next years since *ONEMA* has only been collecting data since 2008. Although there are less observations in the final *ONEMA* database as compared to the final *IFEN* database, we preferred the *ONEMA* database for several reasons. Firstly, the construction of the database mirrors the reality of water services because the unit of observation is the water utility, not the locality. This means that data is collected at the level of the municipality when the water services are municipal and at the level of the intercommunality if water services are provided jointly by several municipalities. In the *IFEN* database, the unit of observation is the municipality, even in cases of intercommunal water provision. Therefore, where the arrangement is intercommunal, the *IFEN* methodology consists in using weights for approximating the communal values. The second advantage of the *ONEMA* database consists in its refined data on investments which allows us to approximate the notion of criticality. For instance, the database contains the monetary value of the investments and a refined index summarising the knowledge on the state of the network. Such essential data for our econometric tests is not contained in the *IFEN* database. For these reasons, we prefer the quality of the *ONEMA* database over the quantity of the *IFEN* database.

Of the five available *ONEMA* databases, we use the data for 2009 covering the largest population served, i.e. nearly 80 % of the French population[12]. *ONEMA* considers it to have the best representation of the French water sector.

The aim of the econometric tests is to link the degree of decentralisation of decision rights to the criticality of assets. We estimate therefore several ordered probit regressions based on standard maximum likelihood estimations with heteroscedasticity-robust standard errors:

$$\boldsymbol{D = C\,\alpha + X\,\beta + u} \qquad \textbf{(1)}$$

where ***D*** corresponds to the degree of decentralisation of decision rights of the governance structure, ***C*** corresponds to indicators for the need for critical assets, ***X*** is a vector of exogenous control variables and ***u*** indicates the stochastic error.

The next two subsections propose ways to measure the degree of decentralisation of decision rights and to approximate the criticality of assets.

3.1. Degree of decentralisation of decision rights

In order to classify the modes of organisation according to the extent to which decision rights are decentralised, it is necessary to match decision rights on the various domains of action of water services, as identified in Boyer et al. (2001, pp. 4 ff.), to the entity holding these decision rights.

The dataset considered in this study distinguishes six types of modes of organisation, namely public management, service contracts, two types of management contracts (management 1 and management 2), lease contracts, and concessions. The following table shows which party is responsible for which aspect of water services under each of these different modes of organisation. The decision rights might pertain exclusively to the local public authority, only to the private operator, or they might be shared by the public and private entities. From this allocation of decision rights, a decentralisation score is derived. This decentralisation score ranges from zero[13], where all the decision rights are held by one party, to three, where the

[12] This database is available on http://www.services.eaufrance.fr/base/telechargement, (28.12.2016).

[13] Note that according to this approach, two modes of organisation achieve a score of 0 concerning the decentralisation of decision rights, i.e. decision rights are fully centralised under two modes of governance: firstly, under public management and secondly under full privatisation. Whilst the score for public management might not be surprising, the case of full privatisation possibly is. In our perspective, full privatisation is a case a fully centralised decision rights because the private operator holds decision rights on all domains of action of the water services.

decision rights achieve the highest decentralisation, meaning that they are quite evenly split between the local public authority and the private operator[14].

Table 1:
Decentralisation of decision rights according to the mode of organisation.

Domain of action	*Mode of organisation*					
	Public manage-ment	*Service*	*Manage-ment 1*	*Manage-ment 2*	*Lease*	*Concession*
Finance	publ	publ	publ	publ	publ/priv	publ/priv
Planning / design	publ	publ	publ	publ	publ/priv	priv
Construction	publ	publ	publ	publ	pub	priv
Renovation	publ	publ	publ	publ	pub	priv
Maintenance	publ	publ	publ	publ	priv	priv
Operation	publ	publ/priv	priv	priv	priv	priv
Collecting / billing	publ	publ	priv	priv	priv	priv
TOTAL public	7	6	5	5	2	0
TOTAL publ/priv	0	1	0	0	2	1
TOTAL private	0	0	2	2	3	6
DR decentralisation	None (100% public)	Low (mainly public)	Intermediate (mainly public)	Intermediate (mainly public)	High (public and private)	Low (mainly private)
DR decentralisation score	0	1	2	2	3	1

Table 1 classifies the six modes of organisation represented in the dataset according to the extent of decentralisation of decision rights. Under public management, the local public authority holds 100 % of the decision rights given the fact that no private actor is involved in the delivery of services. All decision rights being united in one entity, this case corresponds to full centralisation of decision rights, leading to a decentralisation score of 0.

Under a service contract, the local public authority outsources one or several tasks to a private entity which, as a consequence, holds the decision rights associated with these tasks.

