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Better safe than sorry?

Reliability policy in network industries

CPB Netherlands Bureau for Economic Policy Analysis
Van Stolkweg 14
P.O. Box 80510
2508 GM The Hague, the Netherlands

Telephone +31 70 338 33 80
Telefax +31 70 338 33 50
Internet www.cpb.nl

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Abstract in English

This report develops a roadmap for reliability policy in network industries. Based on economic theory, we analyse the relationship between reliability and various types of government policy: privatisation, liberalisation, regulation, unbundling, and ‘commitment policy’. We let government policy depend on (1) the feasibility of competition between networks, (2) contractibility of reliability, and (3) the relation between profit maximisation and public interests. We test this roadmap on the basis of the empirical literature and case studies on electricity, natural gas, drinking water, wastewater, and railways.

Key words: Reliability, Network Industries, Government Policy

Abstract in Dutch

Dit rapport ontwikkelt een routekaart die beleidsmakers helpt beleid te ontwikkelen voor betrouwbaarheid in netwerksectoren. Op basis van de theorie analyseren we de relatie tussen betrouwbaarheid en vijf typen overheidsbeleid: privatisering, liberalisering, regulering, unbundling en ‘geloofwaardigheid’. We laten het beleid afhangen van (1) de mogelijkheid van concurrentie tussen netwerken, (2) de contracteerbaarheid van betrouwbaarheid en (3) de relatie tussen winstmaximalisatie en publieke belangen. We toetsen de routekaart op basis van een overzicht van de empirische literatuur en case studies over elektriciteit, gas, drinkwater, afvalwater, en spoorwegen.

Steekwoorden: Betrouwbaarheid, Netwerksectoren, Overheidsbeleid

Een uitgebreide Nederlandse samenvatting is beschikbaar via www.cpb.nl.

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Preface

In the past few years, reliability in network industries has turned out to be a hot topic: gas explosions, electricity blackouts, and railway accidents reached the front pages of the newspapers. These incidents and the debate that followed beg the question how public policy can secure a sufficient level of reliability in network industries (such as energy, transport, and communication networks). This report develops a roadmap for reliability policy in network industries.

The study is a joint project by CPB Netherlands Bureau for Economic Policy Analysis and OCFEB/SEOR-ECRi (University of Rotterdam). This report contains contributions by Rob Aalbers (OCFEB, chapter 3), Marcel Canoy (CPB, chapter 9), Elbert Dijkgraaf (SEOR-ECRi, chapters 5, 6, and 7), Stéphanie van der Geest (SEOR-ECRi, chapter 6), Sander Onderstal (CPB, project leader, chapters 1 and 2), Adriana Perez (University of Toulouse, chapter 8), Victoria Shestalova (CPB, chapters 1, 2, and 4) and Marco Varkevisser (SEOR-ECRi, chapters 5, 6, and 7).

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Henk Don, Director of the CPB

Summary

In the past few years, reliability in network industries has become a major topic. Several incidents and the debate that followed motivated this study, in which we answer two questions. First, which characteristics of network industries, called underlying market characteristics, are important for reliability? Second, given these underlying market characteristics, which policy is appropriate in order to secure reliability in such industries?

There are two major reasons why reliability is such an important topic in network industries. First, the impact of network failures on social welfare may be very large: separate failures may affect the whole system and also affect the functioning of other industries in the economy. Second, the relationship between the actions of companies and reliability is generally not observable, for example, because of a long lead-time of investment and externalities imposed by the users of the network. Given information asymmetry between the government and network companies, the task for policy makers to develop an appropriate reliability policy is very complex.

Before going into the details of our analysis, it is important to state more precisely what the phrase ‘to secure reliability’ actually means. The debate until today has focused almost exclusively on the issue how to prevent the level of reliability becoming too low. However, from a social welfare perspective, reliability may also be too high, as it is usually extremely costly to build networks that are 100% reliable. ‘To secure reliability’, thus points at a level of reliability that is appropriate from a social welfare perspective. This level of reliability is usually less than 100%. We call this level the ‘*appropriate* level of reliability’.

General framework

In network industries, markets not always provide network companies with the proper incentives to secure the appropriate level of reliability. Therefore, government intervention may be needed. Based on economic theory, this report identifies underlying market characteristics that determine proper government policy regarding network industries. These underlying market characteristics are grouped into three categories which characterise the feasibility of competition between networks, the contractibility of reliability, and commercial and public interests to invest in reliability. We analyse the relationship between these underlying market characteristics and government policy directed at establishing the appropriate level of reliability of networks. The analysis covers five main policy instruments: privatisation, liberalisation, regulation, unbundling and ‘commitment policy’. In particular, we describe which underlying market characteristics make it feasible to privatise networks, what kind of competition may be introduced in different network industries, what affects the choice of a regulatory model, and which trade-offs arise with respect to unbundling and commitment.

The roadmap: theory

Based on economic theory, we develop a roadmap towards the appropriate reliability policy. The three central questions in this roadmap are:

- Is competition feasible?
- Is reliability contractible?
- Are commercial and public interests sufficiently in line with each other?

These questions correspond to the three categories of underlying market characteristics considered above. Of course, such a roadmap only represents a stylised picture of the story, because each of the three questions in our roadmap (e.g., 'is competition feasible?') cannot be answered with a simple 'yes 'or 'no'. Even though the roadmap gives direct answers in polar cases only, it does provide us with general guidance on the direction of reliability policy in more complex (non-polar) cases.

Feasibility of competition between networks

If competition between networks is feasible and sufficiently strong, there is not much reason for government intervention: competition between network firms forces them to provide appropriate reliability, provided reliability is observable by the customers. Complete privatisation is therefore logical and regulation should focus on creating an environment that makes effective competition possible, for example by decreasing entry barriers. If competition is currently infeasible but rapid technical changes are expected to enhance the development of competing networks, the government may decide to decrease entry barriers. This will make competition between networks feasible in the future: new network firms have a chance to enter the market with innovations that compete with the old technology. If competition is feasible but is likely to remain weak, intermediate solutions are called for (e.g. light weight regulation or partial privatisation). The degree to which competition is feasible depends on (i) the degree of scale economies; (ii) the existence of alternative networks; (iii) the level of demand (growth); and (iv) the willingness of consumers to switch between networks (which depends on switching costs).

Contractibility of reliability

When competition is not feasible, then the market 'fails': unregulated firms may have an incentive to exploit market power and to provide sub-optimal levels of reliability. In such a case, government intervention is needed to deal with market failure, either by regulating the private firm or by keeping the firm in public hands. Which solution is more appropriate depends on the degree to which reliability is contractible.

Reliability is more contractible when (i) it is easier to hold the party that is responsible for a network failure accountable; (ii) investments in reliability have a shorter life cycle; (iii) the government is more able and willing to write a contract; (iv) the impact of network failures on society is not so large; (v) reliability and/or underlying network features can be more easily monitored; and (vi) the transaction cost of writing and enforcing a contract is lower.

If reliability is sufficiently contractible, a combination of privatisation and high-powered regulation, such as price-cap regulation or yardstick competition, is usually called for. It is important to supplement the use of high-powered regulatory regimes by quality regulation. The tariffs used under such a high-powered regulatory scheme should allow firms to cover their efficient costs, including the costs of providing the desired level of reliability.

Commercial and public interests

In case reliability is not sufficiently contractible, the combination of privatisation and high-powered price regulation is still preferable, provided that managers' incentives are sufficiently in line with public goals. This is more likely to be the case if (i) a private network operator takes into account the adverse effect of cost reductions on reliability; (ii) cost reductions have a small effect on non-contractible reliability; (iii) opportunities to reduce costs are small; (iv) the management of a public network firm has sufficient bargaining power vis-à-vis the government; (v) incomplete information between the firm and the regulator plays a minor role; and (vi) public service motivation is unimportant.

In any other situation, in which the government cannot use competition or regulation to sufficiently direct the incentives for private managers towards the social optimum, government provision of the network service complemented with low-powered price regulation (such as cost-of-service regulation) and 'low-powered' quality regulation (e.g., technical regulation of underlying network features) is to be preferred.

The reliability of the network may also be affected by government policy with respect to unbundling. In markets where competition between integrated firms is feasible, the government may leave the decision whether or not to unbundle to the firms. In all other cases government intervention may be needed to unbundle some activities from the network. The benefits of unbundling are associated with the possibility of introducing competition in competitive segments of the industry and with improving transparency (and regulation) of regulated segments, which will reduce the social cost of provision of the services. However, unbundling may be costly in other dimensions as it for example may lead to the hold up of investment or real-time operation problems. Real-time operation problems may arise when coordination of actions of different departments has to take place in real time, since unbundling reduces direct communication between the departments.

The roadmap: empirical evidence

The policy recommendations laid out in the roadmap are based on state-of-the-art economic theory. In order to assess whether these recommendations are also sound from an empirical point of view, we have reviewed the existing empirical literature. As the number of empirical papers in the literature was low, we decided to supplement the literature by a number of case studies. Not surprisingly, our case studies suffered from the same problem as a great deal of the existing empirical literature: the lack of sufficient good-quality data on reliability in network sectors. The insights from the empirical literature in combination with our case studies are therefore rather limited, both in number and in kind. On the positive side, however, we found no evidence contradicting the policy recommendations made in the roadmap.

The main insights from the empirical literature are that (i) the introduction of competition, when feasible, leads to lower prices and, in some cases, enhances quality; (ii) privately owned firms are more efficient and more profitable than otherwise-comparable state-owned firms; and (iii) privatisation and high-powered price regulation may have a negative effect on non-contractible, or in practice non-contracted, reliability. Finally, we like to emphasise that the empirical literature provides little to no evidence on the effect of unbundling and commitment on both cost and reliability.

These insights seem to support the recommendations made in the roadmap that it is reasonable to privatise the network firm when either (1) competition is feasible, or (2) reliability is contractible, or finally, (3) commercial and public interests are sufficiently in line with each other. The indication that quality may actually decrease, because of privatisation or the introduction of high-powered price regulation, has to be interpreted as a warning: since these policies may give firms the incentives to underprovide reliability, the government may want to introduce quality regulation (provided quality is sufficiently contractible). While giving this warning, we also explain in the report that quality decreases do not always reduce social welfare, but may be welfare improving in the case when the initial quality level was above the appropriate level.

Case studies

In order to supplement the existing empirical literature, we have conducted a number of case studies, covering five different network industries: electricity, natural gas, drinking water, wastewater and railways. Using panel or cross-section data on network companies, we tried to determine whether the effect of government policy on several indicators of reliability is correctly predicted by the roadmap. Below, we provide more details on each case study.

Electricity

Using data on cost and reliability of electricity distribution in Norway, we find that high-powered price regulation has forced the network companies to decrease their costs, while having an ambiguous effect on reliability. We also find evidence indicating that the introduction of quality regulation in 2001 has improved quality as measured by both the volume of energy non-supplied and the duration of interruptions. Furthermore, we compare our findings for Norway and the findings of other studies for the UK. Given that the aggregate performance of the UK companies did not decrease after privatisation, we conclude that privatisation supplemented by price and quality regulation has not reduced reliability.

Gas

Using data on the gas industry for nine OECD countries over 17 years, we have investigated the effect of private ownership and unbundling on reliability, as defined by the percentage of gas leaked. The main conclusion is that private ownership has had no negative effect on reliability.

Drinking water and waste water treatment

We have conducted several case studies on the water industry: three on drinking water (United States, the Netherlands, England and Wales) and two on wastewater treatment (the Netherlands, England and Wales). Reliability is measured using indicators proxying both the quantity and the quality of water delivered. Using differences in ownership for U.S. firms, we find no clear effect of privatisation on reliability. The effect of privatisation on most indicators available is insignificant.

After its privatisation in 1989 the water industry in the UK has been confronted both with changes in price and quality regulation. Our analysis indicates that the change in price regulation, from rate-of-return to price-cap, has had no effect on reliability. However, the introduction of quality regulation did have a major positive effect on quality. Finally, in 1999 the publicly owned Dutch water companies introduced voluntary benchmarking. We find some indication that benchmarking has lead to an increase of water quality.

Railways

Using a panel of OECD countries, we analyse the effect of regulatory regimes and vertical unbundling on the reliability of railways. Here, reliability is measured by the number of accidents per year. This ignores other dimensions of reliability, such as delays. Controlling for input prices and technological change, we find that under price-cap regulation reliability levels increased considerably while there was no such effect under cost-plus regulation. We notice that this result holds within the range of price-caps in our sample. A possible explanation for our results is that, since accidents are costly to firms, firms under price-cap regulation have a stronger incentive to decrease the number of accidents.

Conclusions

Concluding, we bring together the lessons that we have learned from theory, empirical literature and the case studies conducted. Our report provides a roadmap for reliability policy in network industries. Using empirical evidence from the literature and our own case studies, we have tested the effect of public policy on reliability. The empirical literature and the case studies confirm that high-powered price regulation reduces cost but may ambiguously affect not contracted reliability (see e.g. the case study on electricity). High-powered price regulation supplemented by quality regulation does not endanger contractible and in practice contracted reliability. Instead, we observe an improvement in performance in these indicators under such regulatory regimes, for example, in the case studies on water and electricity. For non-contractible reliability indicators for which commercial interests are in line with public goals, high-powered price regulation performs better than low-powered price regulation. In particular, we have found this effect of regulation on the number of accidents in the case study on railways. According to the results of the case studies on water and gas, privatisation has no adverse effect on contractible indicators of reliability. There is very limited empirical evidence on the effect of unbundling and ‘commitment policy’, which gives no clear-cut answer on their effect.

Some words of caution

We notice that our empirical evidence for particular network industries cover only some dimensions of reliability. Therefore, the results regarding the effects of policy on these dimensions should not be generalised too readily to other reliability dimensions in these network industries.

In the conclusions of the report, we discuss how policy makers can use the roadmap in real cases, which are often much more complex than theory assumes. This complexity manifests itself primarily in two dimensions. First, often reality cannot be described adequately by the polar cases of the roadmap (competition is feasible, reliability is contractible, etc.). This will introduce additional trade-offs for the policy maker that are not visible in the roadmap. For example, when competition is not perfectly feasible, it may still be worthwhile to introduce it, even when reliability is not contractible, and public and private interests are not in line. This may be the case when the benefits from competition are sufficiently large and outweigh the costs of a decrease in reliability due to imperfect competition. Second, even in cases when the roadmap is clear, there may be a discrepancy between theory and practice as not all parts of the roadmap have been tested sufficiently. This creates uncertainty with respect to the effect of the policy measures considered in the roadmap. This uncertainty should be taken into account when designing policy. This can be done either by adapting policy directly or by raising alertness with respect to possible negative effects, such as a decrease in reliability.

1 Introduction

"A process has been underway worldwide for three decades to privatise state enterprises and liberalise markets for the services of infrastructure industries, including water, communications, electricity, fuels such as gas, and transport by airlines, trucks, and railroads. This process is usually viewed as replacing tight regulation of vertically integrated monopolies with light regulation of functionally specialised firms and supervision of competitive markets."

These are the opening sentences from Wilson (2002) in an article on the market design of the electricity industry. The article discusses the electricity crisis in California, among other things. Some policy makers refer to the California crisis to underline their arguments against privatisation and liberalisation in network industries, claiming that it may endanger reliability of the networks.

These arguments were fuelled by several other accidents in the past few years. For instance, in 2003, Italy and the US faced major electricity blackout. Several gas explosions (in 2001 in Amsterdam and in 2003 in The Hague) have raised concerns about the reliability of the gas distribution system in the Netherlands. In 2004, after a train accident near Amsterdam, people argue that the railways are not reliable enough, lacking an accurate safety system. Even larger train accidents have happened in the UK.

Reports in the media on some of these incidents have further provoked the public and political debate. Examples are columns that appeared in newspapers in connection to the crisis in California and failures on the British railways. The California crisis was used as an argument in the political discussion on privatisation of the regional electricity networks in the Netherlands. It seems, however, that the California crisis has little to do with failures of the electricity distribution network itself, but rather relates to poor market design that allowed the electricity generators to exercise market power and that shifted all the risk from the consumers to the distribution companies.[1] In the example of the British railways, public opinion has linked the privatisation of the railway company to the worsening of the reliability of the rail network, while the failures might have been caused by extremely low investment in pre-privatisation years.

The above considerations beg the question what are the driving forces of reliability in network industries. In 2000, the Dutch government published a note[2] about the development and public interests in network industries, followed by the study of OCFEB (2002) that provided economic background on the note. Our report further elaborates on the ideas expressed in these two

[1] Joskow and Kahn (2002) and Wilson (2002).

[2] Ministry of Economic Affairs (2000).

publications and focuses on reliability, which is arguably one of the most important public interests in network industries.

There are two major reasons why reliability is such an important topic in network industries. First, the impact of network failures on social welfare may be large: separate failures may affect the whole system and also affect the functioning of other industries in the economy. Second, the relationship between the actions of companies and reliability is generally not observable, for example because of a long lead-time of investment and externalities imposed by the users of the network. Given information asymmetry, it may be difficult or impossible for the government to control this relationship directly. Therefore, it is crucial that public policy creates right incentives for the companies to optimise this relationship. This means that reliability issues cannot be addressed without paying at least some attention to pricing issues.

1.1 Purpose and research questions

We study the relationship between government policy and market characteristics on the one hand and reliability on the other. The purpose of this report is:

To develop a roadmap for reliability policy in network industries.

The roadmap is a framework for policy makers who develop policy for specific network industries. It guides policy makers through the major steps in forming policy that would secure reliability. We do not intend to provide tailor-made solutions for reliability issues in all network industries. Instead, we give a helicopter view of the effect of market characteristics and the major policy instruments on reliability of networks. This roadmap is also instrumental in removing misunderstandings about government policy, such as the claim that the California crisis is a signal that privatisation and liberalisation always endanger the reliability of networks.

In order to develop the roadmap, we answer the following research questions:

- What is the relationship between government policy and the market characteristics of a network industry on the one hand and reliability on the other?
- Depending on the characteristics of the industry, what can the government do about reliability?

The answers are based on economic theory, empirical literature, and five of our own case studies.

1.2 Definitions

In this section, we first define the two key concepts of this report: network industries and reliability. Furthermore, we discuss the concept of ‘welfare’, which provides us with a criterion for ‘appropriate’ reliability in network industries.

1.2.1 Network industries

The note issued by the Dutch government describes network industries as “the industries in which suppliers supply their products and services via network infrastructures”.[3] The network infrastructure may be either lines connecting several locations (such as the electricity network), or nodes where supply and demand meet (such as airports).

However, the description of network industries given above is not particularly useful for our purposes. Almost any industry fits such a definition, because most industries use some kind of network to transport their products. Searching for a better definition in the literature does not help much, as this concept appears to be not well defined.[4,5] As TILEC (2003) summarises:

“In spite of the fact that economic writings about network industries have really taken flight over the last one or two decades, no clear definition of the term ’network industry’ has really crystallised.”

Given that there is no consensus on definitions of a network industry, we find it more sensible to replace such a definition, with a list of characteristics that are common to the industries that we would like to cover in this report:

- Utilities (electricity, gas, drinking water, sewage)
- Communication (post, telecom, internet, radio, TV)
- Transport (railways, airports, public buses, harbours)

First, all these industries rely heavily on physical network(s). This means that network effects are present, such as complementarities, compatibility, standards and network externalities. The latter means that the value of a particular product for one consumer increases as more consumers join the network. We notice that by focusing on physical networks, we explicitly exclude from consideration financial networks (i.e. banks and credit-card issuers).

[3] The authors’ translation from the original text in Dutch “…sectoren […] waarin aanbieders producten en diensten aanbieden via infrastructuren”. (Ministry of Economic Affairs, 2000, p.4.)

[4] See TILEC (2003, p. 38-41) for a discussion of other definitions of network industries adopted in the economic literature.

[5] OCFEB (2002) lists the following three characteristics which are often used in connection to network industries: (1) suppliers supply their products via (physical) network infrastructures, (2) there are substantial economies of scale in (a segment of) the industry, (3) legal or natural monopolies are present in (a segment of) the industry.

Second, these industries are characterised by the presence of a piece of the network infrastructure which is essential for the system to function and by the strong interdependency of the users' actions. Think, for example, of an airport, a post-sorting station, or an electricity transmission network. The presence of such an essential commonly used infrastructure element requires coordination between the parties that operate on the network. Since failures on one side may affect supply on another side, reliability is a system-wide property in such an industry. This means that we do not consider computer software and hardware industries, or supermarket chains as networks. We will give a more formal definition of reliability in the next section.

Third, these industries are often characterised by large lumpy and/or sunk investments, and large economies of scale and/or scope. These technological characteristics often lead to market power in network industries. Furthermore, market power may arise from legal constraints, which are imposed in order to secure public interests in such industries (e.g., universal service obligation or minimum service quality). Therefore, in most cases, networks are natural monopolies or 'tight' oligopolies.[6,7]

As said, market power often arises on the network side. This places the network operator in the centre of our attention throughout this report. We discuss the concept and the role played by the network operator in more detail in the beginning of chapter 2.

1.2.2 Quality, reliability, and security of supply

Customers care about both the price and the quality of the goods and services they buy. With respect to network industries, quality may refer to several aspects, such as the correctness of bills, the provision of extra services, and friendliness of the personnel. Reliability is also such an aspect. It reflects the ability of the system to deliver the product (or service) transported over the network without interruption and without deterioration of its quality.[8] For instance, in electricity, reliability refers to both interruptions and fluctuation in voltage. In mobile telecommunication, reliability includes both the probability that a call is blocked and the noisiness of the signal. In the water industry, reliability relates to both the interruptions of water supply and the quality of the water supplied. In our case studies, we give more detailed characterisations of reliability in the network industries considered.

Reliability is closely related to security of supply. While the term 'reliability' relates to the quality of the network, the concept of 'security of supply' is more general and refers to the long-run provision of network goods and services. The main difference between reliability and security of supply is that the latter concept also includes sufficient supply of the commodity

[6] A market is a tight oligopoly if (1) there are several firms in the market and (2) these firms have the ability to exploit market power. See CPB (2003b) for more details regarding tight oligopolies.

[7] The legal term that comes closest to the economic term 'market power' is (collective) dominance.

[8] Our definition is based on IEEE (1999).

transported over the network. In other words, in contrast to reliability, security of supply also includes potential crises on the supply side, for example caused by political restrictions or by sharp increases in demand because of unexpected high economic growth or extreme weather conditions. Throughout this report, we will ignore these issues, and refer the reader to CPB (2004).

There may be several factors affecting the reliability of the network, including (1) a lack of network capacity, (2) a lack of maintenance or insufficient operating expenses, (3) failures caused by the users of the network or other parties, e.g. someone hits a cable when digging into the ground, and (4) failures caused by other external events, e.g., a fallen tree blocking the rail track. Therefore, a network operator may optimise the reliability of its network by investing in the capacity of the network, maintenance, operation, process innovation, and product innovation, and by undertaking measures that reduce or prevent network failures caused by third parties and external events. The network operator's incentives to do these investments may crucially depend on government policy, which is the main topic of this report.

1.2.3 Welfare and appropriate reliability

Before we can assess the level of reliability in a network industry, we need to specify the criterion we apply. We use 'welfare' as such a criterion. Welfare is the weighted sum of consumer surplus and producer surplus.[9,10] Consumer surplus is a measure for the prosperity of consumers. Reliability is an important ingredient for consumer surplus: the higher the reliability of a network, the higher the consumers' prosperity (other things being equal). Producer surplus is equal to the profits made by the firms in a network industry. Reliability affects producer surplus ambiguously. Higher reliability may lead to higher demand for the firm's product. However, increasing reliability is costly for a firm. Higher reliability requires more investment in the capacity of the network, maintenance, operation, process innovation, product innovation, and so forth.

In terms of reliability, maximising welfare usually implies that networks are not 100% reliable. Therefore, we distinguish four levels of reliability throughout this report. A network is *perfectly*

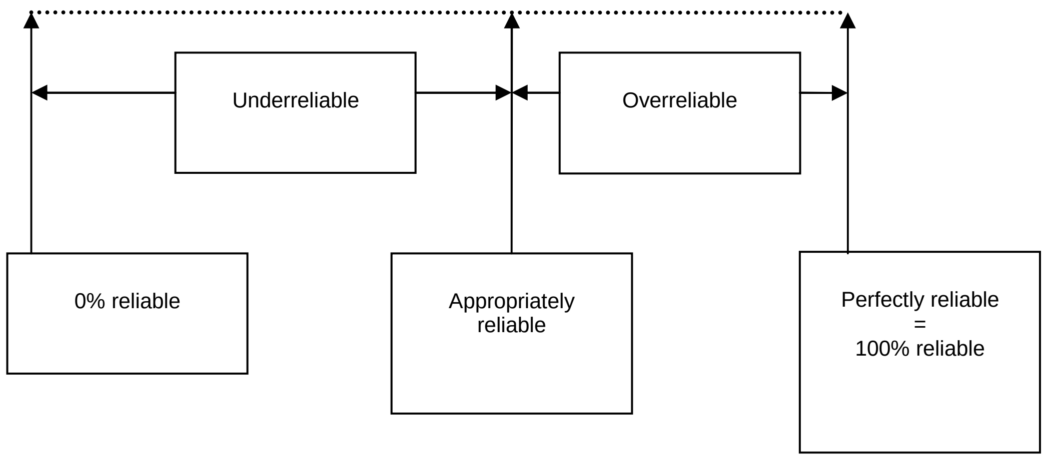
[9] Economic concepts such as static efficiency and dynamic efficiency are closely related to welfare. For reliability, both static efficiency and dynamic efficiency are important. Static efficiency is a measure of the effective use of current technology and resources to satisfy consumers' needs. The related question for our study is then: do firms use the current technology and resources in such a way that satisfies consumers in terms of reliability and other aspects they care about? Dynamic efficiency is a measure of improvements in total welfare generated by better and new products (product innovation) and improved production techniques (process innovation). In terms of dynamic efficiency, we are mainly interested whether firms employ both types of innovation to optimise reliability, both today and in the future.

[10] Not only the *total* welfare, but also the welfare *distribution* among people is important with respect to reliability. Think about the recent discussion on which parts of the country have to be 'shut down' in case of a shortage of electricity in the Netherlands. Although the topic of welfare distribution among different groups of consumers is important for government policy, we will ignore it throughout this report. However, we will touch upon the issue of the welfare distribution between the network and its users, when discuss market design in section 2.4. For a deeper discussion of welfare distribution, see for instance Estache et al. (2001), who shed light on who benefits from privatisation of utilities.

reliable if it is always able to deliver the quantity and quality demanded, it is *appropriately* reliable if the marginal social costs of investments in reliability are equal to the marginal social benefits, and *underreliable* (*overreliable*) if its reliability is less (more) then the appropriate level. See figure 1.1. Since it is very costly or impossible to have back up installations for all unforeseen events, appropriate reliability is unlikely to be perfect reliability. Hence, perfectly reliable is generally overreliable. In other words, welfare maximisation implies that most networks are not failure free: there may be some electricity blackouts, your phone call may sometimes be blocked, or your train may occasionally be late. Throughout this report, we speak about market failure if a free market does not generate appropriately reliable networks.

As we have already stressed, the impact of reliability in network industries on social welfare may be large. This means that the development of appropriate public policy is very important from the social welfare perspective.

Figure 1.1 Levels of reliability



1.3 Outline of the report

The report consists of three parts. In the first part, we develop a roadmap that results from a theoretical analysis of the relationship between government policy and the market characteristics on the one hand, and reliability on the other. An overview of the empirical literature provides empirical evidence on this relationship. The second part includes a number of case studies in which we investigate this relationship in more detail. The third part brings together the lessons from the first two parts. We advise those who wish to get a deeper insight in reliability policy in general to read both chapters of Part I, and the conclusions in Part III. We recommend readers who are mainly interested in reliability policy in a particular sector to study the overall conclusions (chapter 9), as well as the particular case study as far as it focuses on this particular sector (chapters 4 - 8).

PART I. General Analysis

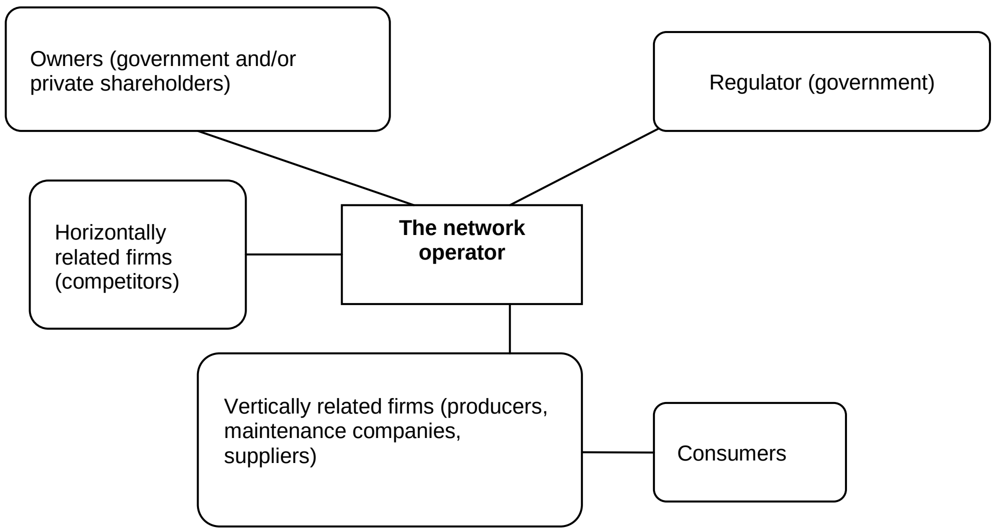
2 Theory

In this chapter, we develop a roadmap for reliability policy in network industries. This roadmap is based on insights from economic theory, and focuses on the question how the government can deal with network operators when markets do not provide the incentives to establish appropriate reliability. The first section of this chapter discusses the sources of market failure that may cause networks to become underreliable or overreliable, which may give the government a reason to intervene in a network industry. In section 2.2, we address three key questions that are crucial for the success of policy instruments, and explain which underlying market characteristics provide answers to the above questions. Section 2.3 discusses main policy instruments, namely privatisation, liberalisation, regulation, unbundling, and commitment, and their relationship to reliability. In the concluding section, we summarise our findings in the roadmap.

Figure 2.1 sketches a stylised picture of what we call a network operator throughout this report. By the network operator, we understand a network company and its management. Usually, the network operator has real-time operation responsibilities (such as system operation and solving congestions in the network) and is in charge of network planning, maintenance and investment. In the case of utilities, when the market for the commodity transported over the network is liberalised, the network operator may also have responsibility with respect to market facilitation. For example, a transmission system operator in the electricity industry may be an operator of the power exchange.

As shown in figure 2.1, the network operator has relationships with four types of agents. First, the owners are the shareholders of the network operator, which *internally* control the network operator. The owners are usually the government and/or private shareholders. Second, the regulator has *external* control over the network operator. The regulator controls the relationship between the network operator and outsiders such as its customers (regulation of prices, monitoring reliability, etc.) and other firms (regulation of entry, access pricing, etc.). Third, the network operator is horizontally related to competitors in the same region and also to its 'peers' in other regions (for instance under a yardstick regime). Finally, the network operator has vertical relationships with production companies, maintenance firms, suppliers that use the network to transport their goods and services to consumers, and so forth. In practice, the network operator may or may not be integrated with these firms.

Figure 2.1 The network operators and related agents



2.1 Market failure

This section discusses different types of market failure that may lead to underreliable or overreliable networks. Government intervention may be required when markets do not provide incentives for appropriate reliability. The three sources of market failure mentioned in the literature are market power, externalities and asymmetric information.

Market power is the major source of market failure in networks. In ‘normal’, competitive, industries, buyers and sellers freely trade goods and services in the market. The distinctive feature of network industries is that a network infrastructure is necessary for transportation of goods or services, and that the network company has market power. In a free market, the network company has an incentive to exploit this market power, for instance by offering too high price or too low reliability.

Externalities are the second type of market failure. Externalities arise when a party does not take into account the effects of its actions on other parties. Let us give two examples. Users of a network impose negative externalities on each other, when the capacity that one customer uses cannot be used by another customer. This may negatively affect reliability if capacity is scarce.[11] Another example of a negative externality is the hold-up problem that may arise after vertical unbundling. The hold-up problem may for instance occur in the railway industry when rail infrastructure is fully separated from train operation. The train operator is very much

[11] Joskow and Tirole (2004).

dependent on the rail infrastructure. If the reliability of the rail tracks deteriorates, the probability that trains arrive late increases and more accidents may happen so that the train operating company may lose its consumers. However, the operator of the rail infrastructure may have little incentives to invest in the reliability of the network since it has to share the gains from his investment with the train operator.