[14] The expression "quite evenly split" does not contain a judgment of the importance of the domain of action where decision rights are held. We are aware that some domains concern rather peripheral than core transactions (such as billing and collecting). However, this does not affect our argumentation.

For instance, this might concern general tasks like cleaning or commercial tasks like meter reading. Most of the tasks however remain with the local public authority so that the overall decentralisation of decision rights is low (score of 1).

Our dataset contains two types of management contracts (*Management 1* (corresponding to "*régie intéressée*") and *Management 2* (corresponding to "*gérance*")) which usually do not differ in the attribution of tasks and consequently show the same allocation of decision rights. The difference between these two types of contract lies in the payment scheme for the private subcontractor and the incentive schemes involved. In both cases, the private entity is responsible for the operation and the tariff collection, whereas investments, construction, planning, and finance remain the sole responsibility of the local public authority. The decentralisation of decision rights is intermediate (score of 2).

Lease contracts on the other hand imply highly decentralised decision rights. Construction works and long-term investments (e.g. the replacement of the primary distribution network) remain usually in the domain of the local public authority. Billing, operation, and maintenance investments are, however, under the care of the private operator. In that way, both parties intervene in the financing and design of water services. Attention might already be drawn to the fact that, under this contractual arrangement, the decision rights concerning critical assets, i.e. the network, are shared and not clearly delineated. As seen under section 1.3, such blurred decision rights might aggravate coordination problems.

In contrast, concessions imply only a low decentralisation of decision rights because most of the decision rights are allocated to one party, although private. The private entity acts in all domains on an exclusive basis except in relation to finance, where the local public authority might participate in certain cases[15].

This classification of the decentralisation of decision rights under different modes of organisation seems uncommon. Usually, the decentralisation of decision rights is considered from the initial point of departure, i.e. the case corresponding to a coincidence of decision rights with property rights which represents complete centralisation. For public utilities this matches direct public management, where all decision rights are held by the local public authority. According to this approach for classifying governance structures, more decentralisation equals a

[15] This fact underlines the idea of residual rights as presented by Baker et al. (2008). Residual rights mean that some decision rights are tightly linked to property rights and cannot be transferred separately from those property rights. Therefore, even in a mode of organisation very close to privatisation, such as exemplified by a concession contract, it is not the private operator who holds 100 % of the decision rights. Part of the decision rights remains with the local public authority.

higher involvement of a private company. This is why full privatisation is often referred to as the case of highest decentralisation[16]. Following this perspective, concessions are also forms of very highly decentralised arrangements since the private party is the main actor in the delivery of water services whereas the public party is ideally quasi invisible. The contrast with the classification of concessions as highly centralised modes of organisation, as presented in this paper, emanates from the different focus points. Whereas the usual approach concentrates on an *ex ante* consideration of problems in the allocation of decision rights, the approach here underlines the potential coordination problems that arise when decision rights are not allocated to one party (be it public or private), but rather shared. The allocation of decision rights is not considered from the perspective of the public authority but from the viewpoint of the utility as an organisation where ownership is a secondary consideration. Decision rights are therefore fully centralised under direct public management and full privatisation and more or less decentralised in hybrid modes of organisation.

This approach allows us to obtain the ***DECENTRALISATION*** variable. It takes the following values: 0 for direct public management, 1 for service contracts and concessions, 2 for the two types of management contracts, 3 for leases. According to the idea that a higher criticality of assets calls for a higher centralisation of decision rights, ***DECENTRALISATION*** is expected to be negatively correlated with critical assets. In other words, in the presence of increasing asset criticality a lower probability is anticipated for modes of organisation where the decentralisation of decision rights is high – corresponding to a decentralisation score of 3 (lease contract) or 2 (management contracts) – and a higher probability for modes of organisation with a low decentralisation of decision rights – i.e. a score of 0 (direct public management) or 1 (service and concession contracts).

3.2. Criticality of assets

The criticality of assets is not a common concept and no direct measures exist. Therefore, it is necessary to identify proxies. Three proxies are identified that indicate the need for critical assets: the rate of renewal of the distribution network, the ratio of investments to the length of the network and the existence of a renewal program for the distribution network.

The rate of renewal of the transmission and distribution network is captured by the ***RENEWAL*** variable. As has been argued in the theoretical part, the renewal of desolate parts of

[16] This corresponds to the vocabulary of the World Bank, for instance.

the network is a highly critical transaction and accordingly involves assets of highest criticality. This variable does not count mere repairs of leaks, but concerns either the replacement of parts of the transmission and distribution mains or their rehabilitation, i.e. measures aiming at giving them a lifespan comparable to that of new pipes, as well as annex equipment such as valves. Service pipes connecting the main pipes to the buildings are not taken into account in this variable. Works that took place during the five years preceding the data-entry are included. To obtain the variable, the total length of renewed pipelines is divided by the total length of the network (without service pipes). The percentage obtained specifies what ratio of the distribution network has been recently renewed and thereby indicates the effort of the renewal works. The higher the renewal rate the higher the criticality of the assets, because a higher part of the network was in a desolate state and needed replacement. The renewal of 10 km in a 100 km long network is more critical than the renewal of 10 km in a network of 1000 km length. The higher the desolate part of a network, the more endangered the technical integrity of the system and the more urgent the need for replacement. According to the theoretical reasoning that more critical assets require more organisational centralisation in order to economise coordination costs, ***RENEWAL*** is expected to be negatively correlated with ***DECENTRALISATION***. This means that in the case of important renewals of the distribution network, more centralised modes of organisation (with a decentralisation score of 0 or 1) should be found.

However, water infrastructures involve other critical assets that are not included in the ***RENEWAL*** variable, which concentrates on the part of the underground transmission and distribution network that has been replaced. Such other critical assets comprise service pipes that connect the water mains to the buildings of users, i.e. the critical transaction would be their installation or replacement, or pumping stations which may be necessary for the catchment of raw water but also to ensure adequate pressure in the transmission and distribution network. The ***RENEWAL*** variable does not comprise repair works of leaks which might be substantial to ensure the proper functioning of the critical assets and the overall system. Repair of critical assets may also include works on a reservoir such as the reinforcement of a dam, repairs or replacement of gates or intake conduits. All these are critical assets that are not considered in the ***RENEWAL*** variable. The costs relating to all these critical assets are generally estimated to represent 80 % of the total costs of water services (Noll, 2002, p. 45)[17]. The *ONEMA* database provides the amount of investments made. This value includes the amounts spent for

[17] These numbers find confirmation in a report on the investments spent in a French municipality (Commune de Thonon-les-Bains, 2012, p. 37).

investments in relation to the ***RENEWAL*** variable, but also the above listed types of investments and works. These investments also concern less critical assets (for instance the refurbishment of the buildings of the water utility, the painting of walls, the acquisition of a photocopier etc.) but since these costs are not very important in comparison to the major part of investments, it can nevertheless be considered that the overall amount provides a good estimation of investments relating to critical assets. By analogy to the ***RENEWAL*** variable, the ***INVESTMENT*** variable used in this paper is obtained by dividing the amount of expenses by the length of the network. This approach has been chosen in order to reinforce the notion of criticality by accounting for the fact that necessary investments of a same monetary amount will be relatively more critical in a smaller network than in a bigger network. On the whole, the ***INVESTMENT*** variable is larger than the ***RENEWAL*** variable insofar as it provides more information on critical assets. Following the same reasoning as with the ***RENEWAL*** variable, ***INVESTMENT*** is expected to show a negative correlation with ***DECENTRALISATION***, accounting thereby for the idea that more critical investments should require a governance structure where decision rights are more centralised, i.e. above all a governance structure with a decentralisation score of 0 or 1.

As third variable to approximate the criticality of assets the dummy variable ***RENEWPROG*** has been introduced, which takes the value of 1 if the local public authority has implemented a multi-year program for the renewal of the network and 0 if not. The existence of such a program might reflect a need for critical assets and thereby involve more centralised modes of organisation. Hence, a negative correlation is expected with regard to ***DECENTRALISATION***. In presence of a programme for the renewal of the water network, modes of governance with a decentralisation score of 0 or 1 should be found.

3.3. Control variables

The database used for the econometric study contains several further variables that might impact on the centralisation or decentralisation of decision rights in the chosen governance structures. ***DENSITY*** measures the number of subscribers per network kilometre. The higher the value this variable takes, the denser the network, meaning that more subscribers per kilometre of network must receive water services. Ménard (2009, p. 88) noted in that respect that a denser population requires more significant and specific investments in order to provide

water in the right amount and of the right quality with an adequate pressure[18]. This idea is in line with the explanation of engineers that capacities of water collection, purification, transmission and distribution are a function of the density of the population (Shammas and Wang, 2011, p. 126). ***DENSITY*** is therefore expected to be negatively correlated with ***DECENTRALISATION***. The higher the number of subscribers per network kilometre, the more probable should the choice of governance structures with centralised decision rights be, i.e. with decentralisation scores of 0 or 1. In that way, a tight coordination in core transactions could be achieved.