Finally, asymmetric information may be a reason for market failure. A superior information position of networks magnifies the market failure associated with their market power: in addition to rationing supply by asking too high price, networks may also deliver suboptimal reliability in order to maximise profit. As many reliability features may not be observed by individual customers, it may be difficult for them to negotiate a fair contract with respect to prices and reliability. For example, most individual customers are unable to specify and/or control the level of purification of water supplied by their water company. By introducing regulation the government can reduce transaction cost of writing such a contract, although regulation may not solve the problem of information asymmetry completely.

Market failures are a reason for the government to intervene in network industries. In many industries, the government used to do so by operating fully integrated network companies. Recently, however, the government’s role in these industries has shifted from player to game designer and referee. In section 2.3, we discuss how the government may play this new role. More specifically, we consider five policy instruments: privatisation, liberalisation, regulation, unbundling, and ‘commitment’. Note that it may be difficult for the government to implement these policy instruments in such a way that it gives the network operator the incentives to provide appropriate reliability: next to market failure there is the risk of government failure, because *inter alia* the government (or the regulator appointed by the government) is usually incompletely informed about the current state of the network and the consumer preferences.

2.2 Underlying market characteristics

Before we analyse the relationship between government policy and the reliability of a network, we first discuss underlying market characteristics that may affect this relationship. It is important to focus on underlying market characteristics for the following reason. In a certain country Y and network industry X, policy makers are facing a policy decision that may affect reliability. As usual, economic theory and practice provides mixed answers to the appropriateness of the various policy instruments. What is appropriate in one industry, may not work in another. Therefore, a checklist of underlying market characteristics helps to understand which factors explain the difference and how to take them into account when making policy choice. It is the purpose of this study to provide such a checklist of underlying market characteristics and the associated policy answers.

The key questions that affect the relationship between government policy and reliability are: Is competition feasible? Is reliability contractible? Are commercial and public interests sufficiently in line with each other? Therefore, we group the verifiable underlying market characteristics into three main categories: feasibility of competition (2.2.1), contractibility (2.2.2), and commercial and public interests (2.2.3). We will argue in section 2.3 that these three groups of characteristics have important implications for reliability policy.

2.2.1 Feasibility of competition between networks

As explained in the section on definitions, in a network industry, a network operator has market power. In some situations, the network is a natural monopoly, so that competition is not feasible. In cases where the market is not a natural monopoly, but a *legal* monopoly, it makes sense to evaluate the reasons for this, and possibly to liberalise the market. In other words, the government may introduce competition between networks if this is feasible. When firms enter, the market becomes an oligopoly in which several firms compete to attract customers.

If there are several alternative networks and switching costs between them are sufficiently low, customers can switch to a company that offers the best price-to-quality ratio. This provides competing network companies with the incentive to safeguard appropriate reliability. Here we assume that customers should observe reliability at least ex post. The latter is often the case (e.g. customers normally observe supply interruptions), but not always (think of maintaining drinking water quality in the water network).

Competition is more feasible…

The presence of competition is not an exogenous factor. However, there are underlying market characteristics that may make competition feasible or not. Competition between networks is more feasible:

- The smaller the economies of scale
- The more alternative networks are available
- The higher is demand (growth)
- The less consumers are locked in

Let us elaborate on these characteristics.

…the smaller the economies of scale

If the technology does not exhibit substantial economies of scale, there is not much reason why only one firm, or a low number of firms, would serve the market. For instance, in wireless telecommunication, there is room for several providers, whereas in railways, it is usually too costly to have more than one network between two places.

…the more alternative networks are available

Sometimes competition between network firms may be feasible in completely different types of networks. Think about the market for Internet services. Now, consumers can connect to the Internet using the fixed telephone line, the cable, or a wireless connection through UMTS.

…the higher demand (growth)

Note that firms may have different opportunities to realise economies of scale in different countries or even in different regions of the same country. If demand is high, it is relatively cheap to duplicate the network. For instance, in a densely populated country like the Netherlands, it is relatively cheaper to roll out a UMTS network than in scarcely populated countries such as Finland. Moreover, within Finland, it may still be profitable for several firms to roll out a network in the Helsinki region, but it is too costly to do so in the scarcely populated North. The same applies to demand growth. In situations where a new product is launched (mobile phones) it is easier for new firms to attract market shares.

…the less consumers are locked in

Competition is not necessarily feasible when several alternatives are present in the market. An additional condition is that switching between alternatives should not be too difficult or costly. In other words, consumers should not be locked in to their current network. Think about railways. Some argue that the car competes with the train. In some cases, consumers may indeed consider using a car as an alternative to the train. However, for many consumers, switching costs are high: perhaps they have to obtain a driver's license first, they may have to buy a car, and they need to inform themselves about the routes.

2.2.2 Contractibility

Another important question is to which degree reliability is contractible.[12] We say that reliability is contractible if it is possible to write a contract, verifiable by a court, that specifies all relevant reliability dimensions and the degree to which the firm can be held accountable for them under different contingencies. An example in which the firm may not be accountable for network failure is when a third party causes damage to the network: think of a traffic accident when a car hits an electricity line. The extent to which reliability is contractible differs from one network industry to the other.

Of course, the effect of government policy on reliability does not only depend on the contractibility of reliability, but also on whether reliability actually has been contracted upon. Moreover, if reliability is contracted, it is crucial *how* this has been done. For example, there is a danger that the network firm 'teaches to the test': it makes sure to score well on the reliability dimensions on which is has a contract, neglecting non-contractible or not-contracted reliability

[12] See Bovenberg et al. (2003) and Martimort et al. (2002) for an elaborate discussion about contractibility.

dimensions. For instance in the Dutch railway industry, the passenger operator NS has a contract specifying the percentage of trains that arrive on time. This may give the NS the incentive to have trains depart before a delayed connecting train arrives. As a consequence, passengers have to wait longer for their connection, so that they are worse off. A more relevant output would be the number of customers that arrive on time, but the latter is much more difficult to measure, and hence to contract upon in practice.

Reliability is more contractible…

Similar to the feasibility of competition, the question regarding contractibility is difficult to answer with a simple 'yes' or 'no'. Several underlying factors contribute to the contractibility of reliability. Reliability is more contractible:

- The easier it is to identify and to hold responsible the party that causes a network failure
- The shorter the life cycle of investments in reliability
- The more the government is able and willing to write contracts
- The lower the impact of a network failure
- The easier reliability or underlying network features can be monitored
- The lower the transaction costs of writing and enforcing the contract

Let us elaborate on these characteristics, giving some practical examples.

…the easier it is to identify and to call to account the party that is responsible for a network failure

In some situations, it is not easy to contract reliability as it may be difficult to identify who is responsible for network failures. For example: was the recent electricity blackout in Italy caused by a failure of the transmission network, lacking generation capacity, or foreign networks? Regarding this outage, BBC news reported on 30 September 2003:

"The blackout appears to have been triggered by a minor accident on a power line in neighbouring Switzerland, causing a domino effect in French lines which affected Italy. Parts of the Swiss city of Geneva were also blacked out. […] Switzerland and France have blamed Italy for failing to take action that would have limited the scale of the problem, while Italy said France was at fault."

…the shorter the life cycle of investments in reliability

In other situations, reliability is non-contractible as it is not feasible to write long-term contracts, while this may be desirable as investments in reliability have a long life cycle and there is a time lag between investment and its effect. For instance, today's investments by the rail network operator may affect reliability of the rail track in a period of more than 30 years, while it is difficult to predict the development in the industry over such a long period. There are three main reasons why the government may not be willing or able to write contracts for a very long or an indefinite time period. Firstly, the government's contracting possibilities may be subject to certain external limitations, such as binding rules of national and supranational law. Secondly, it is considered a general principle of contract law that a party to a contract cannot commit itself 'for life'. This means that parties to a contract that has been concluded for an indefinite period should always have the possibility to terminate the contract *bona fide* and at reasonable notice. Thirdly, a contract of non-intervention with a private party would not prevent parliament from imposing new legislation which results in this contract being terminated or its terms being changed. While this may give rise to damages being paid to the private party to the contract, this certainly implies an element of uncertainty for the latter. (See also section 2.3.5 on commitment.)

…the more the government is able to and willing to write contracts

Moreover, the government may not be willing or able to sign a contract for such a long time period. For instance, in some industries, it is commercially not interesting, but socially desirable to operate a network. Think about railways in scarcely populated areas. In that case, the government may have to subsidise the industry. The government may not be willing to sign a contract that guarantees a certain level of subsidy for the industry, as such a contract has direct consequences for its budget constraint.

…the lower the impact of a network failure

Sometimes the risks associated with network failures are too large to write a credible contract. This holds for networks which may rarely fail, but if they do so, the impact on society in huge. In that case, it is difficult to write a credible contract that gives the network operator the right incentives to appropriately invest in reliability. For instance, the operator of an electricity transmission network would go bankrupt if it was charged for the damage for the society caused by a large network failure, which is undesirable when the network service is crucial for the society. Note, however, that reliability may still be contractible when the regulator is able to monitor the processes that *underlie* reliability. For example, the regulator can ask regulated companies to certify the condition of the network, or check the adequacy of the investment plans of companies. See also the next point.

…the easier it is to monitor reliability or underlying network features

Regulating network operators is costly: a regulatory body has to monitor the network operator. In some cases, reliability features can be easily verified. An illustration is the so-called 'N-1 standard' for high voltage electricity grid in the Netherlands. Suppose that the high voltage network consists of N network components. If one of these components fails, then there is no interruption of the network. According to the network code in the Netherlands, this standard applies to all high voltage electricity lines in the country. Such measures can be verified in court, and hence can be contracted upon. In other situations, it may be difficult to monitor the reliability of the network. The regulator may need substantial expertise and a huge amount of information to check the reliability of a rail track.

…the lower are the transaction costs of writing and enforcing the contract

It may be very costly to write and enforce a contract. In the drinking water industry, the government may need to specify a maximum for each chemical that may pollute the water. Also enforcing the contract may be costly, as it may involve time consuming and expensive court cases. Whether a contract is easily enforceable may also depend on a country's legal system. In some less developed countries, contracts are difficult to enforce, as the legal system is weak, or the judges are corrupt.

2.2.3 Commercial and public interests

Designing a contract with the network operator, the government may consider giving the network operator incentives to maximise its profit. For instance, privatisation and price-cap regulation provide incentives to increase profits. However, these high-powered incentive schemes have an unclear effect on reliability and, more generally, on welfare. According to the theory, profit maximisation has the desired effect on reliability if commercial and public interests are sufficiently in line. Note that we assume that managerial interest and commercial interest coincide. This need not be the case: managers may have other targets in their mind than the owners of the firm. The corporate governance system in a country may influence the manager's incentives, for instance in terms of the bargaining power the management has when negotiating with the government.

Commercial and public interests are in line if…

Commercial and public interests are in line under the following circumstances.

- Cost reductions have little effect on non-contractible reliability
- The opportunities for non-contractible cost reductions are small
- A profit-maximising network operator has the incentive to take into account the adverse effect of cost reductions on reliability
- Incomplete information between the firm and the regulator plays a minor role
- Public service motivation is unimportant
- The management has much bargaining power vis-à-vis the government

Let us elaborate on these underlying market characteristics.

…cost reductions have little effect on non-contractible reliability

Commercial interests may affect two investment types: improvements in (non-contracted) quality of the service (reliability of the network in our case) and cost reductions. The more profit-focused a firm is, the stronger its incentive to engage in both types of investment. However, from a welfare point of view, the firm's incentives to reduce costs may be too strong as the firm ignores the potential adverse effect on reliability. To which extent commercial and public interests are congruent then crucially depends on the trade-off between managers' incentives to improve reliability and their incentives to reduce costs. For instance, a rail track operator may reduce his costs substantially by not investing in the maintenance of the track, which may not be contractible. This goes at the expense of reliability of the rail track. In contrast, when most opportunities for cost reduction are efficiency improvements opportunities, cost-reducing efforts need not have a negative impact on reliability.

…the opportunities for cost reductions are small

If the opportunities for costs reductions are small, cost reducing innovation hardly take place, and hence, there is hardly any negative impact on reliability. As a profit maximising firm has more incentives to innovate with respect to reliability than a not-for-profit firm, commercial interests are in line with public interests.

…the network operator takes into account the adverse effect of cost reductions on reliability

When a decrease in reliability below the appropriate level has a negative impact on the network operator's profit, a profit maximising operator may still decide to supply appropriate reliability. For instance, when the network becomes underreliable, customers may respond by reducing their demand, which may still prevent managers from undersupplying reliability.[13] Another possibility is that it is very costly for the network operator to operate an underreliable network. For instance, in railways, an underreliable network may be the cause of accidents, which are very costly for the industry: the track has to be repaired, trains may have to be replaced, and the accident may chase away customers.

…incomplete information between the firm and the regulator plays a minor role

Laffont and Tirole (1993, chapter 17) claim that information asymmetry between the regulator and a private firm may play a role in terms of reliability, especially when contracts are incomplete. Private (profit maximising) firms have to serve two principals (their shareholders and the regulator) whereas a public (not-for-profit) firm only has one principal (the regulator). The conflict of interest between several principals strengthens the problems related to asymmetric information. The larger the information asymmetry between the regulator and the firms, the stronger the case for low-powered incentives with respect to profit maximisation. In

[13] Laffont and Tirole (1991).

other words, if there is a substantial amount of asymmetric information between the regulator and the firms, public ownership and low-powered price regulation are more likely to be appropriate.[14]

…public service motivation is unimportant

Roemer and Silvestre (1992) and Francois (2000) provide additional arguments in favour of low-powered incentives such as public provision. Roemer and Silvestre assume that the management of a public firm has the incentive to maximise social welfare, whereas the management of a private firm wishes to maximise profit. They show that in many situations, a public firm outperforms a private one, even if the private firm is appropriately regulated. The reason is that the government needs to pay the profit-maximising private manager an informational rent, as he possesses more information about the cost of production. Francois motivates the assumption by Roemer and Silvestre that a public firm's management has more reasons to care about maximising social welfare than a private one. He indicates that when government bureaucrats are not residual claimants, they can commit to a 'hands-off' policy, which elicits greater effort from workers who have 'public service motivation'. A worker for a private firm may then decide not to exert extra effort knowing that the management will have somebody else do the job if he does not do it.

…the management has much bargaining power vis-à-vis the government

If the management has much bargaining power when negotiating with the government, they are more willing to implement socially desirable investments that would be commercially loss-leading otherwise. Think about the operation of rail tracks in scarcely populated areas. High bargaining power gives the firm the opportunity to reap a high reward for the investments, so that the firm is more willing to invest in such areas. This may explain why in the Netherlands, all public network operators are 'hived off', i.e., put at a distance from the government. The other way around, if the network operator has little bargaining power, it may fail to undertake some socially optimal investment, as it can only partly appropriate the returns. Shleifer (1998) gives the following example to illustrate this idea:

"[A]n owner of a postal business who invents a better way to deliver mail can implement this innovation and profit from it. In contrast, if the government or someone else owns the business, the inventor needs the agreement of the owner to implement the innovation, and thus must share the benefits of the invention with this owner. Without the bargaining chip […], the incentives to invest and innovate are lower."

[14] See also Bovenberg et al. (2003).

2.3 Policy instruments

In this section, we discuss the effect of five policy instruments on reliability: privatisation (2.3.1), liberalisation (2.3.2), regulation (2.3.3), vertical and horizontal unbundling (2.3.4), and commitment (2.3.5). All may play a role for reliability. Privatisation stimulates the network operator to work in a profit maximising fashion, which may have (or not have) a positive effect with respect to appropriate reliability. Liberalisation may encourage competition between network operators, so that they are incentivised to maintain appropriately reliable networks. In the case that competition between networks is not feasible, the government may still provide the right incentives to the network operator using regulation. Unbundling may encourage competition in some market segments and improve the efficiency and effectiveness of regulation. However, unbundling may create difficulties with respect to reliability, which are for instance rooted in hold-up problems and real-time operation problems. Finally, the government's commitment is important as in several network industries, investments in reliability have a long time horizon.

2.3.1 Privatisation

We start our analysis of policy instruments with the following question: which network operator is more likely to provide appropriate reliability, a private one or a public one? When privatising a firm, the government partially or completely outsources certain control rights regarding ownership, financing or management of this firm to private parties.

Types of privatisation

Van Damme et al. (2003) distinguish three main forms of privatisation: 'contracting out', 'hiving off'[15] and 'complete privatisation'. The first term refers to contracting out of services that were formerly provided by the state. The second corresponds to the situation in which government agencies are put at arm's length, so that they can operate in more businesslike fashion, while the assets remain to be held by the government. And complete privatisation encompasses the transfer of assets to private shareholders. As currently in the Netherlands most public firms are hived off, the political debate is mainly about ownership: should we have a completely privatised network firm, or a hived-off firm which is owned by the government?

When (not) to privatise?

The government may consider to privatise a public network operator or to nationalise a private one in order to give the network managers better incentives to appropriately invest in reliability. According to Hart, Shleifer and Vishny (1997), the choice between public and private provision crucially depends on the incentives of the provider to innovate. They rely on the idea that managers in a private firm have both more control and bargaining power than public managers.

[15] 'Verzelfstandiging' in Dutch.

Therefore, a private contractor has a stronger incentive to engage in two types of innovations: cost reduction and improvements in non-contractible quality (non-contractible reliability of the network in our specific context). However, the private provider's cost reduction may be too strong as he ignores the adverse effect on the reliability of the network. Hart, Shleifer, and Vishny show that private provision is better than government provision, i.e., there is a case for privatisation, if at least one of the following three questions has a confirmative answer:

- Is competition between networks sufficiently feasible?
- Is reliability sufficiently contractible?
- Are commercial and public interests sufficiently in line with each other?

Note that these questions coincide with the three groups of underlying market characteristics that we have defined in the previous section.

When competition is feasible, privatisation is appropriate. Competing private firms have to take into account the adverse effect of cost reductions on reliability; otherwise, they lose their customers to their competitors. An example is the market for GSM, in which mainly private firms compete. When competition is only partly feasible, i.e. in natural tight oligopolies, it may still be appropriate to keep at least one firm public.[16] This is for instance the situation in electricity market in Norway, where state-owned Stat Kraft owns more than 30% of the generation capacity.[17]

Usually in a network industry, competition between networks is not feasible. Then, the contractibility of reliability is a crucial factor. If reliability is contractible, privatisation is appropriate. The reasoning follows from the observation that if reliability is contractible (and correctly contracted upon), a private manager has to take into account the adverse effect of costs reductions on reliability, as the contract gives him the incentives to do so. Although there may be no difference in the reliability delivered by a private firm compared to a public firm, a private manager has more incentives to operate cost efficiently, so that his profit, and hence welfare (being the sum of consumer and producer surplus) increases. Perhaps the insight is counterintuitive. For instance, an often-used argument for government provision in the postal sector is to ensure postal delivery to sparsely populated areas. However, from the contractual point of view, this argument is weak: the government can oblige a private firm to deliver mail in the entire country.

[16] De Fraja and Delbono (1989) and Barros (1994).

[17] Nese, G. (2002) Acquisitions in the Electricity Sector: Active vs. Passive Owners. WP SBF Bergen.

Finally, when reliability is not contractible, we have to take into account the incentives for private managers. Privatisation may still be preferable over government provision when private managers do not have strong incentives to operate an underreliable network.

The main lesson from this section is that private provision is appropriate if (1) competition between networks is feasible, (2) reliability is contractible, and (3) private managers have little incentives to operate underreliable networks. Later, in section 2.3.3 on regulation, we discuss what type of contracts the government writes with the network operator in order to assure appropriate reliability. Moreover, we will stress in section 2.3.5 in a discussion about commitment that leaving contracts unnecessarily incomplete may be harmful as firms may be cautious investing as they face regulatory uncertainty. Finally, in the box at the end of section 2.3.3, we discuss how the government may deal with the bankruptcy of the privatised firm.

2.3.2 Liberalisation

In addition to ownership, the design of the market plays a role with respect to reliability. There is market power in a network industry, usually because the market is a natural monopoly or a natural tight oligopoly, so that it is efficient that the market is served by a single firm or a small number of firms. However, in the case that the market is a *legal* monopoly or tight oligopoly, it makes sense to evaluate the reasons for this, and possibly to liberalise the market.[18] Usually, competitive markets perform better than monopolies or tight oligopolies, as the firms cannot abuse their market power. Consider, as an example, the market for post.[19] Currently, TPG Post holds a legal monopoly in the Netherlands in post delivery up to 100 grams.[20] However, some argue that sunk costs in this market are low, and the market does not have a monopolistic bottleneck. Therefore, it would make sense to completely liberalise the market, i.e., terminate TPG Post's legal monopoly. In fact, the EU targets full liberalisation of the post market in 2009.[21]

If competition is not feasible at the moment, but rapid technical changes enhance the development of competing network, the government may decrease entry barriers, so that competition may become feasible in the future: new network firms have a chance to enter the market with innovations that compete with the old technology. This has happened in the telecom sector, in which fixed telecom firms now have to compete with several mobile telecom operators.

[18] The following box discusses liberalisation in more detail, focussing on the difference between liberalisation and privatisation – processes that often occur simultaneously, but are quite distinct from each other.
[19] TILEC (2003) and De Bijl et al. (2003).
[20] The rest of the market is liberalised, and several firms have entered.
[21] Europese Commissie (2002).

Moreover, sometimes the government may introduce ‘artificial’ competition in natural monopolies. In some industries, the government may procure the right to serve the market, i.e., firms compete ‘for’ the market, as for some rail tracks in the Netherlands. In other industries, natural monopolies in different regions may ‘compete’ under yardstick competition, as we will see in section 2.3.3.

The difference between liberalisation and privatisation

Privatisation

We define privatisation as partial or complete outsourcing of any kind of control rights regarding ownership, financing or management of the firm from the government to private parties. The definition covers important practical examples that are listed in the main text.

Liberalisation

Liberalisation is opening the market to entry by private parties and removing restriction on prices. Liberalisation makes sense only if there is room for entry. New entry eventually facilitates competition, creating incentives for network operators to optimise reliability.

In other words, privatisation and liberalisation are two (a priori independent) dimensions of government policy. The following picture sketches how the liberalisation and privatisation processes worked out for several Dutch network industries that used to be owned by the government.

Two dimensions of government policy

Liberalisation

	Competition between public and private firms	Free competition *generation electricity, mobile telecom*
Government owned and operated networks	Hived off *elecricity and gas networks, railways, water*	Private monopolies *fixed telecom*

Privatisation

2.3.3 Regulation

When competition is not feasible, the government may use another instrument to encourage the network operator(s) to optimise reliability, namely regulation. Although the law of most modern economies provides for legal rules preventing the abuse of a dominant position or anti-competitive behaviour in general, the general rules of competition law often offer an inadequate instrument to tackle abuses by a network operator with market power.[22] Moreover, the threat of a competitor entering the market may only have a weak effect on the network operator as entry in most network industries involves high sunk costs: network industries are not contestable.[23] Therefore, in the Netherlands, most network industries are subject to some type of regulation. For instance, the passenger railway company NS is subject to a performance based price cap, the post company TPG has to comply with a universal service obligation, and electricity distribution companies are subject to yardstick competition.

Before we discuss how different types of regulation may safeguard appropriate reliability of networks, we need to stress that regulation is a less powerful instrument than competition. As Stelzer (2002) has put it,

"*The quality of regulation is limited not only by the intrinsic difficulty of substituting administrative processes for the marvellous self-regulation tool we call the competitive market. It is limited as well by:*

- The resource advantage that regulated companies generally have over the agencies charged with regulating them;
- The information asymmetry that gives the regulated an advantage over the regulator;
- The ever-present dangers of regulatory capture, or, at the other extreme, the hostility that regulatory staff often have for the companies they regulate;
- The abilities of the men and women chosen for the arduous task of substituting their judgements for that of the absent competitive market; and
- The abilities and interests of the legislators who create the framework within which regulators must operate. "

Still, Stelzer stresses that despite the potential shortcoming of regulation, it is better to have a regulated monopoly than to entrust monopoly power to a private, unregulated, profit maximising corporation. In this section, we put forward the regulatory issues that relate to reliability. We interrelate them with pricing and encouraging cost efficiency, since those regulatory objectives may interfere with reliability.

[22] CPB (2003b).
[23] Baumol et al. (1982).

Types of regulation

The effect of regulation on reliability depends on the type of price regulation and quality regulation that is implemented by the regulator. Both price regulation and quality regulation can be high-powered and low-powered, depending on the incentives they impose on the network operator. The larger the weight that the regulator puts on cost efficiency, the higher is the power of price regulation. High-powered price regulation strongly encourages cost reductions. Quality regulation refers to any regulation that focuses on non-price dimensions, including reliability. We call quality regulation high-powered if it encourages the firm to appropriately invest in quality.

A typical example of low-powered price regulation is *rate-of-return regulation* (or *cost-of-service regulation*). Under such a scheme, revenues are set equal to costs (including a fair and reasonable rate of return) to eliminate the consumer welfare losses associated with monopolistic price distortions. In the early examples of regulation, franchised monopolies were typically subject to this type of regulation. Low-powered price regulation does not motivate the firm to operate efficiently. In contrast, it may encourage excessive investment.[24] In particular, since improvements in reliability are often capital intensive, a firm may choose to overinvest, leading to an overreliable network. Think about such investments in networks as redundant electronics, excessive channel capacity to reduce blockage, and extra software features.[25] In theory, the regulator should be able to mitigate cost inefficiency caused by rate-of-return regulation by allowing compensations only on investments which are ‘used and useful’.[26] However, this may be difficult in practice due to asymmetric information about the cost and the effectiveness of investment. Finally, under rate-of-return regulation, the firm has little incentive to innovate, as the rate of return on capital is fixed.[27]

Price-cap regulation and *yardstick competition* are both high-powered pricing schemes. Under price-cap regulation, the prices (in real terms) are fixed for a few years. For instance, the regulator of British Telecom was one of the first in the world to introduce a price cap to regulate the telecommunication networks, followed by many other regulators in Europe.[28] Price-cap regulation gives strong incentives to reduce costs, which is desirable in terms of welfare. However, price-cap regulation may jeopardise reliability, as short-run incentives to cut costs may outweigh considerations regarding long-term reliability.[29] Therefore, typically such a regulation has to be complemented with quality regulation, as we discuss below.

[24] Averch and Johnson (1962).
[25] Economides and Lehr (1994).
[26] Gilbert and Newbery (1988).
[27] Baumol and Klevorick (1970).
[28] Littlechild (1983).
[29] Vickers and Yarrow (1988).

Under yardstick competition, a regulator compares the performance of various firms featuring the same technology, and rewards or punishes firms based on their relative performance.[30] For example, the regulator sets a price cap for a firm based on average cost of the other companies and allows the firm to keep the difference between the cap and the realised cost: if the firm outperforms the yardstick it earns a higher profit, otherwise it may incur losses.[31] In other words, yardstick competition is artificial competition between network companies. It mimics market forces providing strong incentives for natural monopolies to reduce cost and improve efficiency.[32] However, yardstick competition in its pure form (i.e., not augmented by regulation of reliability) features the same problem with respect to reliability as pure price-cap regulation does. As customers cannot switch to another network, the market mechanism that fosters reliability in competitive markets does not work for natural monopolies. The situation can be improved by including quality regulation.

Minimum quality standards are a typical form of low-powered quality regulation. A minimum quality standard requires the firm to provide at least a given level of quality (in particular reliability), at the threat of a fine for underperformance. Minimum quality standards are widely used by regulators applying high-powered price regulation to protect the customers from decreases in quality below a certain level. Alternatively, the government may not contract reliability itself, but impose standards for the features of the network that influence reliability. As an illustration, think about the so-called 'N-1 standard' for high voltage electricity grid in the Netherlands.[33] Minimum quality standards are low-powered incentive schemes, as information asymmetry makes it hardly feasible for the regulator to determine the socially appropriate level of quality/reliability. Therefore, the standard may be either too low (so that the network operator tends to respond to such a measure by decreasing reliability just to this level) or too high (discouraging the firm to invest at all, or pushing it to overinvest).

In contrast, high-powered quality regulation gives firms the incentives to appropriately balance the costs and the benefits of providing an extra unit of reliability. For instance, the regulator may have the company compensate the customers for the 'disutility' that network interruptions caused to them. In the case of an electricity blackout, the operator of the electricity network may pay its customers (firms and households) according to the disutility they have experienced because of the blackout.[34] Then the network operator will take the customer disutility into account when making operational decisions and will provide appropriate reliability. According to the economic literature, a regime combining such a mechanism with yardstick competition

[30] See CPB (2000) for an overview.

[31] Shleifer (1985).

[32] The practical implementation of a yardstick competition regime requires a sufficient number of 'participants', which urges for the necessity of careful merger policy with respect to franchised network monopolies. See Mikkers and Shestalova (2003b) on the latter.

[33] See section 2.2.2.

[34] SEO (2004) provides estimates of customer disutility due to electricity outages.

can deliver the first best outcome.[35] Recently, there were several regulatory attempts to integrate regulated prices with reliability. For example, the energy regulators in the Netherlands and Norway have proposed schemes that integrate yardstick competition with reliability regulation.[36,37] See the case study on electricity networks for more detail.

The appropriateness of a regulatory regime

Whether a certain regulatory regime is appropriate depends on the incentives that it gives to the network operator. First, it should encourage the network operator to invest in his network in such a way that it establishes appropriate reliability. Second, it should stimulate the network operator to improve the efficiency of its production process. Third, it should foster the network to charge reasonable prices to its customers. Observe that these incentives may be in conflict with each other: the firm may only be able to decrease prices and to improve the cost efficiency of its production if it cuts its expenses on reliability.

What is the relationship between the underlying market characteristics and the regulatory regime that optimally trades-off these incentives? First of all, when competition is feasible, beyond the competition law not much regulation is necessary. Second, if reliability is contractible, the government can deal with the trade-off between different incentives regulating both the reliability of the network and the price the network operators charges to its users. The literature recommends high-powered price regulation, i.e., regulatory schemes that encourage the network operator to invest in cost reduction. In addition, as reliability is contractible, the government can implement high-powered quality regulation in order to safeguard appropriate reliability.

Third, if reliability is non-contractible, high-powered incentive schemes may not lead to a desirable outcome, as they may encourage a network operator to cut its costs at the expense of non-contractible reliability. Therefore, unless commercial interests are sufficiently congruent with private interests, low-powered price regulation is preferable, such as rate-of-return regulation. Because reliability is not contractible, only low-powered quality regulation is feasible (which can still be better than having no quality regulation at all).

[35] Mikkers and Shestalova (2003a). Further discussion of the issue of quality of supply in the context of yardstick competition can be found in Tangeras (2003).

[36] DTe (2003) and Langset (2002).

[37] Also, the outcome of the recent negotiation between the NS and Locov reflects the idea of making price increases dependent on reliability increases. Here NS is the name of the company that performs railway transportation of passengers in the Netherlands, and Locov is the organisation representing consumers' interests. According to the press coverage of the results of negotiations between NS and Locov (NRC Handelsblad, 2003), NS can introduce an extra increase in prices of 2.075% in 2004, if 84.4% of trains arrive on time. Furthermore, it can increase the prices by 2.075% again, if 86.8% of trains arrive on time.

2.3.4 Unbundling

So far, we have looked at each network as an integral company. Such a company may cater to several segments of the market, for example, production of the commodity transported over the network, network operation, construction and maintenance, etc. What is the effect on reliability when the network company is unbundled from particular departments?

Vertical versus horizontal unbundling

The literature makes a distinction between vertical and horizontal unbundling. In some cases it is possible to introduce effective competition into one of vertically linked segments of the network industry, for instance in electricity generation or supply. In other situations, horizontal unbundling allows the government to introduce competition between network operators. Competition may then take place either between network operators on the same geographic market, or artificially under a yardstick regime among regional monopolies. The latter is for example the case in the water industry in the UK, in which yardstick competition determines the tariffs charged by regional water companies. Another example is the Norwegian electricity industry, where the regulator has augmented yardstick competition with quality regulation. As we have seen before, competition between the network companies encourages them to deliver appropriate reliability. Let us for the moment concentrate on complete unbundling, i.e., ownership unbundling. Later, we will discuss weaker forms.

In contrast to privatisation, liberalisation, and regulation, appropriate policy with respect to unbundling does not depend on the answers to the three key policy questions that form basis of our theoretical framework, apart from the feasibility of competition between networks. When competition between networks is sufficiently strong, the government can leave the decision to split or to integrate to the firm itself, and rely on competition law to prevent the firm to engage in welfare decreasing vertical or horizontal relationships. There is no straightforward relationship between the other two questions and desirability of unbundling. Therefore, for each department of the network firm, a cost-benefit analysis is needed to establish whether unbundling is welfare improving. We start this section discussing the potential advantages of unbundling. After that, we discuss potential problems and possible solutions.[38]

Unbundling may have the advantage that…

The main advantages related to vertical and horizontal unbundling are

- Facilitation of competition
- More efficient and effective regulation

[38] We base this section on OECD (2001) and OCFEB (2002) Appendix C.

…competition is facilitated

The most important advantage related to unbundling is the facilitation of competition in a potentially competitive segment. Competition then results in competitive pricing and better service. For instance in the telecom sector, the vertically integrated firm may ask too high access prices to third parties for using its network. A vertically integrated firm may have an incentive to create an unlevel playing field in favour of his own division, at the disadvantage of new, potentially more efficient, entrants. Vertical unbundling reduces these incentives. Also, horizontal unbundling may enhance competition, usually in the shape of yardstick competition between regional monopolies. Notice that the practical implementation of a yardstick competition regime requires a sufficient number of 'participants', which urges for the necessity of careful merger policy with respect to franchised network monopolies.[39]

…the efficiency and effectiveness of regulation is improved

Although unbundling facilitates competition, usually regulation of the network operator is still needed. Unbundling also contributes to the efficiency and effectiveness of regulation. First, the regulator obtains more accurate information about the unbundled divisions of the network operator. In the case of vertical unbundling, the network operator loses the possibility to strategically reallocate its internal costs. Under horizontal unbundling, yardstick competition may yield useful information for the regulator. Second, the market-monitoring task of the regulator becomes easier, since unbundling reduces the incentives of the network operator to favour its department in the competitive segment.

Disadvantages of unbundling may be…

Both horizontal and vertical unbundling may have disadvantages, such as

- Hold up of investment
- Real-time operation problems
- Double marginisation
- Reduced contractibility
- Financial risks

…hold up of investment

Let us first focus on the *hold-up problem*. Economists have argued that in terms of incentives to invest, vertical and horizontal unbundling may not be such a good idea. The separated firms have to share the gains from its investments with other parties, so that they may invest less than they would if both firms were integrated. In other words, unbundling may induce firms to hold up investment. Economists refer to this phenomenon as the 'hold-up problem'. The hold-up problem may for instance occur in the railway industry. A railway company is very much

[39] See Mikkers and Shestalova (2003b).

dependent on the rail infrastructure. If the reliability of the rail tracks deteriorates, the probability that trains arrive late increases and more accidents may happen, so that the train operating company may lose its consumers. However, the operator of the rail infrastructure may have little incentives to invest in the reliability of the network if it has to share the gains from his investment with the train operator.[40]

A similar problem is imminent in the case of horizontal unbundling. For instance, Valletti and Cambini (2003) address the question of network competition between telecommunication operators when they have to invest in their own facilities. Each operator needs access to the rival's network in order to terminate calls originated by its own customers but destined to subscribers belonging to the other network (two-way access). As a caller on network A may wish to terminate its call on network B, he may benefit from the investment of network B in the reliability of that network. When B does not internalise these gains, it may hold-up investment on its network.

Analogously, in electricity, competing network generators may underinvest in capacity, in contrast to a monopolistic generator. Therefore, an integrated monopolist may provide higher reliability than an unbundled firm with competition in the generation segment. Why should this be that case? Boom (2003) gives the following answer.

"The electricity market, like many other markets, is characterised by an uncertain demand. Electricity can, however, usually not be stored. All competing firms must use the same distribution network, and the inflows and outflows of electricity into this network have to be balanced at each point in time. If the balance cannot be preserved, then the network collapses and none of the firms can sell electricity anymore. This creates externalities that might be better internalised by a monopolist than by competing firms. The monopolist might install larger generation capacities, because he cannot free-ride on the capacity investments of others."

Of course, the monopolist also has more incentives to abuse his market power by rationing his supply to the market. How this trade-off works out depends on market characteristics and the way the government regulates the market.

…real-time operation problems

Unbundling may also lead to *real-time operation problems* between separate divisions of the formerly integrated network operator. This is especially important in industries with volatile demand and supply that demand frequent communication between different network divisions, such as in electricity. Unbundling of there divisions may make this communication more difficult, especially if most communication is done informally. For instance, EPRI (2002)

[40] See also the case study on railways.

argues that the California crisis would have been much worse if the grid operators had not been able to coordinate their actions to deal with the system volatility. They argue that most proposals for a better market design did not take into account this stream of informal communication, which they consider crucial for the reliability of the network. The problem can also be observed in other network industries. For example, in railway services, there is a need of coordination between the actions of train operators and the network.

…double marginalisation

Especially under vertical unbundling, a double marginalisation problem may arise. Instead of one firm, two firms wish to put a profit margin on their costs, so that the price of the end product may rise after unbundling.

…reduced contractibility

Moreover, splitting up the network firm may adversely affect the contractibility of reliability. When it is difficult to identify which division is responsible for a network failure, it is more difficult or costly to write enforceable contracts on reliability, because collection of information and conflict resolution are costly. Earlier we observed that the success of privatisation and regulation depends on the contractibility of reliability. Hence, these policy instruments may become less effective after the split.

…financials risks

When vertical or horizontal unbundling introduces competition in a segment, there may be additional financial risks in the network industries. When firms are more subject to competitive pressure, they operate cheaper and more efficient, however, they face a larger probability to file for bankruptcy.

The government may mitigate these disadvantages by allowing for…

The economic literature[41] proposes several solutions to the above disadvantages of separation:

- Contracts between the separated departments
- Competition
- Partial unbundling
- Supplier of last resort arrangements
- Club ownership

[41] See OECD (2001).

…contracts between the separated departments

The separated firms write contracts that mitigate the above disadvantages.[42] This is effectively the same as vertical integration. In the above example about the railway industry, the train operator and the network owner may write a binding contract that describes how the train operator will compensate the network owner for his investments in the network. It makes sense for the competition authorities to be lenient towards this kind of relationships between the separated firms.

…competition

Competition may solve the double marginalisation and hold-up problems. The double marginalisation problem is mitigated as in the competitive segment the margin is low anyway. The hold-up problem is partially solved as competition shifts most bargaining power to the network operator upstream, so that it can realise almost all gains from its investment in the network.[43]

…partial unbundling

In some cases, partial unbundling may serve as a solution. The literature considers several degrees of unbundling:

- Accounting unbundling: unbundling of accounts
- Organisational unbundling: split into different departments within the same company
- Legal unbundling: split into different companies
- Ownership unbundling: split ownership

Note that there is a hierarchy among these types of unbundling: accounting unbundling is the weakest form, ownership unbundling is the strongest. The appropriate degree of unbundling depends on the trade-off between the advantages and disadvantages of unbundling.

Since the main purpose of unbundling is often introduction of competition in some segment of the industry, partial unbundling often does not achieve the desirable outcome. For instance, in the electricity industry, transmission system operators (TSOs) deal with a particularly complex task. On the one hand, they plan, build, and maintain grids in compliance with technical norms of supply reliability. On the other hand, they monitor, price, and enforce the real-time electricity market, with a considerable impact upon price formation, market power and market entry. It has been recognised that such strategic market functions as market facilitation and system operation must be completely independent from the market actors. In particular, Agrell and Bogetoft (2003) stress:

[42] Grossman and Hart (1986).
[43] Bolton and Whinston (1993).

“Independence goes further than just unbundling, since co-ownership or board capture (in non-profit TSOs) by actors would jeopardise the decision autonomy and integrity. Potential entrants in the generation market would be discouraged by the mere suspicion of preferential treatment of incumbents in the construction and operation of the market grid. Sensitive market information could also be exploited by affiliated enterprises to the detriment of market functioning.”

…supplier of last resort arrangements

The higher risk of bankruptcy after unbundling may not be a problem when arrangements are made that guarantee consumers their supply. This can be done, for example, by assigning so-called ‘suppliers of last resort’. A supplier of last resort is a company that is legally obliged to supply to the customers of a bankrupt company until they choose their new provider. For example, in the electricity and gas industries, regional network companies can be assigned to take care of the customers in their corresponding regions during several days after a bankruptcy of their supplier. Such an arrangement should give the customers enough time to choose a new supplier.

…club ownership

Under club ownership, or joint ownership, all firms in the competitive segment own a share in the network company. This arrangement features many of the advantages of unbundling, and mitigates potential disadvantages. For instance, it reduces the incentives to create an unlevel playing field, and hence it facilitates competition and makes regulation easier. However, club ownership has drawbacks in that the members of the club ownership may discriminate non-members, that it may create difficulties in the governance of the network company, and that it is only feasible in a limited number of industries.

2.3.5 Commitment

So far, we have discussed the relationship between reliability and privatisation, liberalisation, regulation, and unbundling. Commitment is the final type of policy towards appropriate reliability of networks. Commitment is the government’s promise not to deviate from the announced policy. Note that commitment does not mean that the government never changes its policy. The government may commit to announcing regime changes far enough in time or to compensating the firms for their investments when changing its policy regime. Commitment plays an important role with respect to the reliability of network services. Uncertainty regarding future regulation may result in short sighted behaviour of the firms so that they may hold up their investment in reliability. Or, as The Economist (2003) has put it,

“for firms, political meddling – dubbed ‘stroke of the pen’ risk – has also created chaotic and incoherent regulatory, making planning trickier and hampering investment.”

An illustrative example is the UK railway industry. Helm (2002) emphasises the effect of both institutional and regulatory uncertainty on the behaviour of investors during the transition period and the first years after privatisation. In particular, privatised under the conservative party mandate, the private investors were fearful of having their recently acquired firms expropriated under the labour-party government. Possibly a similar reasoning can be applied to many cases to explain the hold up of investment prior to privatisation and the improvement of the investment climate afterwards, e.g. in the UK water industry.[44]

The government may organise commitment…

The literature[45] discusses several ways for the government to organise commitment:

- Privatisation
- Contracts
- Law
- Reputation
- Decentralisation to local governments
- An independent regulator

Let us elaborate on each of these instruments.

…privatising the network company

First of all, privatisation can serve as a commitment device.[46] The government bears the risk and the responsibility for purely public firms. Therefore, it is difficult for the government to commit itself not to intervene in the control of a public firm. Privatisation may make this commitment better feasible, depending on the exact conditions under which the privatisation takes place.

In a hived-off public firm, the government is a shareholder of the firm and/or has the right to appoint members of the decision-making bodies (e.g. the right to appoint some of the directors). Therefore, the government has the possibility to influence the firms' policy. As a matter of fact, not intervening as a shareholder or director in a systematic matter under certain circumstances may be considered as a breach of the contractual obligations towards other shareholders or of the contractual obligations of directors vis-à-vis their employer. Therefore, establishing a solid commitment not to intervene under any circumstances may prove difficult.

[44] Saal and Parker (2000).

[45] Bovenberg et al. (2003) and Martimort et al. (2002).

[46] See also Bovenberg and Teulings (2000) and Teulings et al. (2004).

A 100% privatisation occurs when the government loses the possibility of directly influencing the privatised company's policy, for example because it does not have any shares in the company and cannot appoint any of the members of the decision-making bodies. In this case, committing not to intervene seems easier. Moreover, when the government should be in breach of any contractual obligation, a 100 % private, profit-maximising firm has more incentives to initiate legal proceedings against the government than a public firm or a partially government-controlled private firm. This observation strengthens the argument that when reliability is sufficiently contractible, privatisation is appropriate.

However, even in the case of a 100% privatisation, a commitment not to intervene may always be subject to certain legal constraints. The government may in some circumstances be obliged to influence a firm's activities based on legal rules that overrule the legislation surrounding the privatisation operation. For example, as EC legislation takes precedence over any rule of national law, European regulations or directives may force a national government to take certain measures towards certain firms.

…establishing a contract with the network company

A second, straightforward, way for the government to commit is to conclude a specific and separate contract containing an obligation of non-intervention that is verifiable by a court. However, here too, such a contract is subject to certain legal constraints. Firstly, a contract between a government and a private firm always has to comply with binding rules of national and supranational law. Referral can be made to the possible impact of European regulations and directives as described above. The government's commitment may therefore always be subject to certain external limitations.

Secondly, such contract will either be concluded for a certain period of time or indefinitely. In the first hypothesis, the contract's validity will automatically end when reaching the contractually agreed date; a new contract will then have to be renegotiated, which limits the level of certainty offered to the co-contracting firm. In the second hypothesis, one has to bear in mind that in most jurisdictions, it is considered a general principle of contract law that a party to a contract cannot commit itself 'for life'. This means that parties to a contract that has been concluded for an indefinite period of time should always have the possibility to terminate the contract *bona fide* and at reasonable notice. Here too, a contract for an indefinite period of time cannot offer total security for the firms concerned.

Thirdly, one can ask oneself the more fundamental question whether or not a government can agree to such a contract at all from a legal and practical point of view. In parliamentary democracies, the government *sensu stricto* is nothing more than the executive branch of the government *sensu lato* of a state. As such, it theoretically does nothing more than taking measures executing the laws that have been decided on in parliament. Surely, a government could in theory conclude a contract of non-intervention with a private party. However, this would not prevent parliament from imposing new legislation which results in this contract being terminated or its terms being changed. While this may give rise to damages being paid to the private party to the contract, this certainly implies an element of uncertainty for the latter. This leads us to the next point.

…restricting government intervention by law

Also the law serves as a commitment device. For instance, the EU directive against State Aid commits governments not to interfere in the case that a network firm is on the edge of bankruptcy. Although preventing the firm from going bankrupt may be welfare improving in the short run, the commitment not to do so incentives the firm to avoid risky strategies.

…building the reputation not to interfere

When contracts are implicit, i.e. non-verifiable by a court, mutual trust in long-term relationships or reputation are enforcement mechanisms behind implicit contracts. Gilbert and Newbery (1993) show that a repeated interaction between the state and the firm partially solves the hold-up problem. When the ‘game’ is repeated, the state takes into account that investors may stop renewing the capital stock under too tough regulation. At the same time, investors do not stop investing as they are confident that the state will not turn to more pro-consumer regulation.

…decentralising to local governments

In addition, the national government may organise commitment decentralising decisions to local governments. Local governments usually have harder budget constraints. Moreover, when the national government wishes to change its regulatory regime, it first has to negotiate with the local governments. However, decentralisation to local governments does not always solve the problem, since local governments may have too little expertise and therefore may take not well-informed decisions.

…implementing an independent regulator

Finally, the government establishes commitment assigning an independent regulator. In the presence of an independent regulator, it becomes more difficult for politicians to put pressure on the industry, which secures commitment. Unfortunately, there is a risk of regulatory capture.

‘Optimal commitment’

To which extent and for how long is it appropriate for the government to commit? This depends on the classical trade-off between commitment and flexibility. Optimal commitment means that the cost of losing flexibility is taken into account. From a welfare point of view, it may not be appropriate to commit to policy forever: the government can hardly predict the state of the world in 100 years, so that it cannot foresee which type of government policy would be desirable by that time. Furthermore, in some situations, the advantages of intervention may outweigh the disadvantages related to losing commitment. In rapidly changing markets (such as mobile telecommunication), long-run commitment does not make much sense, in contrast to markets that are hardly subject to technological progress and changing demand (such as water). Although the trade-off between flexibility and commitment might depend on the underlying market characteristics that we discussed in the beginning of this chapter, the relationship is not straightforward. Therefore, it is a priori unclear how the trade-off between flexibility and commitment will work out in each particular case.

2.4 Conclusion: Roadmap towards appropriate reliability policy

In this chapter, we have analysed the relationship between reliability and underlying market characteristics, grouped together in three categories: the feasibility of competition between networks, contractibility of reliability, and the convergence of commercial and public interests. A policy maker can verify the answers to the questions regarding the underlying market characteristic, which are summarised in Table 2.1.

Table 2.1 Checklist for underlying market characteristics

Is competition sufficiently feasible?

Are substantial economies of scale absent?
Are alternative networks available?
Is demand relatively high?
Are switching opportunities low?

Is reliability sufficiently contractible?

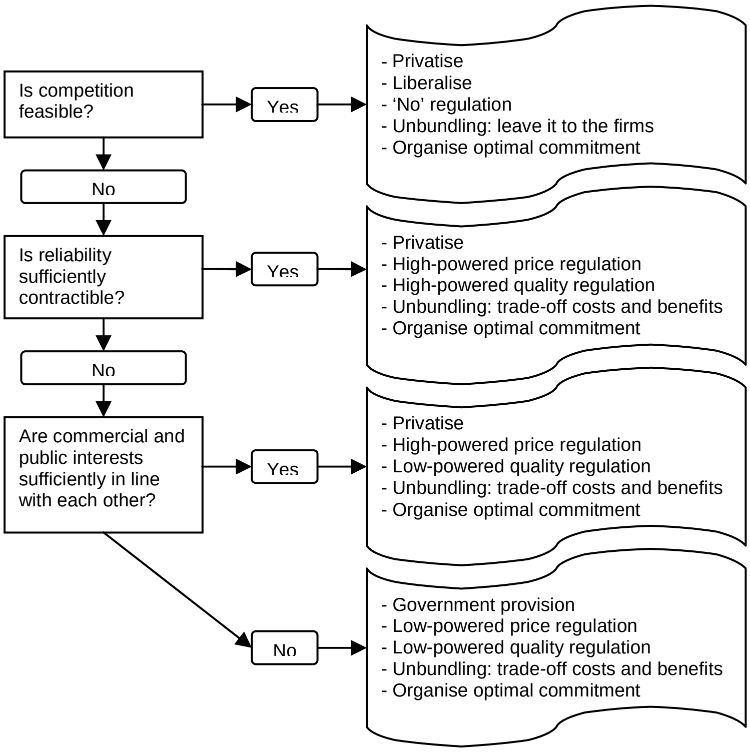
Is it easy to identify and to call to account the party that is to blame for a network failure?
Do investments in reliability have a short life cycle?
Is the government able and willing to write a contract?
Is it unlikely that a network failure has a high impact on society?
Can reliability or underlying network features be easily monitored?
Are the transaction costs for writing and enforcing the contract low?

Are commercial and public interests sufficiently in line?

Do cost reductions have little effect on non-contractible reliability?
Are opportunities for cost reductions small?
Does a profit-maximising network operator have the incentive to take into account the adverse effect of cost reductions on reliability?
Does incomplete information between the firm and the regulator play a minor role?
Is public service motivation unimportant?
Does the management have much bargaining power vis-à-vis the government?

After verifying the answer to the questions of Table 2.1, the next step is what an appropriate reliability policy consists of. We distinguished five types of government policy: privatisation, liberalisation, regulation, unbundling, and commitment. Whether or not to privatise, e.g. depends *inter alia* on the feasibility of competition. The roadmap in Figure 2.2 summarises the main lessons of this chapter. The roadmap focuses on the network operator(s), i.e., how does the government deal with a network industry to provide incentives to the network operator(s) towards reliability. The starting point of this roadmap is a fully integrated network company that is owned by the government.

Figure 2.2 Roadmap



Before we summarise the policy options that are on the right side of Figure 2.2, we stress that these policy answers are in a sense polar cases. Questions such as 'is competition feasible?' often cannot be answered with a simple 'yes 'or 'no'. As an implication, the roadmap can be interpreted as a guide for polar cases. However, it also provides a direction in intermediate cases, although – given the general nature of the study – the level of precision will then deteriorate.

Privatisation

Privatisation of the network company is usually a logical move if competition between networks is feasible, or if reliability aspects are sufficiently contractible, or if commercial interests are sufficiently in line with public interest. The reasons why it is a logical step to privatise under any of these conditions are: (1) under these three conditions, the government can give the network operator incentives to establish appropriate reliability, (2) private firms have more incentives to operate cost efficiently than public firms, and (3) privatisation serves as a commitment device. When none of the above conditions holds, public ownership may give better incentives towards appropriate reliability, as a private firm may have excessive incentives to cut costs at the expense of reliability. Notice that in practice life may not be so simple. Competition may be feasible, but can still be weak (Airports). Reliability can be contractible but not perfectly contractible and public and commercial interests may be in line but not completely parallel. In those cases, the answer to the privatisation question is more subtle. Privatisation may then still be possible in a number of cases (Airports, electricity distribution), but regulation is still needed, in particular quality regulation. Alternatively, intermediary solutions are needed. We cannot go into the subtleties of these questions, since they require tailor made solutions.

Liberalisation

If competition between networks is feasible and sufficiently strong, there is not much reason for government intervention: competition forces network firms to provide appropriate reliability, so that the government can safely liberalise the market. If competition is not feasible, but rapid technical changes enhance the development of competing network, the government may decrease entry barriers, so that competition may become feasible in the future: new network firms have a chance to enter the market with innovations that compete with the old technology.

Regulation

If competition between networks is present, the government does not have to regulate the network operators: the competition law is sufficient. Otherwise, the market is a natural monopoly (or tight oligopoly), for which regulation is needed to give the network firm(s) the right incentives towards appropriate reliability. If reliability is contractible, the regulatory regime can use high-powered incentive schemes (such as price-cap regulation or yardstick competition) combined with high-powered quality regulation. If commercial and public interests with respect to non-contractible reliability are sufficiently in line, the reliability policy features high-powered price regulation and low-powered quality regulation. In any other situation, low-powered price regulation and low-powered quality regulation is better.

Vertical and horizontal unbundling

So far we have looked at each network as an integral company. Such a company may cater to several segments of the market, for example, production of the commodity transported over the network, network operation, construction and maintenance, etc. Unless competition between networks is feasible, there may be need for government intervention with respect to unbundling. The desirability of unbundling does not directly depend on the other two categories of underlying market characteristics (contractibility and congruency of managers’ incentives). For each department of the network firm, costs and benefits should be traded-off to establish whether the unbundling is welfare improving. We have considered several potential advantages of unbundling. For instance, unbundling may facilitate competition. Moreover, the split improves the efficiency and effectiveness of regulation. Disadvantages are related to hold up of investment, real-time operation problems, double marginalisation, reduced contractibility, and financial risks. We have discussed several instruments to mitigate these disadvantages, including contracts between the separated departments, competition, partial unbundling, supplier of last resort arrangements, and club ownership.

Optimal commitment

Regardless of the underlying market characteristics, (optimal) commitment is crucial for reliability in network industries, as usually long-run investments are involved to improve reliability. The network operator may cancel these investments when there is a possibility that the government changes its policy. There are several possibilities for the government to establish commitment: privatisation, contracts, reputation, law, decentralisation to local governments, and appointment of an independent regulator. We have observed that commitment policy does not mean that the government never changes its policy. The government may commit to announcing regime changes far enough in time, or to compensating the firms for their investments when changing its policy regime. Moreover, in some situations, the advantages of intervention may outweigh the disadvantages related to losing commitment.

A few words of caution

We wish to emphasise two caveats of this roadmap. First, the roadmap is only a framework, not a self-contained recipe that gives satisfying answers to all questions regarding appropriate policy for each particular network industry. ‘The devil is in the details’, and the details still have to be filled in. For each specific network industry, further research is needed to come up with a complete master plan for appropriate reliability policy. Second, when arguing for public or private provision, we base our insights on the ‘average’ public and private manager. There is no guarantee that all managers do what the theory assumes them to do. There may be managers pursuing short run goals, underinvesting in the network, and managers who are excessively preventing network failures, overinvesting in the reliability of their network.

3 Empirics

In the previous chapter, a roadmap has been presented that enables policy makers to make informed decisions about privatisation and deregulation of network industries. In essence, this roadmap can be seen as a guide – based on economic theory – of the effects of policy instruments on the main determinants of welfare: costs, prices, and reliability.

In this chapter, an overview of the empirical literature is given of the effects of policy instruments on costs, prices, and reliability. Hence, it can be seen as an informal test for the accuracy of the roadmap presented in the previous chapter.

Before proceeding to the discussion of the empirical literature, a number of observations are in order. First, as there exits only a limited number of papers providing an econometric test of the effect op government policies on reliability of networks, we have decided to broaden the scope of this chapter in two ways. One, we have included papers on *quality* in general instead of reliability only. Two, we have included papers on industries other than network industries. We believe that these additional selected papers contain useful information on the effects of policy instruments on reliability and price as the theory to date (i) makes no distinction between quality and reliability and the effects of policy measures on these two variables; and (ii) has not yet identified any reasons as to why the effect of policy instruments on quality (reliability) are likely to differ between industries (as far as industries are the same w.r.t. feasibility of competition, contractibility of quality, congruence of commercial and public interests).

Second, there exists by now widespread support for the view that cost, quality, prices and government policy are to some degree determined simultaneously[47]. For example, Ter-Martirosyan (2003) argues that quality standards are more likely to be imposed when a utility has poor performance, or that a utility may reject the incentive regulation contract if the quality provisions are too strict in which case only utilities with high quality levels would accept quality benchmarks. Moreover, Klein and Leffler (1981) and Milgrom and Roberts (1986) have argued that price is a signal of quality, so price would not be an exogenous variable in an equation of quality and policy instruments. The practical implication of this is that studies which do not control for the possible endogeneity of these variables, will produce inconsistent (=misleading) results.[48] Therefore, we have decided to exclude these papers at least in those cases where better studies are available.

[47] For example, see Domberger et al. (1995), Emmons III and Prager (1997), Boylaud and Nicoletti (2001), Shen (2002, 2003) and Ter-Martirosyan (2003).

[48] This is known as simultaneous equation bias, see Greene (1997), Chapter 16.

Third, it appears that papers on the effect of policy measures on quality are relatively scarce strongly limiting the available evidence on certain topics. A way to increase the number of papers on which this review is based, is to include papers that study the effect of policy measures on investment.[49] However, the link between investment and quality may be imperfect as higher investment may also be consistent with lower quality, for example in cases where demand has risen sharply. Only if one is able to control for these other factors determining investment, we may treat a higher level of investment as a good proxy for a rise in quality.
In the next sections, we discuss the empirical evidence for the roadmap in the literature. For each policy instrument we shortly discuss the main conclusions drawn in the theoretical chapter after which we present the empirical evidence on that topic.

3.1 Privatisation

There exists by now widespread evidence that privatisation leads both to lower costs and prices, see for example Megginson and Netter (2001). Empirical research on the effect of privatisation on quality is still scarce. The available literature suggests that in some cases the effect of privatisation on quality is non-positive.

Domberger et al. (1995), in a study on cleaning services, find that the effect of ownership (private or public cleaning service companies) on both price and quality is negligible in the Sydney metropolitan area. Emmons III and Prager (1997) show that in the US cable television industry non-privately owned firms charge prices up to 50% lower than privately owned monopolies. Quality is in most cases unaffected.[50] Emmons III and Prager also perform a dynamic analysis on the behaviour of monopolies under different types of ownership in 1983 and 1989. They show that areas in which ownership remained non-private both price and quality increases were smaller than in areas in which ownership remained private. Areas in which a change in ownership from non-private to private took place were confronted with a larger increase in price or a smaller increase in quality than areas in which ownership remained private. Micheal (2000), in a study on franchising in the hotel and restaurant industry, reports that both hotel and restaurant chains that use franchising to a larger degree have lower quality. [51]

Boylaud and Nicoletti (2001) show that both privatisation and the prospect of privatisation have had no effect on both price and quality in the international telecommunications industry. Saal and Parker (2001) evaluate the effects of privatisation and the resulting system of economic

[49] See for example, Masten and Crocker (1985), Joskow (1987), Crocker and Reynolds (1993), Helper (1995), Svensson (1998), Affuso and Newbery (2001) and Williamson (2003).
[50] The other non-privately owned group (subscriber owned or non-profit) included 21% fewer channels in the basic service package than privately owned monopolies.
[51] Franchising is the private analog to privatisation. Whereas in the public domain the franchisor is the government, in the private domain this will be a firm (e.g. McDonalds, Best Western, Park Inn, El Torito, et cetera).

regulation of the water and sewerage industry of England and Wales. They conclude that the growth rate of quality[52] has remained stable after privatisation. One may not conclude from this that privatisation has no effect, since Saal and Parker are unable to control for – as they note themselves – diminishing marginal returns to environmental investment. However, the authors remark that their result is striking, because, the quality index that has been built "into these estimates are, if anything, biased towards finding *higher* quality growth during the post-privatisation period."

Finally, Giannakis et al. (2003) perform a quality-incorporated benchmarking study of the electricity distribution utilities in the United Kingdom between 1991 and 1999. They conclude that Total Factor Productivity (TFP) has risen after privatisation and the introduction of economic regulation mainly because a rise in the quality of service. Their outcome may be flawed, however, because they use planned and unplanned outages as a measure of quality. Their results may be interpreted as *suggesting* that inefficient companies may realise both quality improvements and higher efficiency, as they strongly reduce unnecessary maintenance. However, efficient companies seem to face a trade-off between higher efficiency and higher quality. Note that the effects Giannakis et al. find may be both attributed to privatisation and/or the introduction of benchmarking, as they cannot distinguish between these two drivers.

Concluding, we find that the effect on privatisation on cost and price is non-negative, whereas the effect of privatisation on quality is in some cases non-positive.

3.2 Liberalisation

According to the roadmap, the introduction of competition (liberalisation) decreases prices and optimises quality, at least if competition is feasible, i.e. when there is no natural monopoly or tight oligopoly. The empirical evidence is broadly consistent with this view on the effect on prices. We also observe a positive effect of competition on quality in several cases.

In a study on the effects of tendering cleaning services contracts in the Sydney metropolitan region, Domberger et al. (1995) present indirect evidence that tendering has reduced prices up to 53.5%,[53, 54] while maintaining or enhancing the ex post quality of service.[55] In a study on the determinants of price and quality in the US cable television industry, Emmons III and Prager (1997) confirm these findings. In the cable industry competition resulted in basic cable rates

[52] Here, quality is defined as the average percentage of supply zones and that are complaint with key water parameters relative to the average compliance percentage in 1990. A similar measure was applied for the quality of river water and bathing water.

[53] Domberger et al. are not able to distinguish between the effects of privatisation and tendering in all sub-samples.

[54] Tendering can be seen as a form of competition. The shorter the length of the contract, the more similar tendering will be to competition. If the length of the contract goes to zero, tendering will be identical to competition.

[55] Here, quality is defined as the ratio of clean to total items inspected in a randomly selected contract area.

that were significantly lower (up to 20%) than those charged by privately owned, unregulated monopoly operators. Competition between private firms and non-private firms even lowered prices up to 74% *suggesting* that the type of firm matters as well. Quality, as measured by the number of channels in the basic service package, was not affected by competition. Emmons III and Prager obtain similar results in their dynamic analysis.

Wallsten (2000) studies the effect of granting exclusivity contracts to private telecommunication firms. He finds that longer exclusivity periods entail higher prices and the lower investment. These results are broadly consistent with the findings of Ai and Sappington (2002). They find that operating costs declined as local competition increased under different forms of incentive regulation. Digital switches and fibre optic cable were deployed more extensively under earnings sharing regulation as local competition intensified.[56] Boylaud and Nicoletti (2001) study the determinants of price and quality in the international telecommunications industry. They show that the prospect of competition (as measured by the years remaining before deregulation) has had a strong positive effect on both quality and efficiency and a strong negative effect on price. Surprisingly, the effect of actual competition was similar, but much smaller.

Summarising the available evidence, we may conclude that the introduction of competition leads to lower prices and in some cases enhances quality thus giving support to the roadmap.

3.3 Regulation

Broadly speaking the available evidence is in line with the theoretical predictions: quality may decrease after the introduction of high-powered incentive schemes. Saal and Parker (2001) show that the rise in quality[57] in the UK drinking water industry was lower after a tight system of regulation (price controls) had been adopted. They are however unable to conclude that this has been caused by regulation, as they cannot control for possible diminishing marginal returns to environmental investment.

Ai and Sappington (2002) study the effect of high versus low-powered incentive schemes within the U.S. Telecommunications industry. They find that basic local service rates for business customers are lower under price-cap regulation than under rate-of-return regulation.

[56] Ai and Sappington find evidence that basic local service rates increase as local competition increases under earnings sharing regulation, whereas basic local rates decrease as local competition increases under rate case moratoria. They suggest that these findings arise because competition typically erodes the cross subsidies between long distance telecommunications and local telephone services leading to risen local rates. Regulators in different states have reacted differently towards this phenomena, which may explain these findings.

[57] Here, quality is defined as the average percentage of supply zones and that are complaint with key water parameters relative to the average compliance percentage in 1990. A similar measure was applied for the quality of river water and bathing water.

Surprisingly, this result does not hold for basic local rates for residential customers. It also does not hold for other types of high-powered incentive regulation, as earnings sharing regulation and rate case moratoria.[58] They also find evidence that costs are lower under rate case moratoria, but not under other types of incentive regulation, like price-cap regulation and earnings sharing regulation. Finally, they find no evidence of higher investment under high-powered incentive schemes compared to low-powered incentive schemes. Quality does not seem to be affected by the introduction of high-powered incentive schemes.

Finally, Ter-Martirosyan (2003) studies the effect of high-powered incentive regulation on quality in the U.S. electricity markets for a sample of investor-owned utilities. She finds that high-powered incentive regulation does not affect the number of outages per customer, but does lead to an increase in the average duration of outages per customer. Although the implementation of explicit quality benchmarks reduces the average duration of outages per customer, the effect remains statistically significant. Moreover, the introduction of high-powered incentive regulation leads to a decrease in operational and maintenance expenses.

To summarise, the existing empirical evidence is consistent with the view that the use of high-powered regulation generally decreases prices but may have a non-positive effect on some quality indicators.