Additionally, ***INTERCOM*** is a dummy variable measuring the existence of an intercommunal arrangement for water provision. The variable takes the value 1 if water services are jointly provided by several municipalities and 0 if a single municipality organises the water services. The effect of this variable on the decentralisation of decision rights is *a priori* undetermined. On the one hand, in the presence of an intercommunal arrangement, coordination costs are supposed to increase because the different municipalities constituting the intercommunal arrangement must coordinate their, often heterogeneous, equipment (Cour des Comptes, 2011, p. 21). In such a perspective, the choice of a highly decentralised governance structure, like a lease contract, would worsen already existing coordination problems. This would be based on the idea that the presence of a private operator with whom decision rights are shared would add further to the number of actors requiring coordination. As a consequence, there should be a negative correlation between ***INTERCOM*** and ***DECENTRALISATION***. Hence, the existence of intercommunal drinking water provision should increase the probability for more centralised modes of organisation. On the other hand, the fact that municipalities associate might provide them with the possibility to overcome certain deficiencies of resources and capacity resulting in a reduction of transaction costs related to coordination. In such a perspective, intercommunal arrangements could more easily manage the relations with a private operator in a governance structure with highly decentralised decision rights, such as lease contracts. Therefore, it is also possible that a positive relation between the two variables exists.

Another factor might impact on the decision to decentralise decision rights or not, namely the knowledge of critical assets in the infrastructure. It has been presented in the theoretical section that knowledge of the state of the pipelines is essential to be able to provide efficient investment decisions. The variable ***KNOWLEDGE*** captures the information about the state of

[18] The correlation between ***DENSITY*** and the ratio of the population served by the water service to the length of the network amounts to about 80 %. Because of this high correlation, either variable can be used. The ***DENSITY*** variable is directly contained in the *ONEMA* database, the reason why it has been chosen.

the network on a scale from 0, corresponding to no knowledge, to 100, meaning very good knowledge. The variable is a joint indicator including the existence of a map of the network; an annual update of this map; knowledge on the elements constituting the network, i.e. complete structural information on each segment of the network (diameter, material); the age for each segment; the localisation and description of annex assets, i.e. valves and meters; the localisation of service pipes based on the land registry map; the level of information on the works on the network, i.e. the localisation and identification of various types of intervention, and the existence and execution of a multi-year plan for the renewal of service pipes and mains. Based on the fact that the entity which operates the network gains knowledge of it (Martimort and Sand-Zantman, 2006, p. 764), several cases are possible. If the knowledge of the critical assets is poor, knowledge needs to be retrieved to render the realisation of efficient investments possible. If the chosen governance structure has highly decentralised decision rights (i.e. the case of lease contracts) the retrieval of such relevant information on critical assets entails the need for coordination between the public and the private party. Yet, this coordination is costly[19]. Therefore, the local public authority might prefer to centralise decision rights, thus economising these coordination costs. In that case, the public entity would either choose direct public management or a service / concession contract. All of these centralised modes of organisation should lead to the increase of knowledge on the critical assets. In the case of direct public management or a service contract, the local public authority would operate the network and gain knowledge of it. In the case of a concession contract, the private operator is also incited to gain knowledge of the network in order to provide efficient investments[20]. This corresponds to Laffont and Tirole (1988), who find that gaining such knowledge and the realisation of efficient investments in the first years will reduce the exploitation costs in the following years.

Also, if the knowledge on the critical assets is good, the decentralisation of decision rights will imply lower coordination costs. Therefore, a local public authority might choose a governance structure where decision rights are highly decentralised because the public party is not dependent on the private firm for the retrieval of knowledge on the network. For these reasons, a positive correlation between ***KNOWLEDGE*** and ***DECENTRALISATION*** is expected, based on the idea that little knowledge of critical assets should increase the need for a mode of organisation where decision rights are more centralised.

[19] Also, a lease contract in France has a duration of about 10-12 years. The private operator cannot be sure that his contract will be renewed at the term of the contract. Therefore, he might be less motivated not only to maintain critical assets but also to transfer information on them to the local public authority. The local public authority might therefore be wary of lease contracts in situations where the knowledge on the state of critical assets is poor.
[20] This incentive, however, decreases as the term of the contract draws nearer (Chong and Huet, 2010).

Furthermore, in line with Chong et al. (2006) and Chong and Huet (2010), the regressions control for local factors that might impact on the degree of decentralisation of decision rights in the choice of modes of governance. Such factors might not be captured in the previously presented variables. The idea is to take into account potential local differences in the choice of modes for organising water services. Accordingly, fixed effects for the administrative division of departments in France – a division below the national level and below the regional level – are taken into account.

The following tables provide more information on the variables used in the regressions. Table 2 shows the distribution of decentralisation scores. The decentralisation score varies from 0 to 3, i.e. from full centralisation of decision rights to high decentralisation of decision rights. Table 3 describes the explanatory variables and table 4 the correlations between them.

Table 2: Distribution of modes of organisation according to their score for decentralisation of decision rights.

Decentralisation score	*Corresponding modes of organisation*	*Number of observations*	*%*
0	Direct public management	211	51.46
1	Service and concession contracts	22	5.37
2	Management contracts (types 1 and 2)	13	3.17
3	Lease contracts	164	40.00
Total		410	100.00

Table 3: Definitions of explanatory variables and descriptive statistics.

Variable	*Definition*	*N*	*Mean*	*Std. Dev.*	*Min*	*Max*
DENSITY	Number of subscribers / length of transmission and distribution network in km	410	29.18	19.97	2.66	106.73
INTERCOM	Takes value 1 if the local authority organises the water services cooperation with other local authorities	410	0.56	0.50	0	1
KNOWLEDGE	Index for the knowledge of the transmission and distribution network	410	47.05	26.82	0	100
RENEWAL	Ratio of length of transmission and distribution network in km that has been renewed during the last 5 years to total length of transmission and distribution network in km in %	410	0.56	1.18	0	12.11
INVESTMENT	Ratio of amount of expenses of water service in € to length of transmission and distribution network in km	410	2,813.04	4,754.39	11.46	67,464.88
RENEWPROG	Takes value 1 if a renewal program for the transmission and distribution network exists	410	0.21	0.41	0	1

Table 4: Correlations between explanatory variables.

	DENSITY	*INTERCOM*	*KNOWLEDGE*	*RENEWAL*	*INVESTMENT*	*RENEWPROG*
DENSITY	1					
INTERCOM	-0.4068	1				
KNOWLEDGE	0.1586	0.1537	1			
RENEWAL	0.1694	-0.0833	0.1067	1		
INVESTMENT	0.3290	-0.1852	0.0988	0.2447	1	
RENEWPROG	0.2228	0.1515	0.4933	0.1271	0.1378	1

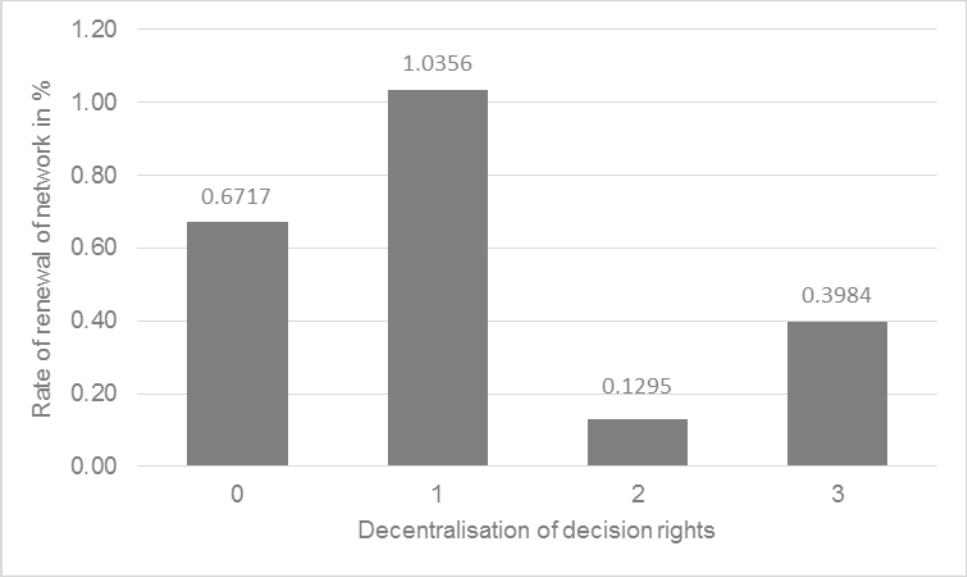
4. Empirical analysis

4.1. Critical assets and centralisation of decision rights

The aim of our analysis is to find support for an idea expressed in the coherence framework, namely, that in cases where specific assets are critical, more centralised modes of organisation are required. The underlying rationale is that, when decision rights on core transactions are split between the local public authority and the private firm, there is an important need for coordination between the two parties. Such coordination however is difficult and costly. Therefore, the local public authority might prefer to choose a governance structure where decision rights are more centralised, which will then serve as coordination mechanism.

This intuition is supported by graphs 1 and 2. They depict the choice of the degree of decentralisation of decision rights according to the presence of critical assets, as approximated by the variables ***RENEWAL*** and ***INVESTMENT***. Graph 1 shows the ratio of the renewal of the drinking water network according to the various decentralisation scores. The corresponding descriptive statistics can be found in the annex.

Graph 1: Mean for *RENEWAL* depending on decentralisation of decision rights.