3.4 Unbundling

Theory predicts that vertical unbundling may affect quality negatively, since it reduces coordination, may cause hold-up or real-time operation problems, and may increase risk of bankruptcy in some segments of the industry. There are to our knowledge no studies that investigate the effect of vertical unbundling on quality. A small number of studies have investigated the effect of vertical unbundling on costs and prices.[59] Although these studies have to be interpreted with caution, they seem to suggest that vertical unbundling leads to lower costs. There is no effect on prices.

Steiner (2000) used the OECD regulatory indicators to assess the impact of vertical unbundling in the electricity industry on costs and prices, based on a sample of 19 OECD countries over the 1986-1996 period. Unit costs tend to fall when generation and the network are unbundled. The effect of unbundling on prices was however insignificant.[60] Shires et al. (1999) compared the costs of the Swedish railway operator after a reform involving vertical unbundling, and found

[58] Ai and Sappington hypothesise that in practice high-powered incentive schemes may not be that different from low-powered incentive schemes.

[59] Notice that the results of these studies may be misleading as they may suffer from simultaneous equation bias.

[60] An explanation for this is, as Steiner notes, that the variable for unbundling was highly correlated with other explanatory variables likes the presence of an electricity market and the presence of Third Party Access.

that operating costs had been reduced by 10%. However, it is difficult to see to what extent such reductions are due to vertical unbundling per se rather than to other aspects of the reforms.

3.5 Commitment

Theory predicts that the higher commitment [from the government] to allow the firms to appropriate the returns of their investment leads to higher quality. The empirical evidence seems to suggest that (i) the level of commitment chosen by market parties is higher as the alternative value of the product that is being sold is lower; and (ii) higher commitment may lead to both higher and lower levels of investment (after controlling for demand factors).

Masten and Crocker (1985) show that take percentages in take-or-pay contracts for natural gas are significantly lower for wells associated with small numbers of sellers and high number of buyers. This suggests that the level of contractual commitment chosen by firms is higher when the alternative value of the gas is lower. Joskow (1987) confirms these results. He shows that in the U.S. coal market, buyers and sellers make longer commitments to the terms of future trade at the contract execution stage and rely less on repeated bargaining when relation-specific investments are more important. Finally, Crocker and Reynolds (1993) find that the degree of voluntarily agreed contractual incompleteness chosen in Air Force engine procurement contracts reflects a desire by the parties to minimise the economic costs associated with contractual change: ex post opportunism and its associated distortions in unobservable investment versus the cost of additional resources expended in ex ante design of the contract. This suggests that firms not only choose higher commitment when needed, but they also choose the appropriate level of commitment by explicitly weighing costs and benefits.

Svensson (1998) studies the effect of political instability on investment. Using data for around 100 countries he shows that political instability decreases the quality of property rights and hence decreases investment suggesting that lower commitment indeed leads to lower investment and quality. Surprisingly, Affuso and Newbery (2001) find that shorter contract lengths generate higher levels of investment, when studying the effect of contract length on the investments in rolling stock in the UK railway industry. One possible explanation is that companies facing reprocurement sooner respond with increased investment to signal their commitment to the regulator and thus increase their probability of re-award the franchise. Another explanation may be that investing just before the end of the franchise raises the entry cost for potential bidders. Finally, Leegomonchai and Vukina (2003) find no evidence between investment and the number of processors in a given area in the U.S. broiler industry.

Summarising we find that a higher level of commitment may lead to both higher and lower levels of investment. Moreover, the evidence suggests that the level of commitment chosen by firms reflects the costs and benefits of commitment.

3.6 Conclusion

In this chapter, we have informally tested the roadmap on the basis of an overview of the empirical literature. Since the evidence on the effect of government policies on reliability of networks was limited, we extended the analysis with papers on other quality aspects, and with papers on several other industries. We reviewed empirical evidence on the effect of the following policy instruments: privatisation, introduction of competition, regulation, unbundling and commitment policy. The empirical literature is broadly consistent with the policy guidelines from the roadmap.[61]

First of all, the introduction of competition leads to lower prices and in some cases enhances quality thus giving support to the roadmap.

Secondly, we observed that research now supports the proposition that privately owned firms are more efficient and more profitable than otherwise-comparable state-owned firms. This supports our recommendation to privatise the network firm when (1) competition is feasible, or (2) reliability is contractible, or (3) commercial and public interests are sufficiently in line with each other.

Thirdly, both privatisation and high-powered price regulation may have a negative effect on reliability, especially on non-contractible (or contractible, but non-contracted) aspects of reliability. We interpret this as a warning that privatisation may not work in all cases, especially as prices seem to rise as well in a substantial number of cases. In other words, privatisation and high-powered price regulation may not work in all circumstances, in particular, when commercial and public interests are not in line. In case of contractible reliability, if the government decides to privatise it may need to consider introducing quality regulation in order to safeguard appropriate investments in reliability.

Still, there are a number of important gaps in the empirical literature. One, there is little to no evidence on the effect of unbundling on cost, prices and reliability. Two, we have not found

[61] In addition to the literature reviewed above, there is also some evidence from the health care sector of the economy. A number of papers have investigated the effect of liberalisation on quality in the health care sector and support the findings of the roadmap. The major conclusions from this literature are broadly consistent with the literature discussed here. Privatisation and high-powered regulation are found to have a non-positive effect on quality, whereas liberalisation has a non-negative effect on quality. (See Kessler and McCellan (1998), Shen (2002, 2003).) However, in cases where the amount of noise in the quality signal is large, i.e. quality is imperfectly contractible, liberalisation may actually lead to a decrease in quality supplied (Propper, 2004).

firm support for the idea that more commitment always induces firms to invest more in the network. A higher level of commitment may both lead to higher and lower levels of investment. These results must, however, be interpreted with caution as (1) the number of papers on this issue is extremely limited; and (2) it is not straightforward to measure the level of commitment. Three, available evidence partly comes from non-network industries, such as cleaning services, hotels and restaurants. Finally, in order to increase the number of available studies, we have included papers that study the effect of government policy on investment and/or quality instead of reliability.

In order to fill the gaps in the reviewed literature, in the following chapters, we conduct case studies for five different network industries: electricity, gas, drinking water, wastewater, and railways. These case studies expand the limited amount of evidence that is available for reliability in network industries and allow us to further test the roadmap.

Part II: Case Studies

Our roadmap presented in chapter 2 shows that the choice of government policy towards appropriate reliability in a network industry depends on three categories of underlying market characteristics: feasibility of competition between networks, contractibility of reliability, and commercial and public interests to invest in reliability. In this chapter, we test theoretical predictions regarding the effects of policy instruments on cost and reliability in selected network industries: electricity, gas, drinking water, wastewater and railways.

The analysis in each case study zooms on the effect of a certain policy instrument(s) in a particular network industry. Using panel data on network companies, we test for the effect of government policy on reliability and on cost (only in the case study on electricity in which data on cost has been available).

The theory presented in chapter 2 highlights the importance of the feasibility of competition, contractibility of reliability and managers incentives for policy choice. Since free competition in the networks that we consider in our case studies is generally infeasible (as there is only one network in each area), there is room for government intervention. The theory suggests that the way in which the government may intervene in such industries depends first of all on contractibility of reliability. While the theory treats only polar cases of (perfectly) contractible or non-contractible reliability, most real network industries represent a mixture of these polar cases. In chapters 4-7, we would like to test for several network industries to what extent the effect of government policy on the observable reliability indicators mirrors the theoretical predictions for the polar case of contractible reliability.

The case study in chapter 8 (railways) is different from the other studies in that the reliability indicator used in our analysis, the number of accidents, relates mainly to safety of railways transportation and does not cover other important reliability dimensions, such as delays. With respect to the number of accidents as a reliability measure, we perhaps move closer to the case of non-contractible reliability. In the theoretical chapter, we argued that in such a situation, either high-powered or low-powered price regulation may be appropriate, depending on managers' incentives with respect to reliability. Therefore, in the case study on railways, we test how price regulation and unbundling affect reliability, and whether managers' incentives with respect to reducing of the number of accidents are sufficiently in line with public interests.

The case studies are structured in the same way. Each case study begins with an introduction, in which we present the purpose and the outline of the study. Then we describe the industry and reliability issues. After this, we turn to the methodological section, in which we summarise the methodology and the data used in the case study. We proceed with an empirical analysis. Each case study ends with conclusions summarising empirical findings.

4 Electricity

4.1 Introduction

The case study contributes to the report by providing empirical evidence on the effect of government policy on costs and reliability of electricity distribution networks. We consider three reliability indicators for electricity distribution networks (namely, the number of interruptions, interruption duration and the amount of energy non-supplied due to interruptions) to test for the effect of government policy on these indicators.

The empirical analysis addresses three policy instruments:

- High-powered price regulation
- Quality regulation
- Public and private ownership

Using a dataset of Norwegian distribution companies in 1995-2001, we provide new empirical evidence regarding the first two policy instruments. Since electricity distribution companies in Norway are public, the issue regarding the effect of ownership cannot be addressed based solely on the Norwegian dataset. Therefore, we need to employ evidence from another country (with high-powered regulation but private ownership), such as the UK. We compare the findings of other studies with respect to the UK to our findings for Norway to see if the companies in both countries show similar trends in the performance. We notice that such a comparison provides only an indicative answer to the question about the effect of ownership.

Since Dutch policy makers are an important part of the audience of this report, this case study provides some practical information, such as the list of standard reliability indicators, and a summary of the current policies with respect to energy distribution companies in the Netherlands, Norway and the UK, which may be of interest to policy makers working on energy. (See section 4.2.3.)

The structure of this chapter is as follows. We first describe a typical electricity supply industry and reliability issues that arise for distribution networks in section 4.2. We present the methodology and the data in section 4.3, after which we turn to the empirical analysis in section 4.4. Section 4.5 concludes.

4.2 The description of the industry and reliability issues

We begin with a description of the electricity industry and standard reliability indicators, after which we give an overview of the government policies with respect to electricity distribution networks in the UK, Norway and the Netherlands.

4.2.1 The structure of the industry

In the last few decades, the electricity industry has been undergoing major structural changes. In most European countries, this industry has been restructured into four segments called correspondingly: production, transmission, distribution and supply. The term 'production' stands for electricity generation. 'Transmission' refers to the main transportation network, which includes a transmission system operator acting at the national level and managing the high-voltage grid. 'Distribution' is represented by a number of regional networks, transporting the commodity further to final customers. Finally, 'supply' refers to retail sales of electricity.

The current study focuses on the distribution segment of the industry and the reliability issues that arise in this type of networks.

4.2.2 Indicators of reliability

Reliability in the electricity industry is characterised by 'continuity of service', which reflects the ability of the system to function without interruptions of supply to final customers. 'Continuity' is often considered the most important dimension of the quality of electricity supply. Strictly speaking, the definition of reliability adopted in this report includes not only 'continuity' but also 'product quality' (i.e., voltage quality in this case).[62] However, the latter will be left beyond the scope of this case study for two reasons. First, the data on product quality is not available. Second, continuity of service represents currently the major concern for distribution networks.

For an individual customer, reliability is characterised by both the number and the duration of interruptions. Several standard indices can be calculated at the network level. These indices represent different ways of aggregation over the customer base or over the system components. Table 4.1 gives an overview of the most commonly used indices of reliability.

[62] Furthermore, commercial quality represents another quality dimension which customers of electricity distribution companies value. Think of quality of responses to customer letters, metering activities, etc.

Table 4.1 Indices of reliability

Index	Definitions and explanations
CAIFI (Customer average interruption frequency index)	This index is also referred to as 'expectation of outage'. CAIFI shows an average number of interruptions for an average customer per year.
CAIDI (Customer average interruption duration index)	CAIDI is average annual duration of interruption for an average customer, expressed in minutes per interruption.
Annual duration of interruptions	Annual duration of interruptions is the product of CAIFI and CAIDI.
CML (Customer minutes lost)	CML is a product of CAIDI and the number of the affected customers.
ENS (Energy non-supplied)	ENS is a product of the number, duration and the load that has not been delivered to the customers.
SAIFI (System average interruption frequency index)	SAIFI is similar to CAIFI, however, it relates not to customers but to components of the network. It is an average number of interruptions per component type.
SAIDI (System average interruption duration index)	SAIDI is similar to CAIDI. It is average duration of interruption per component type.

Source: KEMA (2002, p. 59).

Table 4.2 illustrates the discrepancies in annual duration of interruptions across several European countries. Notice, that the table highlights only one side of the complete picture, as we do not see the corresponding costs. We observe that the Netherlands has the highest reliability in the sample.[63]

Table 4.2 International comparison

Country	Annual duration of interruptions (minutes)
The Netherlands	26
France	57
UK	63
Sweden	152
Norway	180
Italy	191

Source: CEER (2001, table 3.2-A).

[63] CEER (the Council of European Energy Regulators) notices that that the comparison is not without caveats. There are differences in the ways countries account for interruptions. For example, some countries account for both short and long interruptions while some other countries do not. Some countries count only interruptions originating above a certain voltage. Also, network topology may affect reliability. For example, due to the high population density, the Netherlands has a ring-structure of the transmission network, while the network in Scandinavian countries is stretched from the North to the South.

4.2.3 Some practical examples of currently adopted government policies

Here we give an overview of some institutional details and of the policies that are currently adopted by the UK, Norway and the Netherlands. The regulatory experiences of the UK and Norway are especially interesting, since these countries have relatively long history of regulation.

UK

The deregulation of the electricity industry in the UK went parallel with privatisation, which began in 1989. The electricity network comprises the network of the National Grid Company, NGC, and 14 regional distribution networks. Originally, the regional companies provided both transportation and supply services, but they were legally unbundled in 2000, in accordance with the Utility Act 2000. By now, all regional companies have been privatised.

The distribution tariffs are subject to the so-called ‘RPI-X’ system. This means that the tariffs are increasing with inflation (expressed by the retail price index, RPI) and decreasing with the X-factor representing the percentage of the potential cost savings. This percentage is based on benchmark of operation and maintenance expenses, OPEX. While OPEX is benchmarked, the allowed capital costs are estimated by the regulator in the manner that guarantees a regulatory rate of return on the assets of companies – the so-called ‘building block approach’. Such an approach combines both price-cap and rate-of-return features. It is a price cap in the sense that the regulator commits not to change the X’s for the whole regulation period. However, it resembles rate-of-return regulation since the cost of capital is passed through into the tariffs.

The responsibilities of regional network operators with respect to reliability are set out in the standards of performance. There are two types of standards: guaranteed standards and overall standards. Both types of standards include not only standards on network reliability, but also standards on some aspects of commercial quality (e.g., time of the investigation of a complaint). Guaranteed standards set service level to be met for each individual customer and specify fines for underperformance. For example, there is a standard regarding restoration of supply, requiring that supplies should be restored within 18 hours; otherwise, a payment must be made.[64] Overall standards specify a certain average level of performance for a particular service (e.g., minimum percentage of supplies to be reconnected within 3 hours following faults).

In 2002, Ofgem[65] introduced an incentive scheme that penalises or rewards distribution companies dependent on their overall performance against the targets for customer interruptions

[64] The current payments in the UK are 50 pounds for domestic customers and 100 pounds for non-domestic customers, plus 25 pounds for each following 12 hours. Notice that under the current Network Code in the Netherlands, distribution companies begin compensate customers already after 4 hours of interruption.
[65] Ofgem is the Office of Gas and Electricity Markets performing the regulatory duties since 1998.

and customer minutes lost.[66] In particular, if a company does not meet the overall reliability targets, their X factor will be increased by extra 0.5%. This measure integrates price controls with reliability regulation, hence, should improve the incentives of companies to balance cost reductions and reliability.

Norway

The electricity sector in Norway has now been deregulated for more than 10 years. The composition of the network is similar to that in the UK and in the Netherlands: the national TSO Statnett performs the transmission of energy on the national level, while a number of regional distribution companies operate regional transmission and distribution networks. The distribution segment in Norway is characterised by the low degree of concentration: in spite of the wave of mergers in the last several years, there remain more than 100 regional distribution companies in Norway. Almost all distribution companies are publicly owned.

Distribution tariffs are regulated by 'CPI-X'.[67] In contrast to the UK, the X factors in Norway are not based on the building block idea, but on benchmarking of all costs (which means that this system incorporates elements of yardstick competition). Only special investment in the expansion of the network is not included in benchmarking.

Until 2001, the major regulatory measures with respect to regional electricity networks were directed towards the reduction of the cost of network service provision, with no penalties for interruptions of supply. However, recognising that the downward pressure of high-powered incentive regulation on cost may affect reliability, NVE[68] began to require annual reporting of interruption data by network companies already in 1995. In 2001 new regulatory arrangements were introduced: price controls were integrated with quality regulation. The revenue caps are now adjusted in accordance with the customers' interruption cost.[69]

The Netherlands

The national TSO TenneT operates extra high voltages, while regional transmission and distribution are represented by regional networks. All networks are in public hands.

The distribution tariffs in the Netherlands are regulated by 'CPI-X' which is similar to the model applied in Norway. In particular, DTe benchmarks total costs to define the potential for

[66] Ofgem (2003b).

[67] It is 'CPI-X' in Norway, while 'RPI-X' in the UK. Both CPI and RPI are indices for consumer inflation. The difference is merely in the weights used in computation.

[68] NVE is the Norwegian Water Resources and Energy Directorate.

[69] See Langset et al. (2001) and Heggset et al. (2001) for more detail. The current system distinguishes six different customer groups, and assigns different compensation rates to notified and to non-notified interruptions. Furthermore, a recent consultation document of NVE makes a proposal on minimum standards with respect voltage quality. However, the latter is beyond the scope of this case study. (Source: http://www.nve.no.)

cost savings. For the second regulation period (2004-2006) the Dutch regulator proposed to use a yardstick competition mechanism integrating price regulation and reliability regulation. This regulatory scheme will fully come to the force in 2005.

At present, reliability of service has been regulated by means of individual minimum standards, with compensation for violations. In particular, in accordance with the current Network Code[70], a network company is required to pay a customer a fixed amount of compensation for interruptions of supply longer than four hours. The amounts differ per customer group and vary from 35 Euro for a household to the maximum of 91000 for the largest customers.

Table 4.3 Summary of government policies in the UK, Norway and the Netherlands.

	The UK	Norway	The Netherlands
Degree of unbundling of distribution companies	legal unbundling (Utility Act 2000); same companies have sold their supply businesses to different owners.	accounting unbundling, legal unbundling in cases when horizontal merger is taking place	legal unbundling since 1999; recently decision on ownership unbundling
Ownership	1989: privatised 1995: golden shares sold 8 owners hold 14 distribution licences	public and few cooperatives owned by the customers; there is no rule prohibiting selling distribution businesses to private parties	public
High-powered tariff regulation	RPI-X building block approach to setting price caps, while benchmarking OPEX	CPI-X benchmarking model with multi-dimensional inputs (costs) and outputs	CPI-X benchmarking total cost
Quality regulation	before 2002: individual standards with fines for underperformance; since 2002: incentive scheme with overall standards	before 2001: no fines; since 2001: integrated regulation of prices and reliability with targets for overall performance	until 2004: individual standards with fines for underperformance; since 2005: integrated regulation of prices and reliability on overall performance as well as individual standards
Regulator	Ofgem	NVE	DTe

Sources: http//www.gov.ofgem.uk; http//www.nve.no; http://www.dte.nl.

[70] In accordance with section 31(1)(f) of the Dutch Electricity Act (Parliamentary Proceedings of the Lower House of the Dutch Parliament 1998-1999, 26303), quality criteria and compensations for their violation are proposed by the sector and set out in paragraphs 6.2 (criteria) and 6.3 (compensations) of the Network Code.

As said, the price regulation will be integrated with reliability regulation in 2005, which means that reliability of supply will directly affect companies' revenues.[71] This development with respect to regulation of reliability is similar to that observed in the UK and Norway. Similarly to the regulation model of Norway, the amounts of adjustment in companies allowed revenues will reflect the consumer interruption costs as estimated by the regulator.

Summary of the government policies

Table 4.3 summarises the comparison of the regulation system in the UK, Norway and the Netherlands. Notice that in all three cases we are dealing with high-powered regulation.

Remarkably, all three regulators have already either modified or proposed to modify their regulatory models for distribution companies to integrate reliability into price controls. Table 4.3 also highlights differences in ownership. The companies in the UK are private, while in Norway and the Netherlands they are public. Given similarities in the price controls, a comparison of the performance of Norwegian distribution companies to companies in the UK may reveal differences attributed to ownership, which we discuss in section 4.4.2.

4.3 Methodology and the data

In this case study, we consider the effect of government policy on cost and reliability of electricity distribution companies. The three questions that we address are the following:

1. What does the experience of Norway tell us regarding the effect of high-powered regulation on cost and reliability of regional electricity networks?
2. What is the effect of the introduction of quality regulation in 2001?
3. Comparing the performance in Norway and in the UK, what can we say about the effect of privatisation on reliability?

The first two questions will be addressed by an econometric analysis, in which we test for the effect of regulation on both cost and reliability. The third question will be answered by a comparison of the results for Norway to the existing empirical evidence on the UK. The answer that we are able to provide based on such a comparison is only indicative and has to be taken with a pinch of salt because of differences in exogenous factors affecting the performance in two countries, the ways of the implementation of the incentive schemes, data definitions and research methodologies. Still, we find our exercise useful, since it allows us to shed the light on the effect of privatisation on costs and reliability of electricity distribution companies under high-powered incentive regulation.

[71] DTe (2002).

4.3.1 The model

We model the cost of a network company as a function of the company's size and reliability level. It has been recognised in economic literature that reliability and cost are jointly determined. Therefore, reliability is also a function of cost. Furthermore, reliability depends on the intensity of the use of the network.

Using a Cobb-Douglas specification for the corresponding functions, and reducing the system to eliminate the cross dependence between reliability and cost, we obtain the following system of two equations, which forms our basic model:

$$\begin{aligned} C &= A \cdot Y^{\alpha} \cdot S^{\beta} \\ R &= B \cdot Y^{\gamma} \cdot S^{\delta} \end{aligned} \qquad (4.1)$$

Here *C* is cost, *R* is reliability, *S* is network size, *Y* is quantity supplied, and the other variables are parameters of the model. We assume that α, β, γ and δ are constant, while *A* and *B* can be affected by company-specific characteristics (such as, the average age of network equipment, or characteristics of the operation area of a company) and by government policy, in particular, by incentive regulation.

The effect of incentive regulation on *A* and *B* is not straightforward. On the one side, price caps restrict prices and create cost-reducing incentives, which may lead to reliability decreases. On the other side, under price caps, companies may have the incentive to prevent reliability decreases, since those may cause a drop in their output, and hence in revenue. When quality regulation is introduced, prices are directly linked to contracted reliability indicators. This strengthens the incentive to prevent decreases of (contracted) reliability, compared to the situation prior to the introduction of quality regulation.

Notice that the direction of reliability changes under high-powered quality regulation may be either way, depending on the trade off between the costs and the benefits of reliability. Also, the effect of regulation on different reliability indicators may be different, since the performance of the company along different dimensions of reliability affects the cost and the quantity demanded in different ways.

4.3.2 Data

Table 4.4 below summarises the data and the variables used in regressions.

Table 4.4 Summary of the data on Norway distribution companies used in this study

Time period	1995-2001
Number of companies	Unbalanced panel of more than 140 companies
Measure for reliability	
Number of interruptions	Split between planned and unplanned interruptions
Duration of interruptions	
ENS	
Regulation	
Effect of CPI-X	A dummy variable: 1 for 1997-2001 and 0 otherwise
Effect of the introduction of quality regulation in 2001	A dummy variable: 1 for 2001 and 0 otherwise
Other variables	
Network length	
Customer number	
kWh delivered	
Cost	We use Operating and Maintenance expenses as the measure of cost.
Age of the network	Age is proxied as 'network length/Net Book Value'.

Data source: NVE

We use three different reliability measures: the number of interruptions, interruption duration, and the amount of energy non-supplied due to interruptions. For each indicator, a split into notified and non-notified interruptions is available. The two types of interruptions have different causes. Non-notified interruptions are also called 'unplanned interruptions' and reflect failures in network. In contrast, notified interruptions are 'planned' by the companies, as part of maintenance work. Therefore, the customers are notified about such interruptions. It seems that non-notified interruptions should provide a better proxy for the reliability of network than planned interruptions. However, the difference may be subtle: high level of planned interruptions can also be seen as a signal of bad network condition. Furthermore, customer value of planned and unplanned interruptions does not differ much, at least according to the estimates of NVE.[72] Therefore, we will estimate our model for 'non-notified', as well as for 'total' interruptions.

[72] The estimates of customer interruption cost can be found at http://www.nve.no. They are used by NVE in computing the cost of energy not supplied (CENS).

4.4 Empirical analysis

In this section, we describe our findings. We will present the results on the effect of regulation in Norway in section 4.4.1, and then compare our results and the results of other studies for the UK in section 4.4.2.

4.4.1 Empirical results

As explained above, the effect of government policy on different reliability dimensions may be different. Therefore, we estimate several specifications for the model, using three different reliability measures: the number of interruptions, interruption duration, and the amount of energy non-supplied due to interruptions. In order to facilitate the interpretation of the results, we use the inverse of these indicators in our estimation, because in such a case a positive coefficient in a regression corresponds to a positive effect of policy on reliability.

The results of our estimation of the model (4.1) are shown in Tables 4.5 and 4.6 below. A negative coefficient for the effect of regulation in Table 4.5 corresponds to cost reductions. A positive (negative) coefficient for the effect of regulation in Table 4.6 corresponds to an improvement (worsening) of reliability. More estimation detail can be found in the footnote at the end of this page.[73]

Table 4.5 Estimation results: cost

Variables	Estimates
Effect of price-cap regulation	– .0287***
Effect of introducing quality regulation in 2001	– .0116
Age	.0125
Network length	.0375
Customer number	.0929
MWh delivered	.1956**
Constant	6.3628***
Number of observations	1219

Notes: * p<.1; ** p<.05; *** p<.01.

[73] Estimation details: 'MWh delivered' is the number of delivered units, which is our measure for output. The variables 'network length' and 'customer number' represent the size of the network. As said, the age of network may affect the cost function. Therefore, we include 'age of network' as an explanatory variable in the cost equation of our base model (4.1). However, the exclusion of this variable does not change the qualitative results. Furthermore, characteristics of operating areas may affect both cost and reliability. This has prompted the use of a fixed-effect model in all regressions. The estimation has been performed in logarithms. The reduced equations for cost and reliability have been estimated separately. This means that our estimates are consistent, but may be inefficient.

The results show that the price-cap regulation in Norway had a negative and significant effect on costs, while producing a mixed effect on reliability indicators. In particular, we find a negative and significant effect on the inverse number and duration of interruptions, and a positive (and significant under the last specification) effect on reliability in terms of ENS. As we explained before, ENS directly affects companies' revenues. Therefore, companies are likely to care about this particular indicator more than about the duration and the number of interruptions. We tested the robustness of the results by the inclusion of a trend in the regressions. The effect of the trend variable is interpreted as the effect of technical changes in the industry. The inclusion of the trend variable affects the significance of our results. The coefficients for the price-cap dummy become insignificant, while the coefficients for the trend are significant in most regressions on reliability. Given that the data cover only a short time period, and price caps were imposed during the second part of this period, it may be that the time-trend also picks some effect of price-cap regulation.

Table 4.6 Estimation results: reliability

Variable	Duration (NNI)	Duration (Total)	Number (NNI)	Number (Total)	ENS (NNI)	ENS (Total)
Effect of price-cap regulation	–.3853***	– .2177***	–.4780***	– .3403***	.0663	.2204***
Effect of introducing quality regulation in 2001	– .0649	.1739**	– .2430**	– .0908	.2499***	.4689***
Age	–.6234*	– .2244	– .6389*	– .4056	– .6380**	– .3020
Network length	.5681	.0850	.7076*	.4524	.5311	.2330
Customer number	– .9428	– .9083*	– 1.1661*	– 1.2581**	.3724	.1619
MWh delivered	– 1.2962*	– 1.5801**	– 1.4149*	– 1.7990***	– 1.3523**	– 1.6393***
Constant	11.2401	18.5655**	13.9984	21.6142***	3.1555	11.1481*
Number of observations	1153	1155	1157	1159	1153	1156

Notes: * p<.1; ** p<.05; *** p<.01. NNI means non-notified interruptions. Inverse indicators are used in estimation.

The quality regulation introduced in 2001 strengthened the incentive to reduce ENS. A positive coefficient at the dummy corresponding to the year 2001 in the last two regressions shows the safeguarding effect of the new regime on this dimension of reliability: companies are not willing to incur the revenue losses that may result from under-performance on this particular indicator. Furthermore, we observe a positive and significant coefficient in the regression for total duration of interruptions. The coefficients at quality regulation for total duration and ENS, remain positive and significant when we include a trend in regressions. We notice that our results with respect to the effect of quality regulation are based on only one year of observations after the introduction of such a new regime, while the prospective compensations for over- (or under-)performing the reliability target are based on the average performance over five years.

One more result with respect to the effect of price-cap regulation and quality regulation deserves attention. When compare the results for non-notified interruptions with those for total interruptions we see that the coefficients for the effect of regulation on non-notified interruptions are always less than the corresponding coefficients for total interruptions. This shows that the performance on notified (or planned) interruptions was better than on unplanned interruptions. Planned interruptions relate to maintenance. Our analysis highlights that even before the introduction of penalties for interruptions, the Norwegian companies began to prioritise their maintenance in such a way that improved their ENS indicators. It may be however that this development was accompanied by delaying certain maintenance work where consequences of delays are not immediately observable,[74] as for example Heggset et al. (2001) suggest.

4.4.2 A comparison to the UK

Below we compare our findings for Norway with the situation in the UK in 1991-1999. Since the Norwegian companies are public, while the UK companies are privatised, such a comparison may shed light on the effect of ownership on the performance of the companies in these countries. However, we notice that the data on the UK is not directly comparable to Norway, and the applied regulation models are not exactly the same. Therefore, our results should be taken with caution.

Our analysis for Norway has shown that high-powered price regulation has lead to cost reductions. Similarly in the UK, several studies report cost reductions under price caps in the 90-ths, especially towards the end of the second regulation period. However, there is a discrepancy regarding the explanation for these cost reductions: Pollitt (1995) mentions selling the golden shares by the British government in 1995 as a possible reason, while Tilley and Weyman-Johnes (1999) say that perhaps lax price controls were the reason for the low cost reduction during the first regulation period.[75]

Figures 4.1 and 4.2 show simple averages of the number and of the duration of interruptions in the UK. The graphs are based on data from Ofgem,[76] which allows us to split planned and unplanned outages. As said, planned outages are those due to maintenance. Customers are warned about them in advance. Unplanned outages relate to failures.[77] We observe a sharp

[74] For example, one cost item in operation and maintenance costs of companies in Norway is the cost of cutting trees along the overhead lines. If a company systematically does not cut trees, then the effect on reliability will be observable only in several years.

[75] Another reason may be the design of price caps in the UK, featuring a building block structure, in which investment cost passes through. This encourages investment, but may also lead to overinvestment – the famous Averch-Johnson effect. Burns and Davies (1998) has found an indication that this could have been the case in the UK. They write: “Maintenance costs are typically reported as an operating expenditure, whilst refurbishment costs are typically capitalised. Since the difference between the two is not always clear, scope for gaming exists.”

[76] More discussion of this data can be found in Ofgem (2003b).

[77] Our analysis covers only outages that arise on the network side. In the period considered, the contribution of the other interruptions was minor, with the duration of about 1% of the total duration.

reduction in both the number and the duration of planned outages, while no much change in similar indicators for unplanned outages. Therefore the total number and duration of interruptions has declined.