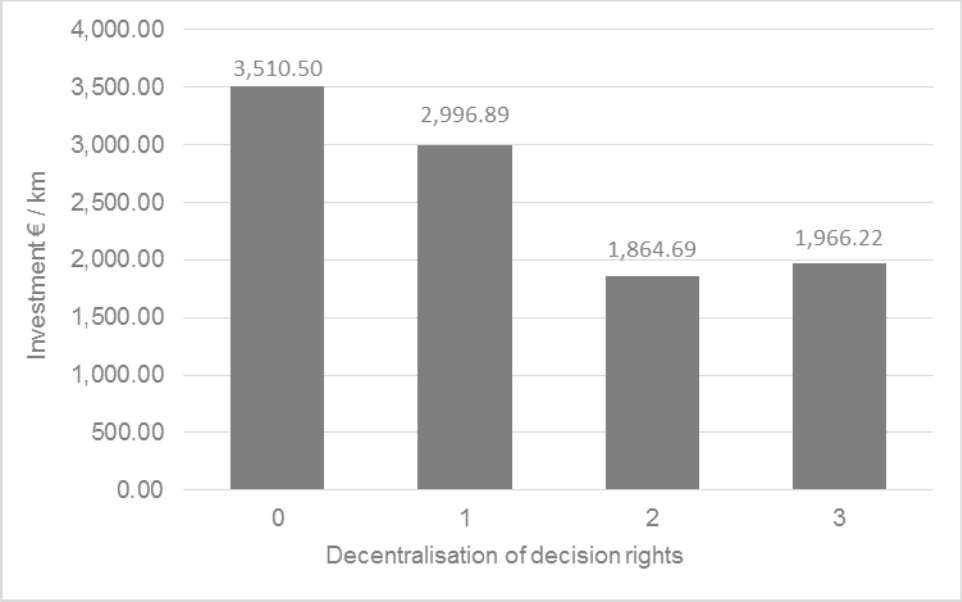


It is apparent from graph 1 that the variable ***RENEWAL*** is much higher for cases where decision rights are centralised, i.e. full centralisation (score of 0) or low decentralisation (score of 1), than for cases with intermediate (score of 2) or high (score of 3) decentralisation. Whereas the ratio for renewal of the network corresponds in average to 0.67 % to 1.04 % in the cases of full/high centralisation of decision rights, it drops to 0.13 % and 0.40 % respectively in cases of decentralised decision rights. This indicates that in presence of more critical assets, decision rights become more centralised. In such cases direct public management (score of 0) or service or concession contracts (score of 1) seem to be preferred over management (score of 2) or lease (score of 3) contracts. It is in cases of less critical investments that management or lease contracts are chosen.

The close link between critical assets and choice of governance structure becomes even more apparent in graph 2. When investments per kilometre of network – our proxy for critical assets – are high, the local public authority chooses a centralised mode of organisation. On the

other hand, when investments per kilometre of network are lower, more decentralised modes of governance can be found. Again, the corresponding descriptive statistics can be found in the annex.

Graph 2: Mean for *INVESTMENT* depending on decentralisation of decision rights.



Investments per kilometre of network amount to 3,510.50 € in the case of full centralisation of decision rights (direct public management), to 2,996.89 € for highly centralised modes of organisation (service or concession contracts) and they drop for decentralised modes of organisation to 1,864.69 € for management contracts, and respectively to 1,966.22 € for lease contracts. Thus, there is a clear negative relation between the criticality of assets and the decentralisation of decision rights. This result indicates that governance structures become more centralised when investments in critical assets increase. In other words, it seems that centralised modes of organisation are chosen in situations where investments are critical. The next subsection tests this relation with the help of an econometric model where more explanatory variables are taken into account.

4.2. Results of the regressions and discussion

Table 5 summarises the results from the regressions with the maximum likelihood method.

Table 5: Estimation results for equation (1).

Specification	*MLM dependent variable: DECENTRALISATION*		
	Model 1	*Model 2*	*Model 3*
DENSITY	0.0107**	0.0127**	0.0127**
	(0.00529)	(0.00563)	(0.00557)
INTERCOM	0.651***	0.602***	0.616***
	(0.197)	(0.198)	(0.198)
KNOWLEDGE	0.0100**	0.0108***	0.0107***
	(0.00414)	(0.00406)	(0.00410)
RENEWPROG	-0.577**	-0.565**	-0.549**
	(0.237)	(0.239)	(0.239)
RENEWAL	-0.138*		-0.0914
	(0.0816)		(0.0811)
INVESTMENT		-6.30e-05**	-5.39e-05*
		(2.87e-05)	(3.00e-05)
DEPARTMENTAL FIXED EFFECTS	Included	Included	Included
Observations	410	410	410
Pseudo R-squared	0.352	0.355	0.356

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

The variable ***DENSITY*** is significant at the 5 % level in all three of the regression models. The correlation however is not as expected. The sign is positive and, therefore, does not support the idea that a denser network requires more specific investments which, according to the logic of the coherence framework, would raise the criticality of assets and thereby the need for a centralisation of decision rights. The higher probability for more decentralisation could be explained by the attractiveness of dense networks for private operators who would then try to obtain such lucrative water contracts. The explanation would then be based on scale economies that may be realised (Chong et al., 2006, p. 163), making the operation of the utility more attractive for private firms.