Figure 4.1 Reliability in the UK: interruption number

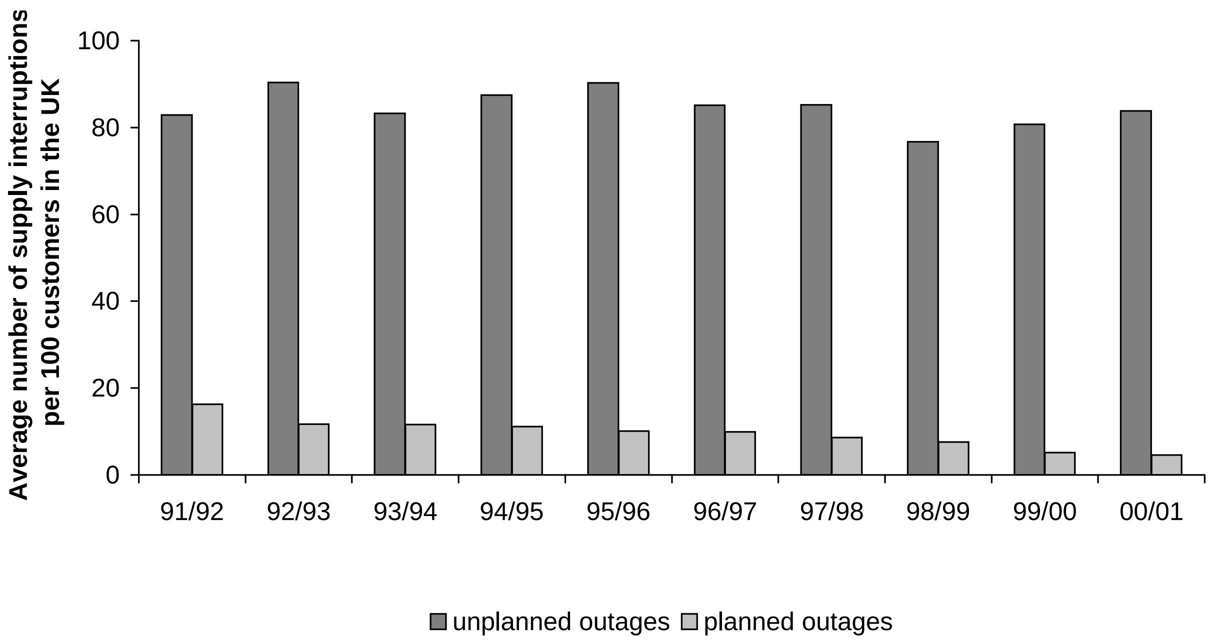
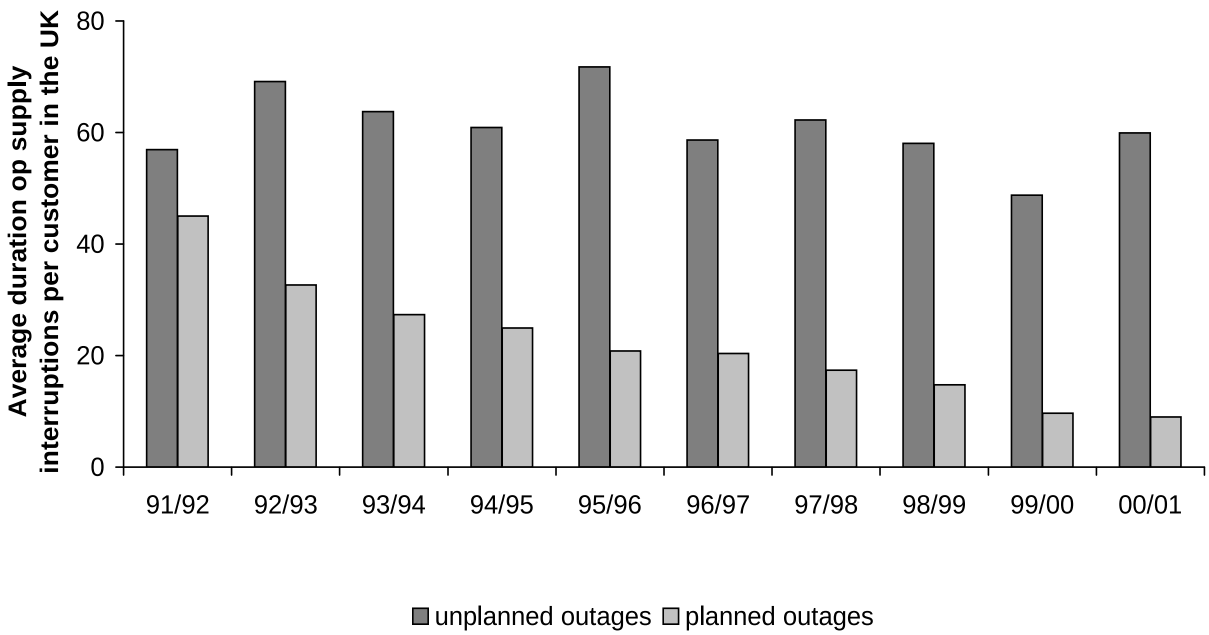


Figure 4.2 Reliability in the UK: interruption minutes



Given that the improvement in reliability indicators comes mostly from reductions in planned interruptions, one can suspect that companies in the UK have simply reduced maintenance. Notice however, that there are indications that the reduction in maintenance possibly were accompanied by changes in organising maintenance work. First, the decrease in duration of interruptions is larger than that in the number of interruptions, which may be an indication of a better-organised maintenance work.[78] Second, we do not observe an increase in unplanned interruptions over the decade, while this should have been an unavoidable result of systematically undercut maintenance. Therefore, it seems that the UK companies were not only decreasing operating and maintenance expenses, but also prioritising maintenance work with the largest effects on their reliability indicators. This effect of government policy on the behaviour of the UK companies is similar to the effect that we have registered for Norway, where we also observe a better performance on planned interruptions rather than on unplanned interruptions, and reduction of duration per interruption. Such similarities may imply that high-powered regulation has a similar effect under both private and public ownership.

4.5 Conclusions

This case study addresses three issues: the effect of high-powered price regulation, the effect of quality regulation, and the effect of ownership. We consider three reliability indicators: the number of interruptions, interruption duration and the amount of energy non-supplied due to interruptions (ENS).

Based on a data set of Norwegian electricity distribution companies over 1995-2001, we find that high-powered price regulation forces companies to decrease their cost, while having an ambiguous effect on different reliability indicators. Under price caps, the indicators of ENS have improved, while the indicators of the number and duration of interruptions have worsened. We explain this by more concern of companies under price caps about reliability indicators directly affecting their output and revenues (such as ENS), and less concern about other indicators. Furthermore, for each indicator, we observe a better performance on notified interruptions than on non-notified interruptions, which may reflect changes in the behaviour of the companies with respect to maintenance.

Second, we find a positive and significant effect of the quality regulation introduced in Norway in 2001 on reliability measured by ENS (the reliability indicator that was contracted by the regulator) as well as on interruption duration. However, this finding is based on only one-year data with respect to regulation of reliability.

[78] We observe an almost 30% decline in the ratio of duration over the number of planned interruptions in the UK over the decade.

Third, we compare our results for Norway to the results from other studies on the UK. Both countries feature high-powered price regulation, while different ownership: public companies in Norway and private in the UK. The empirical literature shows that the UK companies have improved production efficiency under price caps, especially since the mid nineties. Thus here too, price caps have created incentives to decrease costs. With respect to reliability, we do not observe large changes in indicators for unplanned interruptions in the UK, while planned interruptions show a decreasing trend, resulting in the improvement of the total number and duration of interruptions. This means that privatisation, accompanied by price and quality regulation, does not have to have an adverse effect on reliability. We observe similarities in the companies' performance under both types of ownership.

Concluding, we observe that these three findings are generally in line with the theoretical predictions regarding the effects of government policy on contractible (but not necessarily contracted upon) reliability. Notice that the checklist presented in chapter 2 also indicates that the three reliability indicators considered are likely to be contractible for the following reasons:

- It is generally feasible to identify and to call to account the party that have caused an interruption.
- The outages at the distribution level are relatively frequent and their impact is not too high (in contrast to transmission, where outages are rare but have much larger impact).
- Writing a contract with distribution companies on these indicators is relatively cheap.
- We observe that the governments in the considered countries are willing to write such contracts.

However, the indicators that we have considered in this case study do not exhaust all reliability dimensions. According to the checklist, the following factors reduce contractibility of reliability in distribution networks:

- The life cycle of investment in reliability is relatively long, also longer than the period covered by our analysis.
- In practice, regulators may not be able to closely monitor underlying network features.

Therefore, although our empirical findings are in line with the theoretical predictions regarding the effect of government policy on contractible reliability, we cannot extrapolate them to all reliability dimensions of electricity distribution networks. Furthermore, our results can be dependent on the assumptions of the model and data limitations. Further research with data over a longer period can reveal this.

5 Natural gas

5.1 Introduction

In this case study, we analyse the relationship between government policy and reliability in the supply of natural gas. Our analysis focuses on two policy instruments: private ownership and unbundling. However, since unbundling is generally accompanied by some form of regulation of network access, it is not always feasible to split the effect of unbundling from the effect of regulation. Therefore, when speaking regarding the effect of unbundling, we in fact include the effect of regulation. (See section 5.3.1 for more detail.)

The IEA provides information on gas distribution losses and own use[79] for several OECD-countries (in general for the years 1984-2000 on a monthly basis). As these losses can serve as a (partial) indicator for leakages from the network, we use this data source for analysing the relationship between institutional setting (public versus private, and unbundled versus integral) and quality of the network.

The structure of this chapter is as follows. In section 5.2, we first briefly describe the structure of the natural gas industry after which we turn to reliability issues that arise for transmission and distribution networks. We present the methodology and the data used in section 5.3. Section 5.4 presents the empirical analysis and section 5.5 concludes.

5.2 The description of the industry and reliability issues

5.2.1 The structure of the industry

In the natural gas industry, five stages of production can be distinguished:

1. Production: the exploration, drilling, extraction and processing of gas.
2. Transmission: the high-pressure transportation of gas to high-volume customers (e.g. distribution companies, power stations).
3. Distribution: the low-pressure distribution of gas to small and medium-volume customers (e.g. households).
4. Storage: the smoothing of the flow of gas through the transportation network by pumping gas into holding facilities at off-peak times and withdrawing it at peak times.
5. Retailing or marketing: the provision of services of contracting with production, transmission and distribution companies on behalf of the gas customers and associated billing and metering services.

[79] While distribution losses are probably more directly related to reliability in the gas sector than own use, a split between these two components of gas losses is unfortunately not possible.

In this case study, we focus on the stages of transmission and distribution because these involve the use of pipelines. Obviously, network quality is an important issue in these stages.

The market structure for the natural gas industry differs widely from country to country. As a general rule, in most OECD countries the gas industry features significant levels of government ownership and, to an extent, vertical integration.[80] In almost all OECD countries, however, competition continues to spread in the natural gas industry (see section 1.2.3 for some practical examples of currently adopted government policies).[81]

5.2.2 Indicators of reliability

Reliability in the natural gas industry refers to the ability of the system to function without interruptions of supply to final consumers. Especially because of growing gas demand and rising import dependence, in most OECD countries gas supply security is increasingly becoming a concern. During the 1990s, the hope was that liberalised gas markets would automatically ensure security of gas and electricity supply all the way to the final consumer. The reality can be more complex, as is shown in the general analysis (Part I of this document).

Indicators directly measuring the reliability in the natural gas industries are for example the number and duration of interruptions and the number of accidents (like explosions caused by uncontrolled gas releases). Unfortunately, the figures needed to calculate such indices of reliability are not (publicly) available. We therefore have to rely on a more indirect indicator of reliability, which is the amount of distribution losses and own use as a percentage of final gas consumption.[82] It can reasonably be assumed that this indicator represents an important characteristic of reliability in the natural gas industry. Table 5.1 shows that the reliability of the Dutch natural gas industry is relative high.

[80] See OECD (2000).

[81] See for example IEA (2003).

[82] While distribution losses are probably more directly related to reliability in the gas sector than own use, a split between these two components of gas losses is unfortunately not possible.

Table 5.1	**International comparison**		
Country	Distribution losses and own use as percentage of final gas consumption		
	1984	2000	Average
Denmark	3.7	0.3	6.8
United-Kingdom	5.9	6.1	6.4
Austria	5.7	3.6	4.5
Spain	2.9	2.2	3.3
New-Zealand	5.6	2.4	3.3
France	1.3	1.0	1.9
Netherlands	1.2	0.3	1.2
Italy	1.0	0.8	1.0
Japan	1.7	0.6	0.9

Source: own calculations

5.2.3 Some practical examples of currently adopted government policies

In this section, we give a brief overview of the government policies that are currently adopted within the European Union with respect to the gas networks. The focus is on the introduction of competition.

Competition in the natural gas industry?

The question whether competition is feasible in the natural gas industry cannot be answered unambiguously. While strong opportunities are present for competition in some stages of production, in other stages competition is difficult if not impossible to sustain. The transmission and distribution of natural gas seem to be a good example of the latter. As the OECD has put it:[83]

Given the substantial economies of scale in transmission pipelines, it seems likely that for the foreseeable future effective inter-pipeline competition even in fully liberalised markets will be limited to a few geographic locations (near 'hubs'). (…) Local gas distribution exhibits economies of density and because of these economies the distribution of gas is, generally speaking, a natural monopoly.

In other stages, the opportunities for competition are much stronger. Especially in gas production and gas marketing competition seems feasible, but this requires the implementation of a regulatory framework which can ensure access to the non-competitive components. In particular access to the pipeline network at non-discriminatory terms and conditions, for example by unbundling the network from competitive activities, is essential for the development of competition in the downstream market. Table 5.2 illustrates the discrepancies in private ownership of network companies and unbundling across several OECD countries.

[83] See OECD (2000, pp. 24-26).

Table 5.2 Private ownership and unbundling in the natural gas industry

Country	Private ownership?	Unbundling? Ownership unbundling	Legal unbundling
Austria	Yes	No	No
Denmark	No	No	Yes
France	No	No	No
Italy	Yes	No	Yes
Japan	Yes	?	?
Netherlands	No	No	No
New-Zealand	Yes	?	?
Spain	Yes	No	Yes
United Kingdom	Yes	Yes	No

Source: own research

The EU Gas Directive

Within the EU access to the non-competitive transmission and distribution networks is guaranteed by the EU Gas Directive. This directive forms part of the framework for the internal energy market and entered into force on 10 August 1998. All member states had to implement it by August 2000. The scope of the directive is as follows:[84]

The directive establishes common rules for the transmission, distribution, supply and storage of natural gas. It lays down the rules relating to the organisation and functioning of the natural gas sector, including liquefied natural gas, access to the market, the operation of systems, and the criteria and procedures applicable to the granting of authorisations for transmission, distribution, supply and storage of natural gas.

To accelerate the opening of the European gas market a new directive was adopted in June 2003. This directive will open the gas market for all non-household customers by July 2004, and for all customers by July 2007. It also contains further measures in unbundling, requiring legal unbundling of network activities from supply, establishes a regulator in all member states with well defined functions, requires published network tariffs, reinforces public service obligations especially for vulnerable customers and introduces monitoring of security of supply.

[84] See http://europa.eu.int/comm/energy/gas/legislation/explanatory_memo_en.htm.

5.3 Methodology and the data

In this case study, we analyse the relation between private ownership, unbundling and reliability in the natural gas industry. The two questions we address are:

1. What is the effect of privatisation on reliability in the gas sector?
2. What is the effect of unbundling (and the accompanying regulation) on reliability in the gas sector?

We answer these questions by estimating an equation that relates distribution losses and own use in which variables are included that represent private ownership and unbundling.[85]

Although it would be interesting to analyse also other reliability variables, like the number of accidents and interruptions in delivery, data for these variables are not available. Furthermore, limitations are present since we cannot split the effect of unbundling from the effect of the accompanying regulation. This means that our case study is indicative and has to be seen as a first step.

5.3.1 Model

The modelling approach in this chapter is similar to that in chapter 4. We estimate a reduced form equation for reliability assuming that the relevant model can be defined as an interdependent system of a cost and a reliability function. The reduced form equation for reliability includes variables correcting for differences in production levels, production circumstances, input prices, as well as policy variables. To test whether assumptions about the underlying functional form are important we estimate both log and translog specifications for the reduced form.

We use the inverse of distribution losses and own use as percentage of final gas consumption as the variable representing reliability. This means that when distribution losses and own use (given the level of consumption) rises, the reliability variable decreases. Hence, a negative coefficient at a policy variable is interpreted as a negative effect on reliability, and vice versa.

In our model, reliability is a function of:

[85] Note that we use the inverse of distribution losses and own use (as percentage of final gas consumption) as our reliability variable in the estimations, because in such a case a positive effect of policy on reliability corresponds to a positive coefficient in the regression.

- The level of gas production in the own country. This variable corrects for scale differences in time and between countries which are related to the size of the production segment of the industry.
- The level of total final consumption. This variable corrects for scale differences in time and between countries which are related to the size of consumption.
- Input prices for capital and labour. Higher prices for these inputs will make investments in reliability more expensive, suggesting a lower level of reliability in expensive periods and/or countries. Changes in the relative prices might also influence reliability, as reliability is capital intensive.
- Difference in temperature. Distribution losses and own use may be an imperfect measure for reliability as distribution losses are the sum of losses due to leakage and due to difference in gas temperature between the pumping stations and the delivery points. Therefore, we include the average temperature per month to correct for these differences.
- Differences in network density. Although including direct observations about the length and density of gas networks would be preferable, we include as a substitute data on inhabitants per hectare and the percentage of rural population.
- Trends. A (general or country specific) trend and country fixed effects are included. A general trend corrects for time related changes in circumstances which are identical for all countries. As an alternative, we include country specific trends to correct for time related differences between countries. As the influence of trends on reliability might be linear or non-linear, we estimate both for linear and log-linear trends.
- Fixed effects. These variables correct for differences in exogenous factors which cannot be captured by the other covariates (like differences in quality regulation).
- Ownership, regulation and unbundling. To test for the influence of ownership we include a dummy with value 1 if private ownership is present in the transmission and/or distribution segment of the industry and value zero otherwise.[86] In our database, nearly 60% of the observations relate to private ownership. The difference in ownership is not the only institutional difference between countries. Within OECD-countries there exist major differences in regulation and unbundling of the gas industry. Not only are differences present with respect to market opening (can customers choose between different suppliers), differences also exist with respect to unbundling (vertical integration of production and distribution) and regulation of third-party access (negotiated or regulated). Ideally, we would include variables representing all different forms of regulation and unbundling. In this case, it would be possible to discriminate between the effects of these forms of regulation and unbundling on reliability. It showed, however, that the correlations between these three types of variables are very high.[87] To prevent multicollinearity we therefore include only a variable for legal unbundling, which has the value

[86] Including the private dummy multiplied with a trend reveals that we have not enough variation in the dataset to test this alternative.

[87] Note that the correlation between the private ownership dummy and the regulation and unbundling variables is not very high (maximum is 0.37 for negotiated access and private ownership).

1 if legal unbundling is present and zero otherwise.[88] This means that the coefficient estimated for this variable cannot be interpreted as the effect of unbundling on reliability alone but may reflect also the effects of market opening and third-party access. Note that we estimate both models with and without an unbundling variable as the former model has more observations as for some countries and years information on unbundling (and regulation variables) is unavailable.

5.3.2 Data

For distribution losses and own use data are available on a monthly basis for nine OECD-countries for the years 1984 until 2000 (availability in time differs between countries).[89] This makes it possible to estimate a panel model. In total 1,622 observations are available.

Data for distribution losses and own use, gas consumption and own gas production come from the IEA. Data for the price of capital and labour are from the OECD Economic Outlook. Data for inhabitants per hectare and rural population are from World Development Indicators (The World Bank). Temperature data are for the EU based on daily observations published at the website of the Royal Dutch Meteorological Institute (www.knmi.nl), where we choose a large central located town as a measure for the whole country. For Japan, daily figures are used from the website of the World Meteorological Organization (www.wmo.ch) for three towns located at a difference of 5 degrees latitude. Data for private ownership and unbundling are from OECD (2002), EC (2001) and the most recent country reports of the IEA.[90] We would like to note, however, that it was not always clear at which year a policy change had taken place.

Table 5.3 Descriptive statistics gas sector

	Average	Max	Min	St. dev.
Distribution losses and own use (% of total gas cons.)	3.42	24.68	0.04	3.63
Own production gas	1.795	13.364	0	2.905
Total gas consumption	2.581	12.056	10	2.485
Price capital (long term real interest rate)	7.73	15.66	1.55	2.79
Price labour (real dollars using ppp per fte)	27.413	35.439	18.324	4.190
Inhabitants per hectare	1.85	4.70	0.12	1.38
Rural population (% total population)	20.25	35.70	10.50	8.27
Average temperature	11.68	27.30	– 5.19	6.37
Private ownership (dummy)	58.25	100.00	0.00	49.33
Unbundling legal (dummy)	8.75	100.00	0.00	28.26

[88] A dummy for ownership unbundling could not be included as only one country, the United Kingdom, has this form of regulation in our dataset.
[89] For some countries distribution losses and own use are not reported. Furthermore, countries are excluded with a very low level of gas consumption or when consequently a level of losses and own use equal to zero is reported. Finally, some observations, always dated in the beginning of the sample, are excluded with a very high level of losses and own use.
[90] See the IEA-website for an overview of the studies available (www.iea.org/Textbase/publications/index.asp#pubs).

Table 5.3 gives descriptive statistics for all variables. Distribution losses and own use are on average 3.4% of total gas consumption. The standard deviation is relative high, while the maximum is nearly 25% and the minimum is almost zero. This means that our left-hand side variable seems to have enough variation. Private ownership is present in 58% of the observations, while legal unbundling accounts for nearly 9%.

5.4 Empirical analysis

5.4.1 Empirical results

Table 5.4 presents the estimation results for the effect of private ownership and unbundling (and the accompanying regulation) on reliability in the gas sector for the translog model with country specific trends. This model is preferred from a statistical point of view above models with a log specification and/or a general trend (on the basis of an F-test on the sum of squared residuals).

Table 5.4 Estimation results: effect of policy on reliability (preferred model)

	Model without unbundling variable	Model with unbundling variable	
Trend	Effect of private ownership	Effect of private ownership	Effect of unbundling
Linear	0.09	0.19	– 0.35**
Loglinear	0.16	0.56***	0.05

Notes: Variables with */**/*** are significant on 90/95/99%. Here we include only policy variables. The complete results are available from the authors upon request.

In the preferred model with linear or loglinear country specific trends the private ownership dummy is insignificant when no unbundling variable is included. Thus, reliability is the same for public and private companies in these specifications. This result is robust when the unbundling variable is included and the trends are linear. However, if loglinear trends are included in this case the private dummy is significant and positive. This would indicate a higher level of reliability for private companies.

To analyse the sensitivity of our empirical results on the private ownership effect, we have estimated the model with alternative specifications and a different dataset. In general terms we found that our main result (often insignificant results for the private dummy) is robust. Sensitivity analysis with alternative specifications (a log model instead of a translog model and/or a general trend instead of country specific trends) reveals that in most cases the coefficients for the private ownership dummy are insignificant (see Table 5.5). However, for the log model with a linear and general trend a significant and positive effect is found. If the unbundling variable is included, the result is only different for the translog model with a general and loglinear trend. In this case, a significant and negative effect is found. Sensitivity analysis with an alternative dataset (annual observations from the OECD Energy Balances) results in insignificant coefficients.

Table 5.5 Estimation results: sensitivity analysis

			Model without unbundling variable	Model with unbundling variable	
Functional form	Trend	Trend: level	Effect of private ownership	Effect of private ownership	Effect of unbundling
Log	Linear	general	– 0.23**	– 0.27**	0.75***
Log	Loglinear	general	– 0.07	– 0.19	0.46***
Log	Linear	per country	– 0.04	– 0.15	0.20
Log	Loglinear	per country	0.09	0.30	0.37**
Translog	Linear	general	0.04	0.19	0.27*
Translog	Loglinear	general	0.12	0.29**	0.07

Notes: Variables with */**/*** are significant on 90/95/99%.

Results for the unbundling dummy are mixed. In the preferred model, we find a negative or insignificant result dependent on the specification of the trend variable (see Table 5.4). Sensitivity analysis results in three insignificant (at 95%) and three negative effects (see Table 5.5). These result combined with the mentioned problem of high correlation between regulation variables, makes that in our opinion no clear conclusions can be drawn on the influence of unbundling. However, indications exist that unbundling (and the accompanying regulation) might have a negative effect on reliability. As this is very important from a policy perspective, further research is necessary.

5.5 Conclusions

In this case study, we have tested how private ownership and unbundling affect reliability in the gas sector. We have done this using a database with observations for nine countries and 17 years (on a monthly basis).

The preferred model from a statistical point of view reveals that no evidence is found for a negative effect of privatisation on reliability. In most cases, an insignificant effect is found, while negative effects are not present. Sensitivity analysis with other specifications and an alternative dataset reveals that this conclusion is rather robust: only in one case a negative effect is found.

For the effect of unbundling and the accompanying regulation on reliability, it should be noted first that a split between the effects of regulation (like market opening and third-party access) and unbundling was not possible due to statistical problems. Some evidence exists that indicate a possible negative effect of unbundling on reliability. However, the correlation between unbundling and regulation in combination with results that might indicate the absence of such a relation results in inconclusive results. As this is very important from a policy perspective, further research is necessary.

Three major shortcomings of our case study have to be reported. First, the number of countries for which data is available is not very large. We hope that datasets will come available with which more encompassing analyses are possible. Second, the measure for reliability we used may be an imperfect approximation of other reliability variables. Although 'gas losses in the distribution stage' is an important variable, it is an indirect measure of reliability. For example, the number of interruptions in final delivery would be a very interesting variable to include in the analysis. Unfortunately, data about this sort of variables is almost completely unavailable. Finally, it would be very interesting to test our conclusions when variables are included for policies aimed directly at reliability.

6 Drinking water

6.1 Introduction

The purpose of this case study is to investigate the relationship in the drinking water industry between private ownership and changes in regulation on the one hand and reliability on the other. We use data for the United States, England and Wales and the Netherlands:

In the United States, the type of ownership differs between drinking water companies. While some municipalities rely on public drinking water companies, others contract out to private companies. This allows for an analysis of the influence of private versus public ownership on the reliability in the American drinking water sector.

In England and Wales all water companies have been privatised in 1989. At the same time regulation changed for both costs and quality. As data are available for the years 1993 until 2003, it is possible to analyse whether these changes have increased or decreased reliability.

In the Netherlands all water companies are in public ownership. Although in the early nineties discussion started about privatisation and the introduction of competition, until now this has only resulted in a voluntary benchmarking system, organised by the sector itself. As data are available for the years 1997 until 2002, it is possible to analyse whether the threat of privatisation and competition and the actual introduction of benchmarking have affected reliability.

The structure of this chapter is as follows. In section 6.2, we first describe the drinking water industry in the three countries mentioned above. The methodology and the data used in this case study is presented in section 6.3, after which we turn to the empirical analysis in section 6.4. Section 6.5 concludes.

6.2 The description of the industry and reliability issues

6.2.1 The structure of the industry

The drinking water sector is a network industry as suppliers deliver drinking water to consumers over a pipeline network with market power. Market power is present as in all countries drinking water companies are local or regional monopolists.

Drinking water companies operate in two segments. First, raw water is treated to produce water that complies with drinking water requirements. This raw water comes from boreholes (groundwater), rivers or dunes. Second, drinking water is distributed to customers using the network. Each drinking water company is active in both segments.

This case study focuses on reliability issues in the distribution segment. However, where measures are unavailable for this segment, the production segment is included as well. In this case, the influence of policy on reliability might be at least indicative for the distribution segment.

Table 6.1 Variables measuring reliability in the drinking water sector for which data are available

	England & Wales	USA	Netherlands
Variables measuring the quantity of water delivered			
The number of main breaks (per unit length of mains)	yes	yes	
Interrupted properties more than 12 hours	yes		
Interrupted properties more than 24 hours	yes		
Average retention (time water is in distribution system)		yes	
Percentage of unbilled water due to main breaks		yes	
Properties below reference level (not enough pressure)	yes		
Percentage of unbilled water due to leakage	yes	yes	
Percentage of unbilled water due to distribution losses	yes		
Variables measuring the quality of water delivered[91]			
Volume under standards quality regulation	yes		
New volume under standards quality regulation	yes		
Volume with temporary relaxations	yes		
Volume with permanent relaxations	yes		
Volume (%) not in accordance with regulation	yes		
Concentration nitrates and pesticides per m^3	yes		
Total coliform tests that are positive	yes	yes	
Average free chlorine per unit water		yes	
Average combined chlorine per unit water		yes	
Cadmium			yes
Lead			yes
Faecal streptococcus			yes
1,2-dichloorethane			yes
Trichloorethene			Yes

[91] While for most variables the meaning is clear, some variables measuring the quality of water perhaps need clarification. In particular, the first five rows below correspond to the annual average daily volume of water entering the distribution network that does not comply with certain requirements, such as quality regulation in the reported year, temporary or permanent authorisations of relaxations for one or more water quality parameters at the end of the report year, and environmental regulation. See www.ofwat.gov.uk for more information.

6.2.2 Indicators of reliability

In the drinking water industry reliability does not only reflects continuity of supply, but also the ability of the system to safeguard the quality of the drinking water delivered. For both types of reliability several indicators can be calculated.

Table 6.1 presents indices of reliability most commonly used in the drinking water industry. It shows that available measures differ between countries. For England and Wales and the United States variables are available for both the quantity and the quality of water delivered. For the Netherlands only variables are available measuring the quality of water delivered.

Notice that a broad range in reliability measures is available. This, however, does not guarantee that all reliability dimensions are covered which are important for the drinking water sector. For instance, we have no data on the risk of infection, a reliability measure that at least in the Netherlands is thought to be important. Interesting is that information that is available refers to reliability variables that are implicitly or explicitly contracted. See for the discussion about not contracted reliability measures the theoretical part. It is of course possible that conclusions for more or less contracted reliability variables cannot be generalised to not contracted measures.

6.2.3 Some practical examples of currently adopted government policies

In this section we give a brief overview of the government polices that are currently adopted within the drinking water industry in the United States, England and Wales[92] and the Netherlands.

United States

In the United States both public and private water companies are present. Within the American water industry private monopolies are subject to incentive regulation, while public monopolies are not. (WSTB, 2002.) The accountability of publicly owned water companies is influenced through electoral and other public channels (municipal governance). For privately owned water companies, however, accountability is influenced through incentive regulation by public state commissions. These commissions apply a rate-of-return method of incentive regulation.[93] After the regulators have established a company’s total revenue requirement, they approve the prices that can be charged to various classes of customers. Although discussions are going on about the introduction of higher-powered incentive regimes, for example comparable with the price-cap regulation in England and Wales, in 1996 (the year our analysis applies to) no states used this type of regulation.

[92] This case study is only concerned with the drinking water industry in England and Wales, because water services in Scotland and Northern Ireland are still publicly owned.

[93] See also Brow (2001). Note that if differences exist in regulation between states these are neutralised by the state fixed effects in our empirical analysis.

With respect to the quality of drinking water, all water companies are subject to regulation by state drinking water primacy agencies as imposed by the federal Safe Drinking Water Act. At a minimum, water companies must meet the federal quality standards. Individual states, however, can impose additional standards.

England and Wales

In England and Wales the water industry was privatised completely in 1989. Privatisation was accompanied by the establishment of an independent economic regulator, named the Office of Water Services (Ofwat). Since then competition policy in the water industry builds on three elements (Vass, 2002):

- Yardstick competition by a RPI-X system. Every five years Ofwat determines a fixed maximum price for each water company. For individual companies the x-factor is determined in part by making comparisons between the incumbent and its artificial ‘competitors’. Despite these price controls, the privatised water companies made high profits in the early years. Although the first periodic review in 1994 reduced the real growth rate in water bills, it was not until the 1999 review that the water companies faced an immediate cut of water prices. However, companies were faced with significant investment programmes in every year since privatisation.
- Competition for corporate control through the capital market. Mergers between national water companies are however excluded in order to maintain a sufficient number of comparators for Ofwat to carry out yardstick competition.
- Limited market competition. Large suppliers are able to choose their supplier and so-called inset appointments can be provided to alternative suppliers on green field sites.

Ofwat also annually publishes reports on (i) the financial performance and capital investment of the water companies, (ii) water and sewerage service unit costs and relative efficiency, (iii) the security of supply, leakage and the efficient use of water and (iv) the levels of service for the water industry. All these reports contain detailed figures for each individual water company and are made publicly available on their website (www.ofwat.gov.uk).

In addition to the incentive regulation imposed by Ofwat, the Drinking Water Inspectorate monitors and checks the safety of drinking water. The DWI annually publishes its Drinking Water Reports (see www.dwi.gov.uk). In addition to a general overview of water quality in England and Wales, a short report on each individual water company is published. These reports provide information about the percentage of tests, which met the standards and details on drinking water quality incidents.

The Netherlands

In the Netherlands, drinking water companies are public owned regional monopolists. Prices are determined by the water companies themselves, but controlled by the shareholders. These shareholders are both local and regional governments and they are assumed to protect the interest of their citizens. As a part of the Dutch Competition, Deregulation and Legislative Quality (MDW) operation in the early nineties a discussion has started on privatisation and competition in the drinking water industry.[94] Since 1998 the debate on privatisation of water works is actually over. In that year the parliament stated that the water companies would not be privatised. In 2002 the Water Company Ownership Act assures the public ownership of water companies. Although privatisation is no longer a point of discussion, the introduction of competition still is. Initially a system of yardstick competition (like in the Dutch electricity sector) has been announced in the explanatory memorandum of the ownership act mentioned above. This is no longer a serious option as instead an obligatory benchmark is proposed in the plans to revise the Water Supply Act.[95] Currently, the Netherlands Waterworks Association (VEWIN) already tries to promote efficiency by means of a voluntary benchmark, in which almost all water companies participate. This so-called VEWIN-benchmark is carried out since 1997 and maps the performance of waterworks in different areas and compares results.[96] Note that both regulation instruments, obligatory and voluntary benchmarking, differs significant from yardstick competition. Where the former two instruments rely on incentives through naming and shaming and are therefore information generating instruments, the latter instrument imposes explicit cuts in prices through the determination of x-factors.

Dutch drinking water companies are fully responsible for the quality of water supplied. The quality of drinking water is monitored by the Ministry of Planning, Housing and Environment (VROM). The responsibility for the water distribution networks also rests with the water companies. The VEWIN-benchmark contains not only scores on efficiency and services, but also looks at quality and environmental performance.

Some believe that the ongoing discussion on competition during the 1990s and the actual introduction of (voluntary) benchmarking in 1999 could have reduced the quality of drinking water. Their argument is that drinking water companies might have reduced investments in reliability in order to cut costs in the short run. However, as the VEWIN-benchmark includes also information on quality, the opposite effects might also have been the case. As more information comes available, managers might have incentives to invest in quality, as they know that decreases in quality will result in worse figures in subsequent benchmarks.

[94] See Dijkgraaf et al. (1997).

[95] See TK (2004) for the position of the Dutch cabinet. This position is based on Dijkgraaf and Varkevisser (2004).

[96] See for example VEWIN (2001).

6.3 Methodology and the data

In this case study we address the following three questions:

1. What is the effect of ownership on reliability in the American drinking water industry?
2. What is the effect of privatisation, price-cap regulation and reliability regulation on the performance of the drinking water industry in England and Wales?
3. Have the threat of competition and the actual introduction of benchmarking affected drinking water quality in the Netherlands?

These three questions will all be addressed by an econometric analysis.

6.3.1 The model

For each country mentioned above, we estimate the reduced form reliability equation of a system of the relevant cost and reliability equations (when possible the system itself is estimated in a sensitivity analysis).[97] As explanatory variables, we include a set of covariates correcting for differences in production levels, production circumstances, input prices and government policy. To test whether assumptions about the underlying cost function are important we estimate both level, log and (if possible) translog specifications for our model.

Thus, for each estimation reliability is a function of:

- The level of production. Including this variable is necessary if scale effects influence the level of reliability.
- Input prices (if available). Reliability is more expensive to achieve when input prices are higher. Furthermore, the influence of the price of capital might be more important as reliability is capital intensive.
- Variables which may be important for differences in costs or reliability. Per country the available variables differ (see Table 6.2). Thus these covariates are the same for each quality equation within a country, but are different between countries, both due to data availability and country specific factors.
- Variables representing government policy. We discuss these variables for each country in more detail below.

[97] This is similar to the approach that we used in section 4.

Table 6.2 Covariates drinking water sector

	England & Wales	USA	Netherlands
Production (annual water production in million gallons)	yes	yes	Yes
Price of labour (total labour costs divided by the number of fte's)		yes	Yes
Price of capital (capital costs divided by the number of connections)		yes	yes
Number connected properties to water system per unit production	yes	yes	
The surface area of the company per unit production		yes	
The length of the distribution main pipes per unit production	yes	yes	Yes
The number of persons in the service area		yes	
The percentage of meters installed	yes	yes	
The percentage of groundwater used as raw water source	yes	yes	Yes
The percentage of surface water used as raw water source	yes		
The percentage of purchased water		yes	
Water (%) delivered to residential customers		yes	
Water (%) delivered to large customers	yes		Yes
The state the company is operating in		yes	
The average pumping head	yes		
Fixed effects companies	yes		
The amount of substances in raw water			Yes
Administrative connections per physical connection			Yes
Ground stability			Yes
Difference in quality between raw and delivered water			Yes
Percentage of non-drinking water			Yes
Percentage of water from shores			Yes
Percentage of water from dunes (natural)			Yes
Percentage of water from dunes (infiltration)			Yes
Age of the assets (booking value divided by historical value)			Yes

Policy variables: the US

The policy variable used in the estimations with the USA data is directly related to our first main question. To analyse the influence on reliability we include for the United States a dummy variable for private ownership. As the main difference between private and public drinking water companies is the type of ownership this dummy should reflect the influence of ownership on reliability. However, some other differences are present, for example with respect to accountability and economic incentives. The coefficient of the dummy might be influence by these circumstances.

Policy variables: England and Wales

Three policy variables are included in the estimations with the data for England and Wales, which are directly related to our second main question.

First, to analyse the influence of privatisation on reliability we include a time trend starting in 1993 and ending in 2003. A positive (negative) coefficient for the trend indicates a positive (negative) effect of privatisation on reliability. The idea is that if privatisation influences reliability, the influence will follow a linear pattern in time. When, for example, privatisation hinders reliability by not enough investments in infrastructure, reliability will become lower during time. It is not reasonable to assume a one-time effect of privatisation as the quality of the infrastructure will not be influenced immediately.

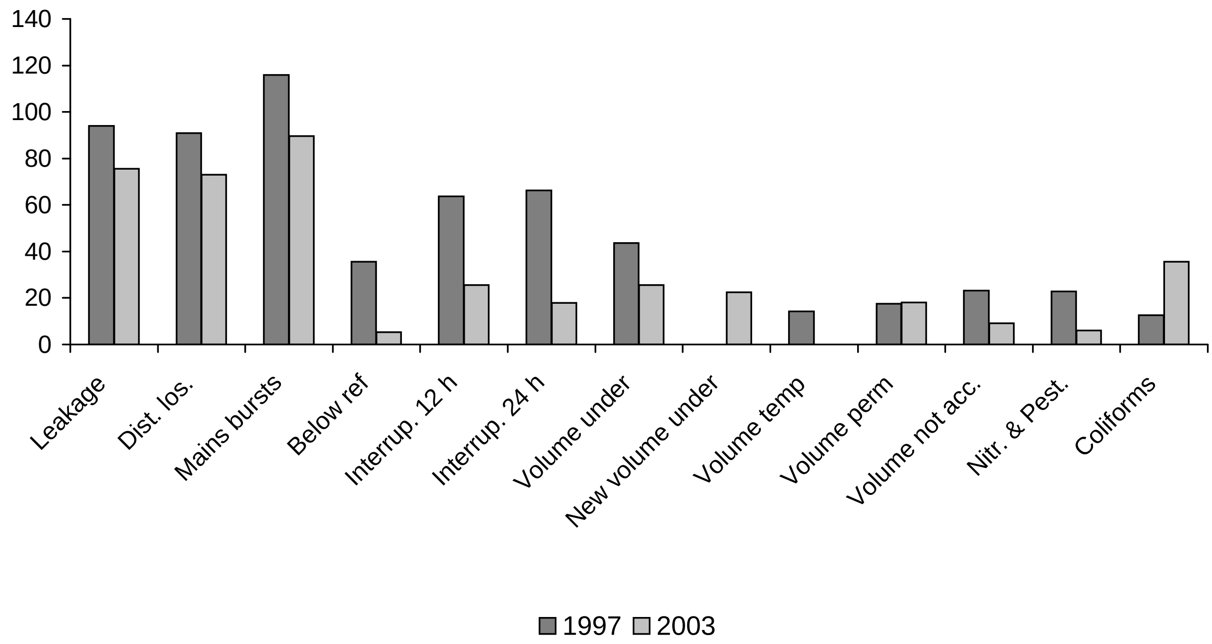
Second, to analyse the influence of price-cap regulation on reliability we include a variable measuring changes in the price limits between 1993 and 2003 (thus including the effect of price-cap revisions in 1995 and 1999). This variable represents the allowed rise in prices. This is done as a higher price level will leave more financial means to invest in reliability. Companies which are enforced to decrease prices more will have more incentives to reduce reliability.

Third, to analyse the influence of quality regulation on reliability we include a variable measuring the gap between the quality starting position in 1993 and the quality performance in 2003 multiplied by a trend. Making use of the large differences in starting position of the water companies when quality regulation was introduced in 1989 we assume that including a variable measuring these differences makes it possible to discriminate between the privatisation and change in quality regulation effect. The differences in starting position are measured by the difference per company in the level of the reliability measures in 1993 compared with the level in 2003. We further assume that dependent on this gap the change in reliability towards the 2003-goals is linearly in time (a trend is multiplied by the gap in reliability between 1993 and 2003). Note that ideally we would like to use the reliability goals that were set for the year 2003, instead of the actual reliability level in 2003. However, as data is lacking on these goals we use the actual level in 2003 as an approximation. Sensitivity analysis will show whether this assumption is important.

That correction for changes in quality regulation might be important is illustrated in figure 6.1 In this figure we plot the quality data for respectively 1997 and 2003 as a percentage of the values in 1993.[98] For nearly all reliability indicators the values in 1997 and 2003 are far below the levels in 1993. This is not surprising as generating investment opportunities was one of the driving forces behind the privatisation process. Under public ownership municipalities in England and Wales did not supply enough financial means to invest enough in reliability, while they prohibited financing by creditors.

[98] Note that for the new volume under standards quality regulation the value in 1997 is 212.

Figure 6.1 Percentage of 1993 value of different quality measures



It is important to note that a perfect split between the three effects is never possible. However, we believe that our approach at least takes account of the changes in the three regulation dimensions. As far as possible estimation results are tested for alternative assumptions. (See section 0.)

Policy variables: The Netherlands

The policy variable in the estimations with the Dutch data directly relates to our third main question. To analyse the influence on reliability we include for the Netherlands a time trend: a positive (negative) coefficient indicates a positive (negative) effect of the threat of competition and benchmarking on the quality of drinking water.

6.3.2 Data

USA-data are from the American Water Works Association and apply to 1996 (more recent data are available for costs, but not for quality variables). Table 6.3 presents the descriptive statistics. Note that the data availability differs for the variables. The ownership dummy (which is 1 for private companies) is available for 852 companies, of which nearly 13% is in private hands.

Table 6.3 Descriptive statistics USA drinking water

	Average	Maximum	Minimum	St. dev.	Observations
Quantity delivered water					
Main breaks	0.28	13.90	0.00	0.63	662
Retention time	1.83	17.00	0.10	1.44	532
Water loss due to breaks	2.45	45.09	0.01	3.33	428
Water leakage	3.58	46.00	0.01	4.84	396
Quality delivered water					
Coliforms	0.15	10.00	0.00	0.71	781
Chlorine free	0.75	3.20	0.00	0.57	634
Chlorine combined	1.52	87.00	0.00	4.55	373
Trihalomethanes	33.92	121.00	0.00	25.27	651
Exogenous variables					
Private (dummy)	12.87	100.00	0.00	33.55	852
Production (gallons/year)	8406	600000	52	26454	839
Price labour	35081	89625	8781	11753	521
Price capital	10240	2496136	0	123154	558
Properties (/production)	7.24	1,309.14	0.00	46.61	785
Surface (/production)	0.04	2.52	0.00	0.17	748
Length (/production)	0.13	11.25	0.00	0.45	793
Persons (*1000)	155	16000	0	639	846
Meter (%)	95.99	100.00	0.00	17.44	792
Groundwater (%)	41.98	100.00	0.00	45.65	839
Purchased water (%)	17.00	100.00	0.00	34.60	839
Water delivered to residents (%)	51.94	149.29	0.31	21.43	545

Data for England and Wales are from Ofwat and apply to 1993-2003. Table 6.4 presents the descriptive statistics. Note that the variables are available for nearly all 11 years and 23 companies with the exception of pumping head, surface water (%), water from boreholes (%) and water to large customers (%). For these variables the missing data for 1993-1999 are set equal to the values of 2000.

Table 6.4 Descriptive statistics drinking water companies in England and Wales

	Unit	Average	Max	Min	St. dev.	Obs.
Quantity delivered water						
Leakage	% input	22	39	14	6	253
Distribution losses	% input	16	32	8	5	253
Mains bursts	Per 1000 km	187	454	74	68	253
Properties below reference level	per property	6	63	0	10	253
Interrupted properties more than 12 hours	per property	1	29	0	3	253
Interrupted properties more than 24 hours	per property	0.4	27	0	2	253
Quality delivered water						
Volume under standards quality regulation	% input	17	106	0	26	247
New volume under standards quality regulation	% input	5	80	0	14	247
Volume with temporary relaxations	% input	3	68	0	10	247
Volume with permanent relaxations	% input	5	80	0	15	247
Volume (%) not in accord. with regulation	% input	20	121	0	29	247
Nitrates and pesticides	per unit input	12	99	0	24	247
Coliforms	per unit input	1	35	0	4	247
Exogenous variables						
Production (*1000)	ML/day	69	287	3	723	253
Connected properties (/production)	per unit input	1.51	2.34	1.07	0.21	253
Length of main pipes (/prod.)	per unit input	22.48	34.66	10.83	5.39	253
Meters (%)	%	22	60	5	11	253
Pumping head	m.hd	131	211	66	35	253
Surface water (%)	%	35	84	0	25	253
Water from boreholes (%)	%	46	100	3	34	253
Water to large customers (%)	%	5	39	0	6	253

Dutch data are from the Netherlands Waterworks Association (VEWIN) and from annual reports. Data are available for 14 companies and apply to 1997-2002. Table 6.5 presents the descriptive statistics. Note that the data availability differs for the variables of quality of delivered and raw water. Especially for the parameter "faecal streptococcus" we have a large number of missing observations. For the quality variables we have not only observations on the average concentration, but also on the maximum concentration. Both measures will be used in the estimations.

Table 6.5 Descriptive statistics (average values) Dutch drinking water

	Mean	Max	Min	St. dev.	Obs.
Quality delivered water (average value)					
Cadmium (µg/l)	0.01	0.19	0.00	0.03	83
Lead (µg/l)	0.15	4.00	0.00	0.52	83
Faecal streptococcus (Kve/100 ml)	0.06	1.75	0.00	0.27	43
1,2-dichloorethane (µg/l)	0.10	1.00	0.00	0.28	51
Trichloorethene (Mg/l)	0.01	0.05	0.00	0.02	71
Quality raw water (average value)					
Cadmium in raw water (µg/l)	0.02	0.20	0.00	0.03	69
Lead in raw water (µg/l)	0.20	1.90	0.00	0.36	68
Faecal streptococcus in raw water (Kve/100 ml)	59.13	285.00	0.00	85.53	35
1,2-dichloorethane in raw water (µg/l)	0.09	1.08	0.00	0.27	56
Trichloorethene in raw water (Mg/l)	0.32	5.04	0.00	1.11	83
Quality delivered water (maximum value)					
Cadmium (µg/l)	0.02	0.80	0.00	0.10	83
Lead (µg/l)	0.31	11.00	0.00	1.26	83
Faecal streptococcus (Kve/100 ml)	2.46	67.50	0.00	10.43	43
1,2-dichloorethane (µg/l)	0.00	0.07	0.00	0.01	51
Trichloorethene (Mg/l)	0.02	0.33	0.00	0.05	71
Quality raw water (maximum value)					
Cadmium in raw water (µg/l)	0.06	1.40	0.00	0.20	69
Lead in raw water (µg/l)	0.94	12.35	0.00	2.13	68
Faecal streptococcus in raw water (Kve/100 ml)	400.51	3595.00	0.00	710.59	35
1,2-dichloorethane in raw water (µg/l)	0.01	0.26	0.00	0.04	56
Trichloorethene in raw water (Mg/l)	0.44	7.38	0.00	1.54	83
Exogenous variables					
Production (in million m^3)	81.17	148.80	23.22	27.14	70
Price labour	38.92	46.14	30.55	4.04	70
Price capital	29.92	49.48	9.26	10.38	70
Connected properties (/production)	4.95	6.61	1.59	1.33	70
Administrative connections (/connect. prop.)	1.29	2.78	0.97	0.49	70
Length (/production)	92.10	160.94	21.17	37.86	70
Ground stability	1.09	1.31	1.00	0.11	70
Difference quality raw and delivered water	8.96	21.80	1.96	7.16	70
Water delivered to large customers (%)	11.92	56.75	2.30	11.14	70
Water delivered to moderate customers (%)	15.81	26.54	2.85	6.25	70
Non-drinking water (%)	4.66	27.67	0.00	7.31	70
Water from boreholes (%)	62.96	100.00	0.00	43.51	70
Water from shores (%)	2.10	19.15	0.00	5.09	70
Water from dunes (natural, %)	1.74	14.89	0.00	4.30	70
Water from dunes (infiltration, %)	18.26	100.00	0.00	33.01	70
Age of assets	56.14	73.43	33.34	9.31	70

6.4 Empirical analysis

In this section, we present the results of our empirical analysis for each country. Please, notice that although the reliability variables that were used in estimation sometimes represent 'negative' reliability (e.g., leakages, main breaks, etc.), we present the results in Tables 6.6-6.8 in such a way that positive coefficients are interpreted as an improving effect of policy on reliability.

6.4.1 Empirical results

United States

We start by estimating the full model for the USA (see Table 6.6). It appears that none of the private ownership dummies is significant.[99] This may be due to the relatively small dataset, resulting from missing observations for some of the companies (especially the length of the network, the surface area and the input prices, which were insignificant in the full model). Restricting the model to only significant variables increases the number of observations significantly. Therefore, we present also estimation results for models excluding insignificant variables.[100]

If the level model is reduced to only significant variables, two quality variables are now significantly influenced by the type of ownership (note that the increase in the number of observations is very large). The result suggests that the retention time is smaller for private companies (significant at 95%), while the water leakage is larger (significant at 90%). For the estimation in logs this result holds for the retention time (although the significance level is now only 90%), but not for water leakage. Retention time is 17% smaller in private companies. A significant effect of private ownership is now found for free chlorine, which is 19% higher than for public companies.[101]

Summarising, we did not find evidence that private ownership has a clear effect on variables measuring reliability, while the direction of the effect is sometimes positive and sometimes negative. This would lead to the conclusion that the ownership effect is not very important for the influence on reliability in the drinking water sector. To check the robustness of this conclusion we estimated models with:

[99] We present only the coefficients of the private ownership dummies as our focus is on the influence of ownership on quality. Results for other variables are available upon request.
[100] Models without state fixed effects generate the same conclusions for the private ownership effect. This holds also for models excluding variables with a relative high number of missing observations. Results are available upon request.
[101] Note that for the log estimation the effect of the dummy variables is calculated as e^x-1.

- A different price of capital. In this estimation the price of capital is measured per unit length instead of per connection. This change in specification did not influence the conclusions about the significance of the ownership dummies.
- A translog specification to allow more flexibility (compared with the log specification) in the underlying cost structure. This change in specification did not influence the conclusions about the significance of the ownership dummies.
- A system of equations for both cost and quality. This is done on the basis of a model without variables for the length of the network, the surface area, the input prices, the use of residential water and state fixed effects for states with few observations as the system estimation necessitates more degrees of freedom than the basic specification generates. The results are comparable to a combination of the results found for the significant variable model in levels and logs; i.e. the effect on leakage and free chlorine is positive (significant at respectively 90% and 95%), while the effects on all other variables are insignificant.

Although the effect of ownership on reliability seems to be small, our conclusion may be biased due to aggregation of the ownership variable. That is, the effect on reliability might be different between classes of private and public owned drinking water companies. Our dataset makes it possible to discriminate for private companies between (i) a single private owner, (ii) investors and (iii) other agents and for public ownership between companies owned by (i) municipalities, (ii) counties, (iii) districts, (iv) states and (v) water authorities. We estimate models with ownership dummies disaggregated to these types of ownership to analyse whether the estimated effect of private ownership holds for less aggregated types.[102] Our main results can be summarised as follows:

- For main breaks, coliforms, combined chlorines and trihalomethanes again none of the ownership types has a significant effect.
- We now find a positive effect (significant at 99%) for the percentage of unbilled water due to leakage for companies owned by a single private agent. Note however that this type of ownership applies only for 4 companies in our dataset. For other types of ownership no significant results are found for the percentage of unbilled water due to leakage.
- The effect of ownership on average retention time is negative (significant at 99%) for investor owned companies and positive for public utilities owned by municipalities (95%) and districts (90%), while the other types have no effect on reliability.
- The effect of ownership on water leakage is negative (significant at 99%) for investor owned private companies, but also negative for public owned companies by municipalities (95%), counties (90%) and districts (90%).

[102] The effects for disaggregated ownership dummies are estimated both for models with all variables (full model) and only significant variables. It showed that the differences between these models are not large. Results are available upon request.

- The effect of ownership on free chlorine is negative for public utilities owned by municipalities (significant at 90%) and counties (90%).

These results indicate that the effect of ownership is not clear-cut, but shattered between the different types. Again, in general not many effects are found. Note, finally, that the refining of the ownership variable is only preferred from a statistical point of view for the percentage of unbilled water due to leakage and total coliforms.

England and Wales

Table 6.7 presents the estimation results for England and Wales. It shows that only 2 of the 26 estimations result in a significant and positive private ownership trend. Note that for the mains bursts variable the positive effect we find is very sensitive to the specification of the estimation model, while other variables are more robust. For 5 estimations a significant and negative coefficient is found, while for 19 estimations insignificant coefficients are found. The estimations indicate that there is not much evidence for a significant influence of privatisation on reliability in England and Wales. Most estimations suggest that there is no relation between privatisation and reliability, although for some variables a positive effect is found.

The price limits imposed by Ofwat have more effect on reliability. In 10 cases, reliability improves if companies have a higher price limit. While the results for the level and log estimations are comparable for most variables, this is not the case for leakage and the number of properties below reference level. For these two variables either the level or log estimation finds a significant or insignificant effect. None of the estimations result in a significant and negative coefficient. However, for most variables the effect of changes in the price limit is insignificant.

That the influence of quality regulation is important is shown by the results for the quality regulation variable. Nearly all coefficients are significant and positive suggesting in general a large increase in reliability after the introduction of quality regulation in 1989.

As the definition of the three regulation variables may influence the conclusions about the effects on reliability we estimated alternative specifications.

First, we estimated the equations with alternative definitions of the price-cap regulation variable. In this specification we constructed dummies for the price-cap revision in 1995 and 2000 and re-estimated the equations including these dummies multiplied by a trend. It showed that especially the price-cap revision of 2000 (which corrected for the relative high prices in

Table 6.6 Estimation results: USA drinking water for private ownership dummy

Reliability measure		Full model Levels	Significant vars Levels	Significant vars Logs
Main breaks	Coefficient	0.03	0.03	– 0.03
	Standard error	(0.10)	(0.05)	(0.15)
	Observations	287	662	662
	- of which private	40	87	87
Retention time	Coefficient	0.34	0.45**	0.19*
	Standard error	(0.22)	(0.19)	(0.10)
	Observations	223	494	494
	- of which private	35	64	64
Water loss due to breaks	Coefficient	0.33	0.02	0.04
	Standard error	(0.66)	(0.06)	(0.25)
	Observations	180	402	402
	- of which private	17	32	32
Water leakage	Coefficient	– 1.48	– 1.42*	– 0.16
	Standard error	(0.97)	(0.83)	(0.23)
	Observations	166	266	266
	- of which private	25	42	42
Coliforms	Coefficient	0.09	0.02	– 0.21
	Standard error	(0.09)	(0.04)	(0.46)
	Observations	300	657	657
	- of which private	44	80	80
Chlorine free	Coefficient	– 0.09	– 0.05	– 0.22**
	Standard error	(0.06)	(0.04)	(0.10)
	Observations	245	500	500
	- of which private	36	62	62
Chlorine combined	Coefficient	– 0.09	0.03	– 0.14
	Standard error	(1.13)	(0.07)	(0.15)
	Observations	146	375	375
	- of which private	25	65	65
Trihalomethanes	Coefficient	– 0.18	– 0.00	– 0.10
	Standard error	(3.07)	(0.04)	(0.12)
	Observations	271	642	642
	- of which private	42	89	89

Notes: The coefficients are multiplied by – 1 to facilitate interpretation: a positive coefficient always corresponds to reliability improvement. Variables with */** are significant on 90/95%. Standard errors between brackets.

preceding years) had a (negative) effect on some reliability indicators. Reliability was lower for 4 out of 13 coefficients in the log specification (and 5 in the level specification) and never higher after the price-cap revision of 2000. Conclusions for quality regulation and privatisation are robust compared with the original specification of the price cap variable. None of the privatisation trends is negative and significant. Six out of 26 coefficients were significant and positive. Thus, again not much evidence is found for lower reliability under private ownership.

Second, we tested whether the conclusions depend on the definition of the quality regulation variable. As an alternative we estimate the equations with the environmental gap equal to the level in 1993. This specification assumes in fact that the goal for each variable is zero. As mentioned before, such an assumption is necessary as information about the 2003 goals is missing. The alternative estimations show that our main result is rather robust. Again nearly all quality regulation coefficients are positive and significant. The coefficients for the private trend are now in 18 cases insignificant, in 3 cases positive and in 5 cases negative. Although the number of negative coefficients is higher, most results are insignificant or positive.

Table 6.7 Estimation results: drinking water England and Wales

	Variables in levels			Variables in logs		
Reliability measure	Private	Price limit	Qual. Reg.	Private	Price limit	Qual. Reg.
Leakage	0.00***	0.03	0.07***	0.02***	0.23**	0.28***
Distribution losses	0.00	0.02	0.09***	0.01	0.17	0.53***
Main bursts	– 4.49***	– 62.60	0.08***	– 0.01	– 0.21	0.00***
Properties below reference level	0.26	18.09***	0.10***	0.12*	0.46	0.01***
Interrupted properties more than 12 hours	– 0.04	– 2.94	0.09**	– 0.09	– 0.43	0.07***
Interrupted properties more than 24 hours	0.00	– 1.24	0.01	– 0.36**	– 2.33	0.33***
Volume under standards quality regulation	– 0.01	0.77***	0.01***	– 0.16	5.97***	0.04***
New volume under standards quality reg.	– 0.01	– 0.04	0.05	0.08	– 0.73	0.29
Volume with temporary relaxations	0.01***	0.38***	0.08***	0.15*	5.70***	0.69***
Volume with permanent relaxations	– 0.00	0.01	0.13***	0.16**	1.76*	0.95***
Volume (%) not in accordance with reg.	1.69	116.50***	0.10***	0.06	5.13***	0.00***
Nitrates and pesticides	0.02***	0.86***	0.10***	– 0.09	7.91***	0.89***
Coliforms	– 0.00	0.04	0.06**	– 0.12	0.11	1.71**

Notes: The coefficients are multiplied by – 1 to facilitate interpretation: a positive coefficient always corresponds to reliability improvement. */**/** means variable is significant at 90/95/99%. Standard errors are available upon request.

The Netherlands

Table 6.8 and 6.9 show the results of the models for respectively the average and maximum values of five quality parameters in the Netherlands. We first discuss the results in Table 6.8. In the full model for “trichloorethene” the coefficient for the trend is positive and significant. This implies that the amount of “trichloorethene” in delivered drinking water has decreased and reliability thus increased during the period 1997-2002. For lead the trend is negative, but only at the 10% significance level. For the other parameters the trend was insignificant.

Table 6.8 Trend in average quality delivered water for Dutch drinking water companies[a]

Reliability measure		Full model	Significant variables[b]	Significant vars[b] + fixed effects	Significant vars[b] + firm spec. trend
Cadmium	Obs.	68	68	68	68
Mg/l	Coef. Trend	– 0.002	– 0.002	– 0.003	e**
	St. error	(0.002)	(0.001)	(0.004)	
	Coef. input[c]	0.498***	0.495***	0.457***	0.409***
	St. error	(0.092)	(0.074)	(0.097)	(0.103)
Lead	Obs.	67	67	67	67
µg/l	Coef. Trend	– 0.054*	– 0.027	– 0.028	f***
	St. error	(0.032)	(0.021)	(0.029)	
	Coef. Input[c]	0.709***	0.616***	0.755***	0.774***
	St. error	(0.129)	(0.115)	(0.125)	(0.149)
Faecal	Obs.	34	34	na	na
Streptococcus	Coef. Trend	– 0.015	0.022	na	na
Kve/100ml	St. error	(0.206)	(0.043)	na	na
	Coef. input[c]	– 0.002	– 0.001	na	na
	St. error	(0.001)	(0.001)	na	na
1,2 -	Obs.	51	51	51	51
Dichloorethane	Coef. Trend	– 0.003	0.001	– 0.009*	Insignificant[d]
µg/l	St. error	(0.002)	(0.001)	(0.005)	–
	Coef. input[c]	0.527***	0.569***	0.482***	0.534***
	St. error	(0.045)	(0.042)	(0.038)	(0.040)
Trichloor-	Obs.	70	70	70	70
Ethene	Coef. Trend	0.0022**	0.0015**	0.0071*	Insignificant[d]
Mg/l	St. error:	(0.0009)	(0.0006)	(0.0035)	–
	Coef. input[c]	0.002	0.001	0.009	0.003
	St. error	0.003	0.001	(0.007)	(0.002)

Notes: The coefficients for the trends are multiplied by – 1 to facilitate interpretation: a positive coefficient always corresponds to reliability improvement. a. Variables with */**/*** are significant on 90/ 95/ 99%. b. Significant at the 5% level. c. Coefficient of variable measuring the quality of raw water. d. For all individual drinking water companies. e. Significant for one company (– 0.006,(0.003)) and insignificant for the other 12 companies. f. Significant for two companies (– 0.092 (0.052) and – 0.104 (0.053)) and insignificant for the other 10 companies

To investigate the robustness of the results we also estimated models excluding the insignificant variables. We do this as the number of observations is not very high and excluding the insignificant variables increases the available information to estimate the trend coefficient.[103] For lead we do not find a significant effect anymore. For dichloorethane we find a negative trend at the 10% significance level when estimating a model with fixed effects. From the models with firm specific trends we conclude that one company had a negative trend for

[103] Note that this should not influence the trend variable in the case that all variables are orthogonal. However, when exogenous variables are correlated, this may be the case. This procedure is not only followed with the goals to perform a sensitivity analysis, but also as a reference to the models with fixed effects and firm specific trends.

cadmium and two companies had a negative trend for lead. Thus, the trend for most companies is insignificant.

Table 6.9 Trend in maximum quality delivered water for Dutch drinking water companies[a]

Reliability measure		Full model	Significant variables [b]	Significant vars [b] + fixed effects	Significant vars [b] + firm spec. trend
Cadmium	Obs.	68	68	68	68
Mg/l	Coef. Trend	– 0.010	– 0.010**	0.006	e
	St. error	(0.006)	(0.004)	(0.015)	
	Coef. Input[c]	0.549***	0.522***	0.570***	0.701***
	St. error	(0.049)	(0.043)	(0.051)	(0.081)
Lead	Obs.	67	67	67	67
µg/l	Coef. Trend	0.004	0.022	0.010	Insignificant[d]
	St. error	(0.041)	(0.027)	(0.049)	
	Coef. Input[c]	0.177***	0.135***	0.171***	0.156***
	St. error	(0.035)	(0.021)	(0.032)	(0.023)
Faecal	Obs.	34	Na	Na	Na
Streptococcus	Coef. Trend	1.269	Na	Na	Na
Kve/100ml	St. error	(8.161)	Na	Na	Na
	Coef. input[c]	– 0.003	Na	Na	Na
	St. error	(0.005)	Na	Na	Na
1,2 -	Obs.	51	51	51	51
Dichloorethane	Coef. Trend	– 0.005**	– 0.003***	– 0.004	F
µg/l	St. error	(0.002)	(0.001)	(0.003)	
	Coef. input[c]	0.017	0.027	0.011	– 0.010
	St. error	(0.046)	(0.039)	(0.047)	(0.045)
Trichloor-	Obs.	70	70	70	70
Ethene	Coef. Trend	0.008*	0.008***	0.009***	G
Mg/l	St. error:	(0.004)	(0.003)	(0.003)	
	Coef. input[c]	0.018*	0.013***	0.017	0.035***
	St. error	(0.010)	(0.003)	(0.017)	(0.006)

Notes: The coefficients for the trends are multiplied by – 1 to facilitate interpretation: a positive coefficient always corresponds to reliability improvement. a. Variables with */**/*** are significant on 90/ 95/ 99%. b. Significant at the 5% level. c. Coefficient of variable measuring the quality of raw water. d. For all individual drinking water companies. e. Significant for five companies (– 0.059 (0.021), – 0.034 (0.011), – 0.020 (0.009), – 0.015 (0.008) and – 0.018 (0.009)) and insignificant for the other eight companies. f. Significant for three companies (– 0.009 (0.003), – 0.010 (0.005) and – 0.006 (0.003)) and insignificant for the other eight companies. g. Significant for five companies (0.008 (0.005), 0.037 (0.009), 0.043 (0.007), 0.015 (0.004) and 0.011 (0.004)) and insignificant for the other nine companies.

Summarising, there is not much evidence that the introduction of benchmarking in the Dutch drinking water industry has significantly reduced average reliability.

Interestingly, the results for the quality of delivered water are sometimes different when quality is defined at the maximum concentration level. Again most results are insignificant or positive (trichloorethene). However, for lead no significant effect is found anymore, while in one model a negative effect is found for cadmium. The negative effect found for average values for dichloorethane in the fixed effects model is not reproduced anymore, while in two other models (full and significant variables) such an effect is found.