The characteristic that water services are provided through an intercommunal arrangement raises the probability of a decentralisation of decision rights. The variable ***INTERCOM*** is significant at the 1 % level for the three regression models. This finding is coherent with the idea that municipalities which associate would reinforce their competencies in managing contractual relations with a private firm in the case of decentralised decision rights on critical assets. Within an association of municipalities, capacities and resources would be concentrated so that it

would be easier to coordinate with a private firm. This increase in capacity would then open the door for the choice of more decentralised governance structures, a choice that might not have been possible if the municipality had been on its own. In order to further analyse this idea, it would be interesting to compare single-purpose, i.e. water-only, and multi-purpose associations (e.g. water, waste, transport…). In a single purpose association the intercommunality can concentrate exclusively on the water services so that it might be easier to manage a relation with a private firm in a decentralised mode of organisation. Such coordination in a decentralised governance structure might however be more difficult in a multi-purpose association because, in the latter situation, the intercommunality must not only concentrate on the water services but also on other public utilities[21].

The ***KNOWLEDGE*** variable is highly significant in the three models and shows the expected positive sign. This confirms the idea that a good knowledge of the network decreases the potential for coordination problems. As soon as coordination is easier, decision rights may be more decentralised. When there is only little knowledge on the network, the criticality of the related assets is increased due to the higher degree of uncertainty. This might result in serious coordination issues in a setting where decision rights are decentralised because the local public authority would have to retrieve private information from the operator of the network in order to be able to efficiently renew the network. Such a situation would imply very high coordination costs because the private firm might not be interested in gaining knowledge on the network and transferring it to the local public authority, for instance because it cannot be sure that the contractual relation will be renewed in the future. In such a context, the local public authority might prefer to centralise decision rights in order to escape these potential problems.

On the other hand, there is the situation where the knowledge of the network is good, e.g. because of an effort that the local public authority has made in the past to keep up to date the maps positioning the pipes and annex infrastructure. Under these conditions, the decentralisation of decision rights might be less problematic because the local public authority does not depend on the private operator for information on the network. Good knowledge of the network would enable the local public authority to efficiently approach critical investments. Hence, the need for coordination would be lower and, accordingly, the coordination costs too, thus easing the way for more decentralised decision rights.

[21] The increasing complexity of coordination issues would then explain why local public authorities tend to choose the same operator when they deliver several services at once. This is also the finding of a recent study for France (Desrieux et al., 2013).

As for the proxies for the criticality of investments, all three of them are significant with the expected signs. The findings imply that, in the presence of critical assets, more centralised modes of governance might be chosen and substantiate the link between critical assets and organisational decentralisation depicted in graphs 1 and 2. The existence of an investment program for the renewal of the network (variable ***RENEWPROG***) is significant at the 5 % level for the three regression models. Since the existence of such a program translates a need for critical assets, this corroborates the idea that centralised modes of organisation (with a decentralisation score of 0 or 1) might be chosen, in order to facilitate the coordination in core transactions.

Expectations are also met with regard to the ***RENEWAL*** variable. The correlation with the decentralisation of decision rights is negative and the coefficient is significant at the 10 % level in model 1. The higher the rate of renewal of the network, the lower is the probability of decentralised decision rights. In other words, the higher the rate of replacement, the more probable it becomes that a governance structure with centralised decision rights will be chosen. This gives substance to the idea that critical assets involve a need for coordination, which is very costly when decision rights are split, especially when the split decision rights concern core transactions – in this case the renewal of deteriorated parts of the transmission and distribution network. Therefore, the local public authorities might choose to economise these coordination costs by centralising decision rights in a more appropriate mode of organisation.

In model 3, when ***INVESTMENT*** is introduced, the coefficient for ***RENEWAL*** is still negative but the variable is not significant any more. This result however does not challenge the relevance of the renewal of parts of the network. Rather, it must be seen in light of the fact that ***RENEWAL*** is part of ***INVESTMENT***. It seems that ***INVESTMENT*** takes over the part that the replacement variable plays in the explanation for the centralisation of decision rights. This result might also suggest that the investments per network kilometre are a better proxy for the criticality of assets. This is not surprising because the assets referred to in the ***RENEWAL*** variable form a substantial part of the ***INVESTMENT*** variable. Besides, ***INVESTMENT*** contains additional critical assets like treatment facilities and service pipes, for instance.