6.5 Conclusions

In this case study we analyse the influence of private ownership, incentive regulation and quality regulation on reliability in the drinking water sector. We do this by analysing datasets for the United States, England and Wales and the Netherlands. For the United States the main difference between companies is the type of ownership (although differences exist also with respect to accountability). While some municipalities use public drinking water companies, others contract out to private companies. This makes a comparison possible between public and private companies with respect to reliability. In England and Wales all water companies are privatised in 1989. At the same time regulation changed for costs and quality. As we have data for 1993 till 2003 we analyse whether these changes resulted in a rise or deterioration of reliability in time. In the Netherlands all water companies are public. Since 1997 a discussion started about privatisation and competition. Finally, this discussion resulted in the introduction of benchmarking, organised by the sector itself. As we have data for 1997 until 2002, we analyse whether this discussion and the use of benchmarking has influenced reliability.

Most results for the USA and England and Wales indicate that no direct relationship can be observed between privatisation and reliability. Nearly all effects are insignificant. Only in some cases a significant effect is found, most times in favour of private ownership.

The case study for England and Wales shows that incentive regulation may have some effects on reliability, although in most estimations the effects are insignificant. For the Netherlands nearly no effects of the introduction of benchmarking on average reliability are found. If effects are found, they are in most cases positive.

For quality regulation the England and Wales-case shows that the effects are large and important. For nearly all of the thirteen quality variables a significant and positive relation is found between quality regulation and reliability levels.

In this case study a number of remarks are made about the used methodology and the available data. A number of assumptions had to be made to make the estimations possible of the influence of private ownership, incentive regulation and quality regulation on reliability. More research is therefore necessary to test the robustness of our analysis.

7 Wastewater treatment

7.1 Introduction

The purpose of this case study is to investigate the relationship between private ownership, changes in regulation and reliability in the wastewater treatment sector. We do this by analysing datasets for the Netherlands and England and Wales:

- In England and Wales, all wastewater companies are privatised in 1989. At the same time regulation changed for costs and quality. As we have data for 1993 until 2003, we analyse whether these changes resulted in a rise or deterioration of reliability in time.
- In the Netherlands, all wastewater companies are public. Since 1997 a discussion started about privatisation and competition. Finally, this discussion resulted in the introduction of benchmarking, organised by the sector itself. As we have data for 1999 until 2002, we analyse whether this discussion and the use of benchmarking influence reliability.

The structure of this chapter is as follows. In section 7.2, we first describe the wastewater treatment sector. The methodology and the data used in the analysis are presented in section 7.3, after which we turn to the empirical analysis in section 7.4. Section 7.5 concludes.

7.2 The description of the industry and reliability issues

7.2.1 The structure of the industry

The wastewater treatment sector is a network industry as suppliers offer wastewater treatment capacity to consumers via pipes connecting the wastewater treatment plants with firms and municipalities. Market power is present as wastewater treatment companies have a legal monopoly.

The wastewater treatment sector has three main segments. First, wastewater is collected by (and in the Dutch case under responsibility of) municipal wastewater collection systems. Second, after collection the further transport and treatment of wastewater is the responsibility of Water Boards (the Netherlands) or waste water treatment companies (England and Wales). Third, the collected wastewater is treated in wastewater treatment plants. After treatment the wastewater is transported to rivers or the sea.

This case study focuses on the first and second segment of the industry. However, where measures are unavailable or sparse for these segments, the third segment is included as well. In this case the influence of policy on reliability might be at least indicative for the first two segments.

7.2.2 Indicators of reliability

In the waste water industry reliability mainly refers to the risk of overflows and water quality after treatment (environmental impact). For both types of reliability several indicators can be calculated. Table 7.1 summarises which quality variables are available for the two countries:

- For the Netherlands, variables are available for both the quantity and the quality of water delivered.
- For England and Wales, only variables are available measuring the quantity of delivered water.

This means that not for all relevant reliability dimensions data are available and that our analysis is partial. Especially for the quality of water delivered data are missing for England and Wales while data are limited for the Netherlands with respect to the quantity of water delivered.

Table 7.1 Variables measuring reliability in the waste water industry

	England and Wales	Netherlands
Variables measuring the quantity of water delivered		
Sewer collapses	yes	
Properties affected by flooding (any cause)	yes	
Properties at risk flooding > twice in 10 years	yes	
Percentage of critical sewers (total length)	yes	
Percentage of unsatisfactory CSOs	yes	
Input treated (with a minus sign)		yes
Variables measuring the quality of water delivered		
Nitrogen removed (with a minus sign)		yes
Phosphate removed (with a minus sign)		yes
Oxygen b.s. removed (with a minus sign)		yes

7.2.3 Some practical examples of currently adopted government policies

In this section we give a brief overview of the government policies that are currently adopted within the waste water industry in England and Wales[104] and the Netherlands

England and Wales

In England and Wales wastewater treatment companies are privatised in 1989. At the same time quality regulation was introduced as well as incentive regulation (price-caps). As the wastewater treatment companies have exactly the same regulation as the drinking water companies (in England and Wales all wastewater treatment companies provide also drinking

[104] This case study is only concerned with the wastewater industry in England and Wales, because sewerage services in Scotland and Northern Ireland are still publicly owned.

water, whereas drinking water companies exist that do not provide wastewater treatment) we refer to the drinking water case for more information on regulation in England and Wales.

The Netherlands

In the Netherlands so-called Water Boards are responsible for flood control, water quantity, water quality and treatment of urban wastewater. Operational task include the management of pumping stations, waste water treatment plants, maintenance of waterways and flood defence structures. Water Boards are decentralised public authorities with legal tasks and a self-supporting financial system which are embedded in the general democratic structures. In 1850 there were about 3,500 Water Boards. Mergers soon reduced this number; by 1 January 2004 there were only 37 Water Boards.

Until 1997 no governmental policy existed to give the Water Boards incentives to promote efficiency. Only the quality of wastewater treatment was monitored by the Ministry of Planning, Housing and Environment (VROM). However as in the drinking water industry, in 1997 a discussion about competition, privatisation and benchmarking also started for the wastewater treatment industry. By now this has (only) resulted in the introduction of voluntary benchmarking by the Water Boards themselves. They argue that this should give them incentives to reduce costs and increase reliability, as these aspects are included in the benchmark reports. Both the increase in available information and the quality of this information should correct for the market failure generated by the monopolistic and public character. This means that the regulation of the wastewater treatment sector looks like the regulation in the drinking water sector. However, wastewater treatment firms and drinking water companies are completely separated.

7.3 Methodology and the data

This case study focuses on the relation between private ownership, regulation and reliability in the waste water industry. We address the following two questions:

1. What is the effect of privatisation, price-cap regulation and reliability regulation on the performance of the sewerage industry in England and Wales?
2. Has the threat of competition and the actual introduction of benchmarking affected the quality of wastewater treated by the Water Boards?

Both questions will be addressed by an econometric analysis.

7.3.1 The model

For each country mentioned above, we estimate the reduced form of a system of cost and reliability equations. The quality equations not only include the regulation variables but also covariates to correct for differences between companies and in time. For a more specific description of the estimated models we refer to the drinking water case. The covariates that are available for the wastewater sector are the same for each quality equation within a country, but are different between countries, both due to data availability and country specific factors (see Table 7.2).

Table 7.2 Covariates wastewater industry

	England and Wales	Netherlands
Properties connected for sewerage (*1000)	yes	yes
Equivalent population served (average persons that can be served)	yes	
Population	yes	
Length of the network	yes	
Wastewater from trade effluent customers	yes	
Fixed effects companies	yes	
Production (quantity of wastewater input)		yes
Price of capital		yes
Price of electricity		Yes
Contamination input wastewater		yes
Sludge per unit production		yes
Bubble aeration (% of total input)		yes
Point aeration (% of total input)		yes
Rotor aeration (% of total input)		yes

7.3.2 Data

Data for England and Wales are from Ofwat and apply to 1993-2003. Table 7.3 presents the descriptive statistics. Note that the variables are available for all 11 years and 10 companies.

Table 7.3 Descriptive statistics: wastewater England and Wales

		Average	Max	Min	St. dev.
Quantity of water delivered					
Sewer collapses	Per 1000 km	17	42	3	10
Properties affected by flooding	Per 1000 connect.	0.28	0.95	0.06	0.16
Properties at risk flooding > 2 in 10 years	Per 1000 connect.	0.44	1.84	0.04	0.39
Percentage of critical sewers	%	25	40	14	7
Percentage of unsatisfactory CSOs	%	23	59	1	15
Exogenous variables					
Properties connected for sewerage	Number (*1000)	2,216	5,333	591	1,337
Equivalent population served	Per connection	2.67	3.78	1.54	0.52
Population	Per connection	1.91	2.52	1.10	0.46
Length of the network	Per connection	14	25	6	5
Wastewater trade effluent customers	%	93	246	13	65

Dutch data are from the Association of Water Boards.[105] Data are available for 1999 to 2002 for more than 300 wastewater treatment plants. As for some plants data over the years 2000 and 2001 are missing, we use an unbalanced panel with a maximum of 1,287 observations. Table 7.4 presents the descriptive statistics for the whole period.

Table 7.4 Descriptive statistics: wastewater treatment Netherlands

		Mean	Maximum	Minimum	Std. Dev.
Quantity of water delivered					
Input treated	Equivalent population served	90	99	16	6
Nitrogen removed	%	75	96	12	15
Phosphate removed	%	76	100	4	15
Oxygen b.s. removed	%	90	100	5	5
Exogenous variables					
Production (*1000)	Supply waste water	72	1549	1	125
Price of capital	Capital costs per unit capacity	6.38	57.36	0.01	6.15
Price of electricity	Electricity price per kWh	0.07	0.29	0.01	0.03
Contamination	Concentration dirt per litre	218	601	16	59
Sludge	Sludge per unit production	0.06	0.85	0.01	0.00
Bubble aeration	%	34	100	0	45
Point aeration	%	42	100	0	48
Rotor aeration	%	23	100	0	42

[105] In Dutch: Unie van Waterschappen.

7.4 Empirical analysis

7.4.1 Empirical results

England and Wales

Table 7.5 present the estimations results. Nearly all quality regulation variables are significant. This indicates that correcting for the original gap between reliability in 1993 and the goal in 2003 is important. After correction for this effect the privatisation trend variable coefficients are only significant in two cases. For the level model none of these coefficients are significant. However, the log model finds significant effects (on 99%) for properties at risk of flooding and (on 90%) for the percentage of critical sewers. As the found effects are positive, privatisation may have led to improvements in reliability for these variables. Finally, none of the price limit variables is significant.

Table 7.5 **Estimations results: wastewater England and Wales**

	Variables in levels			Variables in logs		
Reliability measure	Trend	Price limit	Qual. Reg	Trend	Price limit	Qual. Reg
Sewer collapses	0.27	3.06	0.11***	0.02	0.53	0.01***
Properties affected by flooding (any cause)	0.00	0.31	0.04**	– 0.03	0.78	0.13
Properties at risk of flooding > twice in 10 years	– 0.01	0.11	0.11***	0.13***	– 0.12	0.09**
Percentage of critical sewers (total length)	– 0.03	0.10	0.08***	0.02*	– 0.21	0.00***
Percentage of unsatisfactory CSOs	– 0.69	3.31	0.15***	– 0.00	– 0.27	0.01***

Notes: The coefficients are multiplied by – 1 to facilitate interpretation: a positive coefficient always corresponds to reliability improvement. */**/*** means variable is significant at 90/95/99%. Standard errors available upon request.

As the definition of the three regulation variables may influence the conclusions about the effects on reliability we estimated alternative specifications. For example, we defined the price cap-regulation variable different. In this specification we constructed dummies for the price-cap revision in 1995 and 2000 and re-estimated the equations including these dummies multiplied by a trend. None of the 2000 price-cap revision variables is significant. However, for the 1995 revision significant effects are found for properties at risk of flooding more than twice in 10 years, the percentage of critical sewers and the percentage of unsatisfactory CSOs. These effects imply a positive effect of the 1995 revision on reliability. Effects for quality regulation are more or less unchanged. All privatisation trend variables are now insignificant, except for the percentage of unsatisfactory CSOs where a negative coefficient is found. However, as the coefficients for the price-cap revision variable of 1995 and the coefficient for the trend are each others opposite, this may just be a statistical feature.

The Netherlands

Table 7.6 presents the empirical findings for the 2002 dummy. Results are presented for estimations in both levels and logs. Furthermore, we present results for coefficients estimated by single equation techniques and by system estimation (combined estimation of the cost function and quality equations).

Table 7.6 Estimation results: Dutch wastewater treatment for the 2002 dummy

		Variables in levels		Variables in logs	
Reliability measure		Single	System	Single	System
Input treated	Coefficient	0.301	0.166	0.001	0.000
	Standard error	0.389	0.476	0.006	0.010
Nitrogen removed	Coefficient	2.864***	2.400**	0.032*	0.028
	Standard error	0.914	0.969	0.016	0.017
Phosphate removed	Coefficient	– 0.784	– 0.873	– 0.021	– 0.019
	Standard error	1.050	1.178	0.017	0.021
Oxygen b.s. removed	Coefficient	0.279	0.208	0.001	0.000
	Standard error	0.345	0.529	0.007	0.029

Notes: */**/*** means variable is significant at 90/95/99%.

It shows that only for nitrogen removed significant results are found for the effect of changes in regulation. This effect is significant at usual levels in the level estimation, while for the logs estimation only a marginal significant effect is found for the single equation estimation. When a significant effect is found it is always positive, indicating that the change in regulation had a positive effect on reliability.

Alternative analyses with other specifications reveal that the estimated effects for the 2002 dummy are robust. For instance, a translog specification, leads to nearly the same conclusions as the log specification. While the significance levels are the same for the single equation estimation, the effect on nitrogen removed is now only significant at 90% for the system estimation. Furthermore, including a trend in the single log specification leads to zero marginal effects at two digit level, although the coefficients are significant for nitrogen removed (positive) and phosphate removed (negative). With respect to this last result it is noted that Water Boards invest currently in new equipment for phosphate removal.

7.5 Conclusions

In this case we analyse the influence of private ownership, incentive regulation and quality regulation on reliability in the wastewater treatment sector. We do this by analysing datasets for England and Wales and the Netherlands. In England and Wales all wastewater companies are privatised in 1989. At the same time regulation changed for costs and quality. As we have data for 1993 till 2003 we analyse whether these changes resulted in a rise or deterioration of reliability in time. In the Netherlands all wastewater treatment companies are public. Since 1997 a discussion started about privatisation and competition. Finally, this discussion resulted in the introduction of benchmarking, organised by the sector itself. We analyse whether this discussion and the use of benchmarking influence reliability.

Most results indicate that, in line with economic theory for the contractible case, there is no direct relationship between privatisation and reliability. Nearly all effects are insignificant. Only in some cases a significant effect is found, most times in favour of private ownership.

Incentive regulation has had no effects in England and Wales on reliability of the wastewater treatment sector according to the estimation results. For the Netherlands some effects of the introduction of benchmarking on reliability were found. As the found effects are positive, benchmarking may provide more information resulting in a higher level of reliability. However, for most indicators no effects are found.

For quality regulation, the analysis for England and Wales shows that the effects are large and important. For nearly all quality variables a significant and positive relation is found between quality regulation and reliability levels.

Conclusions can of course be dependent on the assumptions that had to be made in this case study. Future research with more general data on reliability in the waste water treatment sector can reveal this.

8 Railways

8.1 Introduction

The purpose of this case study is to investigate the effect of regulation and vertical unbundling on reliability in the railway industry. Similarly to the previous case studies, reliability in the railway industry is not perfectly contractible, but represents a mixed case between contractible and non-contractible reliability, perhaps being closer to non-contractible case. In the theoretical chapter, we argued that in such a situation, either high-powered or low-powered price regulation may be appropriate, depending on managers' incentives with respect to reliability. If managers' incentives under high-powered price regulation are in line with public interests then such regulation is appropriate. Regarding unbundling, the theory says that it may affect welfare in one or another way.

In this case study, we test how price-regulation and unbundling affect reliability in the case of railways. Our analysis uses a dataset of the OECD countries over the period 1980-2000. We observe various policy choices in our data set: some countries feature high-(or low-)powered price regulation such as price cap (or cost-plus regulation), some keep their railway companies integrated, while some have unbundled operating companies from their infrastructure managers.[106] The only reliability indicator available for all companies in the data set is the number of accidents per traffic km, which we use to measure reliability. We notice that this indicator does not cover all quality dimensions in the railway industry.

This chapter is organised as follows. In section 8.2, a typical railway industry is described and the potential reliability issues that may arise. The methodology and the data used in the analysis are presented in section 8.3, followed by the analysis of the empirical results in section 8.4. Finally section 8.5 concludes.

8.2 The description of the industry and reliability issues

8.2.1 The structure of the industry and the institutional context

As a transport sector, the railway industry carries basic network features. It has a network, composed by nodes (the rail stations) which are connected through lines (the rails themselves). The operator of the rail track has market power, as there is usually one rail track between two places, and only on some lines do railway services face strong competition from planes, buses, or cars. The railway industry delivers the transportation of units, which can be passengers or freight. Passenger transport can be further categorised between commuters and long distance

[106] According to the Laffont and Tirole's taxonomy, price-cap regimes do not allow transfers between the regulator and the railway operator. In this study, we assume that price-cap regimes allow transfers among the parties.

travellers. Similarly, in terms of freight we distinguish cargo, postal services and others.

The typical cost structure of a railway company is composed by the train working costs, track and signalling costs, terminal and station costs, and administrative costs. The proportions of the costs differ according to the service provided by the industry. Investments include asset renewal, the development of infrastructure, and training programs for the rail workers, among other things. This industry is also characterised by lumpy investment, as certain aspects require high leverage.

Featuring characteristics of a natural monopoly, the integrated industry was closely monitored if not operated by the government. In fact, since its infant years, the industry has been in the core of public debate regarding the role of the state in the economy. Similarly, in the last 15 years, it has been an object of a major structural change, reflecting the new public demands and also advances in the economic reasoning.

The evolution of the economic debate and its social counterpart has called for a diminished role of the state in the railway industry. Presently, this industry is not entirely seen as a natural monopoly, as it can be divided into two segments, (1) the infrastructure, which is the basis for the distribution of its products, and (2) transportation over the rail system. Indeed, once infrastructure and transportation are separated, passenger and freight transportation may be subject to market competition just like in many other industries.

Table 8.1 presents two directions of changes that were followed by different countries during the 1990s: one regarding the level of vertical integration and another regarding privatisation. The mode of change followed different patterns in different countries. Privatisation of integrated companies can be observed in New Zealand, Japan and USA. Still, nearly 90% of the OECD countries had at least one state controlled company in 1998, the highest percentage after the telecommunications sector. On the other hand, infrastructure unbundling, with sale or franchising of operations, can be seen in Romania, Chile, UK, Estonia, Poland, and several other European countries.

Table 8.1 Directions of change in the railway industry[107]

	Public Ownership	Public/private partnerships	Private Ownership
Vertically integrated	China Russia India Thailand (SRT) Poland (MAV)	Argentina Brazil Peru Guatemala Bolivia Panama	New Zealand Chile (Ferronor, A&B) Brazil (CVRD)
Mainly vertically integral	US (Amtrak) Canada (VIA) Japan (freight)	Mexico (Mexico City suburban) India (CONCOR)	Japan (CP, East, West, and Central Japan Railways)
Vertical unbundling	EU (directive 91/440) Chile	Sweden (suburban) Chile (FEPASA) Poland (LHS line)	UK (franchises, and English, Welsh and Scottish Railways) Poland (freight) Romania (freight)

For some of these countries, Table 8.2 gives the year when these reforms were implemented. For the case of the European countries, the year represents the moment when the respective member state adopted the European Union Directive 91/440. This directive concerns the unbundling of the management of the railway operation and infrastructure from the provision of railway transport services, via unbundling of accounts, organisational or institutional unbundling. Additionally, it envisages the improvement of the financial structure of undertakings. It ensures the access to the networks of member states for international groupings of railways undertakings and the endurance of management independence of railway undertakings. In summary, the directive deals with the adoption of a reform with a common trend.

Table 8.2 Year of Institutional Reform in the Railway Industry[108]

Year of change	Countries
1987	Japan
1988	Sweden
1994	Germany, Spain, the Netherlands
1995	Finland, France
1997	Belgium, Austria
1998	Italy, Denmark

Although different countries have adopted the same pattern of reform, the choice of regulatory regime is quite different across countries. In addition, one can not find the implementation of a polar case of regulation, such as pure price-cap and cost-of-service regulation. Usually, we

[107] Source: Worldbank, 2000

[108] Source: UIC database and European Commission, International Railways

observe approximations of one or another polar regulatory regime.[109] Table 8.3 below lists, according to the OECD International Database on Regulation,[110] the (approximate) regulatory regime options for some OECD countries. Note that Germany, Finland and Spain have adopted 'no regulation', but their respective rail companies are both public. In this sense, no regulation has a dubious meaning since it can be complete control by the state.[111]

Table 8.3 Regulatory regimes in passenger services[112]

Regulatory regime	Countries
Rate-of-return	France, Japan, Italy, Austria
Price-cap	Denmark, the Netherlands, Sweden, Belgium
No regulation	Germany, Finland, Spain

It seems that these reforms increased production levels: most companies managed to increase their output after the reforms.[113] Nonetheless, the implications on reliability are not that straightforward. While there has been some evidence that overall reliability has improved,[114] it is still an open question whether regulatory regimes chosen by the governments have been able to tackle the proper incentives for boosting reliability of the rail track. In this case study, we aim to contribute to answering this question.

8.2.2 Reliability

In the railway industry, as in any transport industry, consumers are interested in the following dimensions of quality: reliability, interaction with the users, safety, environmental impact, and 'dynamic quality' (which captures the firms' efforts to maintain or improve quality).[115] Table 8.4 lists the candidate variables that could be a proxy of these quality dimensions. Although all these dimensions are important from the consumer's viewpoint, here we only focus on reliability. Reliability of the rail track relates to its ability to satisfy the demand of the railway operator's customers, which includes among other things punctuality, percentage of available seats per passenger, and frequency. Our empirical analysis uses the number of accidents per 10^6 traffic unit kilometres, as we do not have sufficient data on the other reliability dimensions.

[109] See Campos and Cantos (2003) for a general discussion. Vibes et al. (2003) provide a comprehensive description of the institutional reforms occurred in each European country.
[110] The OECD International Regulation Database was formed based on answers from each respective government to a questionnaire proposed by the OECD during 1999 over its regulatory regimes and the constraints to competition that are usually imposed in some regulated industries. The industries covered by this database are railways, telecommunications, aviation and energy.
[111] As said, the OECD database provides information on the regime the respective countries have declared, which can be different from what is actually implemented.
[112] Source: OECD International Database on Regulation, with exception of countries with *.
[113] Gonenc (2000) and Pollitt (2002).
[114] Gonenc (2000) cites the recent OECD studies for the freight railway industry in Mexico and the US, where the improvement in quality was significant after privatisation and liberalisation, respectively. See also Pollitt (2002).
[115] Cantos and Campos (2003).

Table 8.4 Quality Dimension in the Railway Industry[116]

Quality dimension	Related variables
Reliability (trains)	Age of the vehicle/number of years in service Vehicle size and load factor Availability of seats Accessibility Travel comfort: noise, vibration, temperature, tidiness Train renewal rates
Reliability (tracks)	Number of accidents Distribution and number of stations Frequency (number of trains per hour) Number of interruptions (planned and unplanned) Track renewal rates Track and stations maintenance Durations of interruptions (planned and unplanned)
Service	Ticket sales/reservations Handling Staff adequacy and competence Inquiries and general information Response to complains
Safety and externalities	Number of accidents Safety procedures Environment protection (noise, pollution) Congestion
Dynamic quality	Fleet and track renewal rates Track and stations maintenance Investment obligations

8.3 Methodology and the data

Based on an econometric analysis on data available for OECD countries in the period 1980-2000, we address the following research questions:

1. What is the effect of the power of the regulatory regime on the reliability of the railways services?
2. What is the effect of vertical unbundling on the reliability of the railways services?

Reliability is measured as the inverse of the number of accidents per traffic km. We use the inverse indicator, because this simplifies interpretation of the results: an increase of the reliability indicator corresponds to a higher reliability level. There are some potential shortcomings of measuring reliability in terms of the number of accidents. The number of accidents is closer related to safety than to reliability, and they are differently measured in some

[116] Partly based on Cantos and Campos (2003).

countries. Still reliability is positively related to safety. In fact, if tracks are not very safe, they are unlikely to be reliable either: when there is an accident, the train is obliged to move slower, or if the traffic signals are not trustworthy, double checking is urged, leading to some considerable travel delays. Therefore, given the unavailability of reliability data for our sample of countries, the number of accidents seems to be the best feasible proxy for reliability.[117]

8.3.1 The model

We model reliability as a function of input prices, the regulatory regime, vertical unbundling, and a technological trend:

- Input prices. We use data on wage and energy price levels for input prices. We conjecture that an increase in these prices implies higher costs in the provision of reliable services. Therefore, we expect a negative relationship between input prices and reliability.
- Regulatory regime. The regulatory regime choices are represented by three dummy variables for the three regulatory regimes for passenger services: [118] price-cap regulation, cost-plus regulation, and 'no' regulation.[119] These dummies are equal to 1 when it is the regulatory regime to which the rail firm is subject and 0 otherwise. The dummies are step dummies since they assume value 1 starting the period the regime was adopted.[120] Although we test whether reliability depends on the choice of the policy regime, the relation may also be the other way around. The choice of the regulatory regime may depend on the reliability level before the institutional reform. We ignore this endogeneity problem as it does not change the interpretation of our results.
- Vertical unbundling. Another relevant feature of the reforms is the vertical unbundling of train operation from the network. Many OECD countries have implemented vertical unbundling. One of the reasons to do so may be that that unbundling facilitates competition and increases the industry's transparency, leading to better regulation. On the other hand, disadvantages arise for example from real-time operation problems and hold up of investment. Our aim is to test in which direction unbundling affects reliability. The variable for unbundling is also a step dummy, taking value 1 starting from the year of complete unbundling (separate accounts are discarded), and zero otherwise.
- Technological trend. The technological trend aims to grasp the industry's technological changes for the whole period of the sample. This technological evolution is expected to have a positive effect on the reliability of services.

[117] Notably, the few countries that present a wide dataset on reliability are the ones with the most developed regulatory regimes. In this sense, the restriction of the study to these countries may lead also to biased estimates of the regulatory regimes` performance.

[118] Although our study is focused on passenger services regulation, the railway industry is a typical multiproduct industry. By adopting an aggregated measure of the industry's production, we aim to take this feature into account.

[119] These are proxies for the real regulatory regimes, which are usually much more complex than these 'polar regimes'.

[120] The complementary dummy represents the period before the reform and is imbedded in the constant term, which is the reliability average.

8.3.2 Data

The data set is an unbalanced panel with yearly information on 11 OECD countries, namely Finland, France, Germany, Japan, Italy, Netherlands, Spain, Denmark, Belgium, Sweden, and Austria. It covers the period of 1980 to 2000. For each country, information is provided on the number of accidents, traffic unit kilometres, input prices, the industry structure and the regulatory regime.

The data sources are widespread. The number of accidents is made available by the Union des Chemin de Fer, an international representative of the industry. It is the sum of four types of accidents: derailments, collisions, accidents at level crossings and others. In order to give a measure of the asset utilisation, the typical unit of account for the transport industry has been adopted, traffic unit kilometres, which is the sum of ton-kilometres and passenger-kilometres. This information was obtained through the Worldbank Database on Railways. Labour prices classified according to the STAN-2000 industrial classification come from the OECD OLIS database. The most disaggregated industry data is available for the transport and storage sector.[121] Both variables are based on this dataset information. The energy prices are industry prices per kWh, obtained through the International Energy Association. For estimation, input prices have been expressed in the American dollars, corrected by its purchasing power index.

The information on the regulatory regime choice is based on the OECD International Database on Regulation (see table 8.3). Table 8.2 provides the year of the institutional change used in this study. In the European countries, the year of the implementation of the Directive 91/440 by national law is a good approximation of the moment the regulatory regimes were adopted. It defines the period of change of the national institutional model for railways. Against this approximation, one can argue that the changes were already foreseen since 1991, when the directive was issued. On the other hand, its effect on the actual day-to-day practices is more palatable when the Directive has been implemented at the national level.[122]

8.4 Empirical analysis

In this section we report the results of our estimation of the linear model outlined in section 8.3.1. The model was estimated by means of a panel data regression with fixed effects, which

[121] This can pose a problem to our estimations since our (linear) regression approximates an implicit marginal cost function. Taking a more aggregated measure of the railway industry, the transport and storage industry can lead to biased estimates. Some reasons: former public rail employees are better paid, production volumes measured in monetary terms are distinct.
[122] As an illustration to this point, the European level debate on the adoption of a common language and practice regarding safety procedures in railways raises "(…) little curiosity about the likely content of future European requirements" among Member States (NERA, 2000).

means that each country had its own constant parameter to be estimated. In this sense, we take the idiosyncrasies of each country into account.[123] Table 8.5 presents the estimation results.

Table 8.5 Estimation results: reliability (measured by the inverse number of accidents per traffic km)

	Estimates[124]	Standard errors
Constant	2.73*	1.50
Trend	0.06***	0.01
Wages	– 0.29***	0.13
Energy prices	– 0.04	0.21
Price-cap regulation	0.38**	0.19
Cost-plus regulation	– 0.16	0.17
No regulation	0.41**	0.17
Vertical unbundling	– 0.17	0.15
Number of observations	150	
F-statistic	20.27	
R^2	0.52	

The main findings with respect to the effect of policy on reliability are the following. First, vertical unbundling of operation from infrastructure has a negative effect on reliability, albeit not significant. Second, we obtain that both the effect of the price cap and 'no regulation' is positive and significant. In contrast, the cost-plus regulation has a negative (but not significant) effect. The main conclusion we draw is that high-powered price regulation elicits more reliable rail services (in terms of the number of accidents) than the low-powered price regulation. These estimation results are qualitatively the same for different panel data modelling and different measures for input, which brings robustness to our analysis.[125]

It is not easy to interpret our finding that reliability under price-cap regulation and 'no regulation' is statistically the same. 'No regulation' in our sample is understood as the rail firm being run by the government after the reform period, specifically, the adoption of the European Directive EC 91/440. As it is not clear how the managers of these state firms are incentivised by the governments, we cannot explain why reliability under a price cap is the same as for a state-run enterprise.

[123] See Greene (2000), chapter 14, and Wolldridge (2002) for more details.

[124] *** Statistically significant at 1% level, ** statistically significant at 5% level and * statistically significant at 10% level. Remaining estimations are not statistically significant.

[125] As alternative input price measure, we adopted real prices based on the domestic currency of the countries, corrected by their respective PPI. We obtain the same qualitative results regarding the regulatory regimes, that is, PC and NR affects positively quality and the corresponding coefficients have approximately the same magnitude. The significance of the estimates for input prices has been reversed: wages elasticity becomes null and energy elasticity is now negative. The estimates are provided upon request to the authors.

Regarding the effect of the other explanatory variables, we observe a small but positive and highly significant trend with respect to reliability. Correcting for the governments' policies, reliability improves slowly over time, which may be caused by technological changes. Notice also that the input prices (wages and energy prices) also have the expected sign, that is, the firm's input price elasticity[126] is non positive: in our fixed effect model, an increase in 1% on the wage costs lead to a 0.29% decrease on the reliability of services. On the other hand, energy prices do not have a statistically significant effect.

8.5 Conclusions

In this case study, we focus on the railway industry, which is a typical network industry that was subject to a major reform on its structure during the 1990s. Using the dataset of the OECD countries over 1980-2000, we analyse the effect of regulatory regimes and vertical unbundling on the reliability of railway services.

In our empirical analysis, we measure reliability as the inverse number of accidents per traffic km. Controlling for input prices and technological change, we obtain for our sample that price-cap regulation has a positive and significant effect on this reliability indicator, while cost-plus regulation had a non-significant negative effect. We suggest the following explanation for this effect. Under a high-powered incentive scheme (a price cap in this case study), firms have strong incentives to reduce their costs, as it increases their profits. In the railway industry, failing to prevent accidents has a serious impact on their costs (repair costs, private lawsuits). Under high-powered incentive regulation, the driving force behind the increases in the rail network's reliability is the existence of an implicit penalty system, as a high number of accidents has a sharp negative impact on the profits of the network company. Under cost-plus regulation, this penalty system is not as effective, as the firm is allowed to increase its prices. This indicates that managers' incentives with respect to this particular reliability indicator (and therefore with the underlying indicators) are in line with public interests. Naturally, the companies may be more sensitive to safety than other dimensions of reliability, so that we have to be cautious interpreting the results.

Our second empirical finding is a negative (although not statistically significant) impact of vertical unbundling on reliability measured by the inverse number of accidents. We interpret this as a warning that reliability in railway industry may be affected by vertical unbundling.