As expected, ***INVESTMENT*** is negatively correlated to the decentralisation of decision rights and, additionally, significant in both models where this variable is present. This further substantiates the idea of the role of critical assets in the choice of the mode of organisation. Higher investments per kilometre correspond to a higher criticality of the assets and increase the probability for a centralised mode of organisation. In accordance with the coherence

framework, this might correspond to the desire to escape coordination problems in situations where decision rights on critical assets and the related core transactions are split between the public and the private party.

5. Conclusion and possible extensions

This paper has undertaken the first econometric study of the coherence framework as initially developed by Finger et al. (2005). It has been applied to the French drinking water sector. The coherence framework stresses the importance of the alignment between technical characteristics of infrastructures and matching governance structures. The findings from the empirical analysis in this paper corroborate a central idea of the coherence framework, namely that in the presence of critical assets, core transactions, like the renewal of the network, require more centralised modes of organisation. The centralisation of decision rights is a possible solution to coordination problems that might occur in decentralised organisational settings, especially when decision rights concerning core transactions are split. The regressions proposed in this paper indicate indeed that, in presence of critical assets, the probability for more centralised modes of organisation increases.

As a policy implication, when faced with the choice of a mode of organisation to provide water services, local authorities should not exclusively think in terms of public vs private provision. Rather, they should pay attention to the distribution of decision rights within the possible modes of organisation and also to their knowledge of the underground network. When they have little knowledge of the network, and face the need for critical long-term investments in it, they should avoid modes of organisation where decision rights on these critical assets are highly decentralised, such as in a lease contract. In that way, they can economise high costs related to the necessary coordination with the private contracting partner from whom knowledge on the state of the network needs to be transmitted to the local authority.

Since this is the first econometric application of the coherence framework, several challenges remain. At the empirical level, the dataset used in this paper contains only little data on one category of modes of organisation, i.e. service contracts and concessions, with typically highly centralised decision rights. Although this mirrors somewhat the reality of the French water sector, this group of contracts is underrepresented in the sample used throughout this paper. Since the *ONEMA* database is still young, there will hopefully be more observations for this group of governance structures in the future. Notwithstanding this small representation of

service contracts and concessions, the findings that decision rights are more centralised where the criticality of assets is higher are not invalidated.

Furthermore, there might be possible causality issues: is it the need for critical assets that leads to the centralisation of decision rights? Or is it because decision rights are centralised that investment effort is higher? From the point of view of the coherence framework the former possibility would be the right interpretation. Interviews or surveys of water service providers that fall into the categories of governance structures with highly centralised decision rights (direct public management, service contracts, and concessions) would help to clarify the causality of the two variables.

Once these issues have been addressed, a wide research program could be opened. A next step could be to study the link between criticality and performance. The central idea of the coherence framework is that alignment is needed in order to guarantee technical integrity, which is a requisite for safeguarding infrastructure performance. The increased use of performance indicators in the French water sector is a helpful factor for such analyses.

An additional extension would be to depart from the static view we apply here. In this paper, the criticality of assets is identified as an imminent need for investments. It would be interesting to adopt a dynamic view, allowing for a better evaluation of the criticality of investments in time, by using panel data. The annual publication of the *ONEMA* database provides a possible initial basis for this type of study.

Furthermore, the approach towards criticality is still at its inception in this paper. The notion in the coherence framework is more evolved and covers the organisational constraints imposed by the technology related to the infrastructure components. Therefore, it would be relevant to collect more detailed data on infrastructure components in order to deepen the operationalisation of the notion of critical assets and critical transactions. This would allow the use of econometrics to study the idea of technological complexity, another factor motivating the centralisation of decision rights.

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Annex

Table A.1
Descriptive statistics for ***RENEWAL*** classified according to the decentralisation score.

Decentralisation score	*N*	*Mean*	*Std. Dev.*	*Min*	*Max*
0	211	0.6717	1.3509	0	12.11
1	22	1.0356	2.3104	0	11.1
2	13	0.1295	0.1931	0	0.5811
3	164	0.3984	0.5923	0	3.7975

Table A.2
Descriptive statistics for ***INVESTMENT*** classified according to the decentralisation score.

Decentralisation score	*N*	*Mean*	*Std. Dev.*	*Min*	*Max*
0	211	3,510.50	6,078.36	11.54	67,464.88
1	22	2,996.89	3,134.38	118.56	10,100.21
2	13	1,864.69	2,434.45	32.95	7,893.76
3	164	1,966.22	2,447.32	11.46	11.948.06