[126] Since the non-discrete variables, accidents and input prices, are in logarithms, the inputs' estimates should be read as input price elasticities. For references on that, see Greene, chapter 10, pages 426-428.

Similarly to the previous case studies, our analysis does not cover all dimensions of reliability, but just the considered dimension, therefore the results cannot be generalised to describe the effect of the government policy in the railway industry on all reliability dimensions.

Part III: Conclusions

9 Conclusions

In order to make an informed decision about the proper role of government in promoting reliability within network industries, one has to understand the crucial link between underlying market characteristics and reliability. Network industries are characterised by large economies of scale and scope, possible vertical integration, related access problems and a need for large investments in maintenance and capacity. As a consequence, competition often puts insufficient pressure on performance in network industries. This creates a concern for many aspects of performance, e.g. price and quality, in particular, because network industries supply services that are vital to society (think of rail accidents or electricity blackouts). While there may be distinct problems with regard to pricing within certain network industries, pricing creates arguably less concern than quality, most notably reliability, because of two reasons. One, it is difficult to measure reliability. Two, as reliability is mainly determined by the size and state of the capital stock, it is difficult to change on the short term.

One way of ‘guaranteeing’ reliability for governments is to provide the services themselves. The main reason this ‘old fashioned’ model is becoming somewhat obsolete, is that governments may face budget problems which impair reliability (e.g. U.K. Rail). Another reason relates to the tendency of governments to overinvest in reliability as a consequence of lobbying and political comfort. For these and other reasons more and more network industries have been restructured (a common model being that downstream markets are open to competition while upstream network markets are still public or regulated). The restructured industries are believed to be more capable of making decisions regarding reliability, at least if they face the proper incentives for doing so. These decisions should be based on a cost benefit methodology, because ‘appropriate’ reliability is not given by an exogenous technological standard. It requires trading off the welfare costs of failure with the costs of preventing those failures. Typically, it will be too costly to target 100% reliable networks.

The deregulation of these decisions confronts governments with new questions: to what extent should the firms be regulated? How to regulate? How to overcome hold-up problems? What to do when firms underperform? It is therefore important to understand first under which circumstances firms have proper incentives to make proper decisions about reliability and second how government policy can influence these incentives. Government policies that influence reliability, directly or indirectly, are (i) privatisation; (ii) liberalisation; (iii) regulation; (iv) unbundling; and (v) commitment policies. The purpose of this study is to

identify the underlying market characteristics and to analyse how policy, aimed at establishing appropriate reliability, depends on these underlying characteristics.
When markets function properly, or activities are perfectly measurable and perfectly contractible, the government faces relatively minor problems: it either leaves the market to do the job, or – when competition is unfeasible – writes appropriate contracts. Also, when public and private goals are in line with each other there is relatively little concern. The central questions are thus under which circumstances: (1) competition in network sectors is likely to be sufficient; (2) reliability is sufficiently contractible; and (3) commercial and public interests are sufficiently in line with each other. Before we go into the details of the answers to these questions, some qualifying remarks are needed.

9.1 Competition

9.1.1 Competition? What kind of competition?

The question whether or not competition in a network industry is feasible or not is too crude to be used for our analysis. Firstly, are we talking about competition on the market or for the market? Secondly, when we conclude that competition is feasible, should it be feasible in all sectors of the industry or only parts? Thirdly, do we allow for competition between (similar) networks only (e.g. mobile phones) or is it equally possible to allow for competition between different modes (e.g. of transport). Fourthly, what do we do if competition is feasible but weak (such as between airports)? And finally, what do we do when fierce downstream competition impacts choices upstream?

Despite these caveats, the extent to which competition is feasible is central to government policies aimed at reliability. The fact that reality does not look like the polar cases of ‘full competition’ or ‘no competition’, implies that the conclusions drawn from those polar cases should be interpreted with some care.

9.1.2 Underlying market characteristics

The following four factors influence the feasibility of competition between networks:

1. To what extent are economies of scale absent?
Network sectors are defined as industries where economies of scale are present. Yet the extent to which this hinders competition varies across industries. For instance, in wireless telecommunication there is room for several providers, whereas in railways it is usually too costly to have more than one network between two places.

2. Are alternative networks available?
   Sometimes competition between network firms may be feasible in completely different types of networks. Think about the market for Internet services. Currently, consumers may connect to the Internet using the fixed telephone line, the cable, or a wireless connection through UMTS.

3. Is demand relatively high at present or in the near future?
   The higher the level of demand (in the near future), the more likely it is that duplication, tripling or even quadrupling of networks will be socially desirable, making competition more feasible. For instance, in a densely populated country such as the Netherlands, it is cheaper to roll out a UMTS network than in a scarcely populated country such as Finland. Moreover, within Finland, it may still be profitable for several firms to roll out a network in the Helsinki-region, but it is too costly to do so in the scarcely populated North.

4. Are consumers eager to switch between providers?
   An additional condition is that switching between alternative providers should not be too difficult or costly. In other words, consumers should not be locked into their current network.

Typically, checking these four factors will yield mixed answers. Economies of scale may partially inhibit competition, competition from outside sources might be present (but how strong?), it is not so clear when demand is 'high' and some sort of switching cost will always be present. Yet, these factors still provide the basis for judging whether competition is feasible. In this sense the exercise is not too different from competition authorities having to assess whether or not a firm has (substantial) market power. Despite the absence of a single uncontested measure of market power, judgments about market power stand in court, so that there is no need to be overly pessimistic on judgments about the feasibility of competition in a particular market.

9.1.3 Reliability policies

When competition between networks is feasible and sufficiently strong, the task of the government with respect to reliability policies for network operators becomes much easier. Compare the absence of regular government interventions on the reliability of cellular phone networks to the permanent political struggles of railways. Clearly, the feasibility of competition is hard to reconcile with government provision or market protection. Even if competition is feasible, but not perfect, it is often less costly to privatise and (lightly) regulate than to rely on government provision. The example of fixed telephony illustrates this point. Consequently, the desired level of regulation depends on the possibilities for competition in the industry.

Yet, in most policy relevant network industries the network part of the industry has limited possibilities for competition so that we move to our next issue, contractibility.

9.2 Contractibility

9.2.1 Underlying market characteristics

Similar to the feasibility of competition, contractibility is not an easily verifiable factor. Several underlying market characteristics contribute to the contractibility of reliability. Reliability is more contractible if:

1. It is easier to hold responsible the party that causes a network failure
   In some situations, it is not easy to contract reliability as it may be difficult to identify who should be blamed for network failures. For example: was the recent electricity blackout in Italy caused by a failure of the transmission network, lacking generation capacity, or foreign networks?

2. The life cycle of investments in reliability is shorter
   Reliability becomes non-contractible if it is not feasible to write long term contracts, even if this may be desirable as investments in reliability have a long life cycle. For instance, today's investments by the rail network operator may affect reliability of the rail track in a period of more than 30 years, whereas it is difficult to predict the development in the industry over such a long period.

3. The government is more able and willing to write contracts
   Moreover, the government may not be willing or able to sign a contract for such a long time period. For instance, in some industries it is commercially not interesting, but socially desirable to operate a network. Think about railways in scarcely populated areas. In that case, the government may have to subsidise the industry. The government may not be willing to sign a contract that guarantees a certain level of subsidy for the industry, as such a contract has immediate consequences for its budget constraint.

4. The potential impact of a network failure is lower
   Sometimes the risks associated with network failures are too large to write a credible contract. This holds for networks which rarely fail, but if they fail the impact on society is huge. In that case, it is difficult to write a credible contract that gives the network operator the right incentives to appropriately invest in reliability. For instance, the operator of an electricity transmission network would go bankrupt if it was charged for the damage for the society caused by a large network failure, which is undesirable when the network service is crucial for the society.

5. Reliability or underlying network features can be monitored more easily
   Regulating network operators is costly: a regulatory body has to monitor the network operator. In some cases, reliability can be easily verified. An illustration is the so-called ‘N-1 standard’ for high voltage electricity grid in the Netherlands. Suppose that the high voltage network consists of N network components. If one of these components fails, then there is no interruption of the network. According to the network code in the Netherlands, this standard applies to all high voltage electricity lines in the country. Such measures can be verified in court, and hence can be contracted upon. In other situations, it may be difficult to monitor the reliability of the network. The regulator may need substantial expertise and a huge amount of information to check the reliability of a rail track.

6. The transaction costs of writing and enforcing the contract is lower
   It may be very costly to write and enforce a contract. In the drinking water industry, the government may need to specify a maximum for each chemical that may pollute the water. Also enforcing the contract may be costly, as it may involve time consuming and expensive court cases. Whether a contract is easily enforceable may also depend on a country’s legal system. In some less developed countries, contracts are difficult to enforce, as the legal system is weak, or judges are corrupt.

9.2.2 Reliability policies

While the relationship between competition and policy seems rather intuitive, the relationship between contractibility and policy is more subtle. It is for that reason that we executed several case studies to shed some empirical light on policy. We could use the underlying market characteristics described above to define contractibility in the case studies.

The first result from these case studies is that the type of regulation matters a lot. Notice that we restrict attention to situations where competition is weak or absent. In the electricity market (chapter 4), high-powered price regulation, supplemented by quality regulation of relevant contractible dimensions of reliability is likely to be welfare improving: in the year when such regulation was introduced in Norway, Norwegian companies responded by reducing costs and decreasing the amount of energy non-supplied (ENS), the indicator for reliability that was contracted by the regulator. Also the other case studies demonstrate that if high-powered incentives are combined with quality regulation positive results can be expected. In particular, we have observed the English and Welsh water companies (chapter 6) also responded to such regulation in a similar vein. The opposite is also true: without quality regulation high-powered incentives can backfire. In the electricity case we observed that under price caps, i.e. before the quality regulation was introduced, the performance of companies on ENS improved (however less than under quality regulation), while their performance in terms of duration and number of interruptions worsened.

The second – perhaps surprising – result is that there is no clear evidence of an effect of privatisation and unbundling on reliability. The effects of effective regulation seem to outweigh effects of ownership differences by a mile. There was no clear difference in reliability performance between public and private water, wastewater and gas companies.

9.3 Commercial and public interests

9.3.1 Underlying market characteristics

If competition is weak or absent and contractibility is problematic, the key to policy lies in the fact whether commercial and public interests are in line with each other. They are more in line with each other if the following conditions are satisfied:

1. Cost reductions have little effect on non-contractible reliability
   Commercial interests may affect reliability of the network and cost reductions. The more profit-focused a firm is, the stronger its incentive to engage in both innovations in reliability and in cost reductions. However, from a welfare point of view, the firm's incentives to reduce costs may be too strong as it ignores the potential adverse effect on reliability.

2. The opportunities for cost reductions are small
   If the opportunities for costs reductions are small, cost reducing innovations hardly take place, and hence, there is hardly any negative impact on reliability. As a profit maximising firm has more incentives to innovate with respect to both cost and reliability than a not-for-profit firm, commercial interests are in line with public interests.

3. A profit-maximising network operator has the incentive to take into account the adverse effect of cost reductions on reliability
   When a decrease in reliability below the appropriate level has a negative impact on the network operator's profit, a profit maximising operator may still decide to supply appropriate reliability. For instance, when the network becomes underreliable, customers may respond by reducing their demand, which may still prevent managers from undersupplying reliability. Another possibility is that it is very costly for the network operator to operate an underreliable network. For instance, in railways, an underreliable network may be the cause of accidents, which are very costly for the industry: the track has to be repaired, trains may have to be replaced, and the accident may chase away customers.

4. Incomplete information between the firm and the regulator plays a minor role
   Information asymmetry between the regulator and a private firm may play a role in terms of reliability, especially when contracts are incomplete. Private firms have to serve two principals (their shareholders and the regulator) whereas a public (not-for-profit) firm only has one

principal (the regulator). The conflict of interest between several principals strengthens the problems related to asymmetric information. The larger the information asymmetry between the regulator and the firms, the stronger the case for low-powered incentives with respect to profit maximisation. In other words, if there is a substantial amount of asymmetric information between the regulator and the firms, public ownership and low-powered price regulation are more likely to be appropriate.

5. Public service motivation is unimportant
   Suppose we assume that the management of a public firm has the incentive to maximise social welfare, whereas the management of a private firm wishes to maximise profit. It can be shown that in many situations a public firm outperforms a private one, even if the private firm is optimally regulated. The reason is that the government needs to pay profit-maximising private management an informational rent as they possess more information about the cost of production. Of course a less rosy assumption on public motives changes this picture.

6. The management has much bargaining power vis-à-vis the government
   When the management negotiating with the government has more bargaining power, they are more capable to negotiate a higher compensation. Therefore, they are more likely to undertake socially optimal investments that otherwise would be commercially loss-leading. Think about the operation of rail tracks in scarcely populated areas. High bargaining power gives the firm the opportunity to reap a high reward for the investments, so that the firm is willing to invest more. This may explain why in the Netherlands, all public network operators are 'hived off', i.e., put at a distance from the government. The other way around, if the network operator has little bargaining power, it may fail to do certain investment, as it can only partly appropriate the returns.

9.3.2 Reliability policies

If commercial interests are in line with public goals there is no danger that managers jeopardise reliability. Therefore, in this case public policy is similar to the contractible case. It is safe to privatise such companies and introduce high-powered price regulation. A difference arises only with respect to the possibility and the need to implement high-powered quality regulation: as reliability is not contractible the latter will not be feasible. But strictly speaking, there is no need for such a high-powered quality regulation, since the market provides managers with incentives to take welfare effects into account.

When commercial interests are not in line with public goals, public policy can provide only weak incentives for quality, because high-powered price regulation may endanger reliability. In such cases, low-powered price regulation combined with 'low-powered' quality regulation (e.g.

technical regulation of underlying network features) is needed. It would also not be desirable to privatise such companies.

An example of an industry in which commercial and public interests with respect to reliability *as measured by the number of accidents* may be sufficiently in line is the railway industry. In our rail case (chapter 8), we measure reliability as the inverse number of accidents per traffic km. Controlling for input prices and technological change, we obtain that price-cap regulation has a positive and significant effect on this reliability indicator, while cost-plus regulation had a non-significant negative effect. Under a high-powered regulation regime, such as a price cap, firms have strong incentives to reduce their costs, as it increases their profits. This is in sharp contrast with low-powered regulatory regimes, such as cost-plus regulation. In the railway industry, failing to prevent accidents has a serious impact on firms' costs (repair costs, private lawsuits). Under high-powered incentive regulation, the driving force behind the increases in the rail network's reliability is the existence of an implicit penalty system, as a high number of accidents has a sharp negative impact on the profits of the network company. Under cost-plus regulation, this penalty system is not as effective, as the firm is allowed to increase its prices. This indicates that managers' incentives with respect to this particular reliability indicator (and therefore with the underlying indicators) are in line with public interests. Naturally, the companies may be more sensitive to safety than other dimensions of reliability, so that we have to be cautious interpreting the results.

The case study of railways also shows that our cases studies should not be generalised too readily. Clearly in the railway industry there are also other aspects of reliability where public and private goals may very well *not be in line at all*. The point of the case study is to show the direction of the effect of government policy on a particular dimension of reliability for which commercial and public interests are in line with each other. Our roadmap suggests that high-powered incentives are possible when public and private goals are in line. This can be checked by comparing high- and low-powered incentives and verify which incentive scheme does best on the dimension in question.

Often there are mixed cases. One can think of airports where commercial and public interests are roughly in line (both want a large network), but not completely. In such cases it depends on (i) the magnitude of potential problems; (ii) the probability of occurring of such problems; (iii) other ways of solving those problems. If the magnitude of problems and the probability are large, and alternative ways seem hard, then privatising is obviously risky.

9.4 Unbundling

Another policy option is to unbundle the network part (which often has the highest economies of scale and the least competitive possibilities) from the downstream part. This discussion plays in rail, electricity, gas, airports and telecoms. In general, there are a number of arguments both in favour of and against vertical separation.

Unbundling is most logical when there are large differences in competitive opportunities between upstream and downstream. Apart from the expected advantages of downstream competition, the regulation of the unbundled monopoly part may also become easier. On the downside, unbundling becomes less attractive in the presence of substantial synergies, hold-up problems or reduced contractibility.

The hold-up problem may for instance occur in the railway industry when rail infrastructure is fully separated from train operation. The train operator is very much dependent on the rail infrastructure. If the reliability of the rail tracks deteriorates, the probability that trains arrive late increases and more accidents may happen so that the train operating company may lose its consumers. However, the operator of the rail infrastructure may have little incentive to invest in the reliability of the network since it has to share the gains from its investment with the train operator.

Unbundling may also lead to real-time operation problems between the separated divisions of the formerly integrated network operator. This is especially important in industries with volatile demand and supply that demand frequent communication between different network divisions, such as in electricity. Unbundling of the divisions may make this communication more difficult, especially if most communication is done informally. For instance, EPRI (2002) argues that the California crisis would have been much worse if the grid operators had not been able to coordinate their actions to deal with the system volatility. The problem can also be observed in other network industries. For example, in railway services, there is a need of coordination between the actions of train operators and the network.

Finally, splitting up the network firm may also adversely affect the contractibility of reliability. When it is difficult to identify which division is responsible for a network failure, it is more difficult or costly to write enforceable contracts on reliability, because collection of information and conflict resolution are costly.

Whether to unbundle or not, depends on the weights of the advantages and disadvantages. The government can also design policies to influence these weights. It can e.g. decide on partial unbundling, or it can create joint ownerships of the network to create commitment devices.

9.5 How can policy makers use this report?

We conclude by discussing how policy makers can use this report. We do this by means of a stylised example: the electricity sector. We do not go into all technical details. Our goal is just to demonstrate the general direction which our roadmap proposes.

The network

The first observation is that the electricity network is made up of a transmission and a distribution network. The transmission network transports electricity over large distances and keeps the whole system in balance. The distribution networks deliver the electricity to households and firms. One may compare it with the backbone and last mile in telecommunications. Since transmission and distribution have different characteristics, the policy conclusions between the two may very well be different. An important factor with regard to reliability in electricity networks is that problems with respect to the networks may also be caused by outside factors, e.g. problems in the production part of the chain. Here, we focus – for demonstration purposes – only on the reliability of networks themselves.

Competition between networks

Competition is generally unfeasible, both for transmission and distribution. Although there have been some attempts in Australia and North America to introduce competitive transmission lines, this option is feasible only for very specific transmission lines, where investment in such lines competes with investment in generation. Moreover, duplication of networks is too expensive. There is also no competition from other technologies (in contrast with telecoms or rail). This leads us to the contractibility question.

Contractibility

One of the most important characteristics of reliability in the distribution segment of the electricity industry is continuity of service, measured by the number of interruptions, interruption duration and energy non-supplied due to interruptions. From our case study it followed that reliability is likely to be contractible on these dimensions. It is relatively easy to establish who is responsible for interruptions, long term contracts can be written and monitoring is possible. The outages at the distribution level are relatively frequent and their impact is not too high. This contrasts with transmission, where outages are rare but have much larger impact.

Suppose for a moment that the aspects of reliability mentioned above cover every aspect of reliability (which they do *not*). We could then conclude that reliability is contractible. It follows that high-powered incentives coupled with quality regulation can be applied. One could then also argue that the distribution networks may be privatised. Based on theory, ownership turns out to be neutral with respect to contractible reliability but may be preferred for efficiency reasons. Indeed distribution networks are privatised in the UK, without indications of serious reliability problems.

Yet, this does not imply that we can simply conclude from our framework and the case study on electricity that privatising the distribution in the Netherlands or in other countries is called for. There are a number of reasons for that; some of them are beyond the direct scope of this study.

1. There are other dimensions of reliability which our analysis did not cover, e.g. ‘product quality’ (i.e., voltage quality). Also the life cycle of investment in reliability is longer than the period covered by our analysis, and we do not know if the regulator can closely monitor underlying network features.
2. The way the chain is structured determines the appropriateness of privatisation. The extent to which production, transmission, distribution and retail are unbundled will determine whether or not a privatised distribution is likely to yield reliable electricity (more on unbundling below).
3. There are other policy goals than just reliability that weigh in when deciding on privatising. One has to be careful not to draw conclusions from just one policy dimension.

We conclude that for distribution high-powered incentives coupled with quality regulation are worthwhile as long as they do not have adverse effect on other important reliability dimensions. For more general conclusions, more information is needed and other questions have to be taken into consideration as well.

For the transmission network, contractibility is much more problematic, since outages are rare but have a much larger impact. This means that commercial and public interests play an important role for policy choice.

Commercial and public interests

For the non-contractible aspects of the transmission part of the network, we consider whether or not public and private interests are in line for all activities performed by a transmission system operator. While certain functions seem to be contractible (e.g. building the network), there is considerable doubt that this is the case for other functions (system operation, market facilitation). In particular there seem ample opportunities for the system operator to increase profits by creating network congestions. Hence, a profit-maximising transmission system operator may not have the incentive to take into account the adverse effect of its actions on reliability, especially if it is also active in generation or retail market. For this reason independent ownership, in fact in many cases government ownership, of transmission system operators is called for, as is common throughout the world.

Unbundling

There is a case for unbundling distribution and retail. The competitive upstream opportunities can be more easily exploited in an unbundled world and distribution can be more easily regulated. Yet, the potential disadvantages of unbundling cannot be overlooked. Possible problems with commitment, leading to hold-up problems should be mitigated. In some cases when costs of unbundling are high it may be reasonable not to unbundle all parts of the industry. In the UK (where electricity networks are unbundled) the regulator has not required complete unbundling of production and retail. By doing so they have established a commitment device between the supply and demand sides, which reduces the hold-up problem in generation. However, this may not be a suitable solution for every country. In a country such as the Netherlands there are few large generators in the market, so that other solutions need to be investigated. This only shows that our framework, while serving its purpose of pointing in the direction of policy concern, does not provide clear-cut answers to detailed questions. Other potential disadvantages of unbundling seem less prevalent. There are arguably not so many synergies between retail and distribution and contractibility issue between retail and distribution can be solved, as the UK example has demonstrated.

Whether to unbundle or integrate transmission and distribution is a matter for an extended debate. The outcome of such a debate does not depend on competitive opportunity differences (absent in both transmission and distribution, possibly with the exception of yardstick competition in distribution and competition of specific transmission lines with investment in generation), but primarily on whether it becomes easier to coordinate actions that influence reliability.

Concluding

The roadmap can be used by policymakers interested in finding appropriate policies for reliability in network sectors. The roadmap asks the right questions, it often provides directions for answers, but clearly does not give all the answers. This is impossible to do, since specific answers will depend on institutional details and other specific features that cannot be squeezed into a general framework as the one introduced in this study.

Literature

A&O, 2002, *Corporate Law and Practice of the Netherlands, Second Edition*, Schuit, S.R. (ed.). Allen and Overy Legal Practice.

Affuso, L., and D. Newbery, 2001, Investment, Reprocurement and Franchise Contract length in the British Railway Industry, University of Cambridge, mimeo.

Agrell, P., Bogetoft, 2003, Charter of Accountability for Transmission Operators, TSO project, http://www.sumicsid.com.

Ai, C. and D.E.M. Sappington, 2002, The Impact of State Incentive Regulation on the U.S. Telecommunications Industry, *Journal of Regulatory Economics* 22, 133-160.

Averch, H., and L.L. Johnson, 1962, Behaviour of the Firm under Regulatory Constraint, *American Economic Review* 52, 1052-1069.

Barros, F., 1994, Delegation and Efficiency in Mixed Oligopoly, *Annales d'Economie et de Statistique* 33, 51.

Baumol, W.J., Klevorick A.K., 1970, Input choices and rate-of-return regulation: an overview of the discussion, *The Bell Journal of Economics and Management Science* 1(2), 162-190.

Baumol, W., J.C. Panzar, and R.D Willig, 1982, *Contestable Markets and the Theory of Industry Structure*. Harcourt Brace Jovanovich, New York.

Bolton, P. and M.D. Whinston, 1993, Incomplete Contracts, Vertical Integration, and Supply Assurance, *Review of Economic Studies* 60, 121-148.

Boom, A., 2003, Investments in Electricity Generating Capacity under Different Market Structures and with Endogenously Fixed Demand. Working paper, Wissenschaftszentrum Berlin für Sozialforschung.

Bovenberg, A.L., H.P. van Dalen, and C.N. Teulings, 2003, Het Borgen van het Publieke Belang, Report for the Ministry of Economic Affairs and the Ministry of Finance of the Netherlands.

Bovenberg, A.L., and C.N. Teulings, 2000, De Economie van Privatisering, ESB 85, 304.

Boylaud, O., and G. Nicoletti, 2001, Regulation, Market Structure and Performance in Telecommunications, *OECD Economic Studies* 32.

Brow, C., 2001, Funding America's Drinking Water Infrastructure: From Public to Private, *Washington's internship for engineering students*, NSPE.

Buehler, S., A. Schmutzler, and M.-A. Benz, 2003, Infrastructure Quality in Deregulated Industries: Is there an Underinvestment Problem, CEPR discussion paper 3836.

Burns, P., T. Weyman-Johnes, 1994, Regulatory Incentives, Privatization and Productivity Growth in UK Electricity Distribution, CRI technical paper 1, London, UK.

Burns, P. and J. Davies, 1998, Regulatory Incentives and Capital Efficiency in UK Electricity Distribution Businesses, CRI occasional paper 12, Centre for study of Regulated Industries, London, UK.

Canoy, M. and D. Newbery, 2003, Fusie Controle Voldoet Niet bij Elektriciteit, *Het Financieele Dagblad* 18 January 2003.

CEER, 2001, Quality of Electricity Supply: Initial Benchmarking on Actual Levels, Standards and Regulatory Strategies.

Commission Tabaksblat, 2003, *The Dutch Corporate Governance Code: Principles of Good Corporate Governance and Best Practice Provisions. Draft: An Invitation to Comment.* http://www.corpgov.nl.

CPB, 2000, Yardstick Competition; Theory, Design, and Practice, CPB Working Paper 133.

CPB, 2003a, Equal rules or equal opportunities? Demystifying level playing field, CPB Document 34.

CPB, 2003b, Tight Oligopolies: In Search of Proportionate Remedies, CPB Document 29.

CPB, 2004, *Energy Policies and Risks on Energy Markets: A Cost-Benefit Analysis*, CPB Special Publication 51.

Crocker, K.J., and K.J. Reynolds, 1993, The Efficiency of Incomplete Contracts: an empirical analysis of air force engine procurement, RAND Journal of Economics 24, 126-146

De Bijl, Van Damme, and Larouche, 2003, Op Weg naar een Vrije Postmarkt. *ESB* 88, 566-568.

De Fraja, G. and F. Delbono, 1989, Alternative Strategies of a Public Enterprise in Oligopoly, *Oxford Economic Papers* 41, 302-311.

Dijkgraaf, E., R. de Jong, E.G.van de Mortel, A. Nentjes, M. Varkevisser and D. Wiersma, 1997, Mogelijkheden tot marktwerking in de Nederlandse watersector, Onderzoeksreeks directie Marktwerking, Ministerie van Economische Zaken, The Hague.

Dijkgraaf, E. and M. Varkevisser, 2004, Kosten en baten van toezicht op de doelmatigheid van drinkwaterbedrijven, OCFEB Research Memorandum 0404, Erasmus University Rotterdam.

Domberger, S.,C. Hall and E. Ah Lik Li, 1995, The determinants of price and quality in competitively tendered contracts, *Economic Journal* 105, 1454-1470.

Dranove, D., D. Kessler, M. McClellan and M. Satterthwaite, 2003, Is More Information Better? The Effect of "Report Cards" on Health Care providers, *Journal of Political Economy* 111, 555-588.

DTe, 2002, NetCode.

DTe, 2002, Yardstick Competition, Regional Electricity Network Companies, Second Regulation Period, Information and Consultation Document.

Dutch Electricity Act, 1998.

EC (2001), First benchmarking report on the implementation of the internal electricity and gas market, European Commission.

Economides, N. and W. Lehr, 1994, The Quality of Complex Systems and Industry Structure, in Lehr, W. (ed.), *Quality and Reliability of Telecommunications Infrastructure*. Lawrence Erlbaum, Hillsdale, US.

The Economist, 2003, America’s Regulatory Mess. July 26th 2003.

Emmons II, W.M. and R. Prager, 1997, The effect of market structure and ownership on prices and service offerings in the U.S. cable television industry, *RAND Journal of Economics* 28, 732-750.

EnergieNed, 2003, Condities voor een Betrouwbare Energievoorzinning.

EnergieNed, 2003, Stroomstoringcijfers 2002.

EPRI, 2002, California's Electricity Restructuring: The Challenge to Providing Service and Grid Reliability, consultancy report.

Estache, A., A. Gomez-Lobo, D. Leipziger, 2001, Utility Privatisation and the Poor: Lessons and Evidence from Latin America, *World Development* 29, 1179-1198.

Europese Commissie, 2002, Verslag van de Commissie aan het Europees Parlement en de Raad over de toepassing van de postrichtlijn (Richtlijn 97/67/EG), 25 november.

Fletcher, P., 2002, The Periodic Review in Context, presentation at the water city conference January 22, 2002. http://www.ofwat.gov.uk.

Francois, P., 2000, 'Public Service Motivation' as an Argument for Government Provision, *Journal of Public Economics* 78, 275-299.

Frontier Economics, 2003, Developing Monopoly Price Controls, A final report prepared for Ofgem, http://www.ofgem.gov.uk.

Giannakis, D., T. Jamasb and M. Pollitt, 2003, Benchmarking and Incentive Regulation of Quality of Service: An Application to the UK Electricity Distribution Utilities, CMI Working paper 35, The Cambridge-MIT Institute.

Gilbert, R.J., Newbery, D.M., 1988, Regulation games, WP 8879, University of California, Berkeley.

Gilbert, R., D. Newbery, 1993, The Dynamic Efficiency of Regulatory Constitutions, *RAND Journal of Economics* 25, 538-554.

Giulietti, M., Waddams Price, C., 2000, Incentive Regulation and Efficient Pricing: Empirical Evidence, CMuR Research Paper 00/2, University of Warwick, UK.

Grossman, S. and O. Hart, 1986, The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration, *Journal of Political Economy* 94, 691-719.

Hart, O. and J. Moore, 1990, Property Rights and the Nature of the Firm, *Journal of Political Economy* 98, 1119-1158.

Hart, O., A. Shleifer, and R. Vishny, 1997, The Proper Scope of Government: Theory and Application to Prisons, *Quarterly Journal of Economics* 112, 1091-1126.

Heggset, J., Kjølle, G.H., Trengereid, F. and H.O. Ween, 2001, *Quality of supply in the deregulated Norwegian power system*, NVE, Norway.

Helm, D., 2002, Critique of Rail Regulation, in Robinson, C. (ed.), *Utility Regulation and Competition Policy*, Edward Elgar, Cheltenham, UK.

IEA, 2003, Energy Policies of IEA Countries, 2003 Review, Paris.

IEEE, 1990, *IEEE Standard Computer Dictionary: A Compilation of IEEE Standard Computer Glossaries*, IEEE, New York.

Joskow, P., 1987, Contract Duration and Relationship-Specific Investments: Empirical Evidence from Coal Markets, *American Economic Review* 77, 168-185

Joskow, P.L., Kahn, E., 2002, A Quantitative Analysis of Pricing Behaviour in California's Wholesale Electricity Market during Summer 2000, *Energy Journal* 23, 1-35.

KEMA, 2002, Betrouwbaarheid Elektriciteitsnetten in een Geliberaliseerde Markt.

KEMA, 2003, Aanvullende Studie Betrouwbaarheid Elektriciteitsnetten in een Geliberaliseerde Markt.

Kessler, D. and M. McClellan, 1998, Is Hospital competition socially wasteful? Stanford University and NBER, mimeo.

Klein, B., and K.B. Leffler, 1981, The Role of Market Forces in Assuring Contractual Performance, *Journal of Political Economy* 89, 615-641.

Laffont, J.-J. and J. Tirole, 1991, Provision of Quality and Power of Incentive Schemes in Regulated Industries, in Gabszewicz, J. and A. Mas-Colell (eds.), *Equilibrium Theory and Applications, (Proceedings of the Sixth International Symposium in Economic Theory and Econometrics)*, Cambridge University Press, Cambridge.

Laffont, J.-J. and J. Tirole, 1993, A Theory of Incentives in Procurement and Regulation, MIT Press, Princeton.

Langset, T., Trengereid, F., Samdal, K. and J. Heggset, 2001, *Quality Dependent Revenues - Incentive Regulation of Quality of Supply*, NVE, Norway.

Leegomonchai, P., and T. Vukina, 2003, Oligopsony power, Asset Sepcificity and Hold-Up: Evidence form the Broiler Industry, North Carolina State University, mimeo.

Leibenstein, H., 1966, Allocative Efficiency versus X-efficiency, *American Economic Review* 56, 392-415.

Littlechild, S., 1983, *Regulation of British Telecommunications*, HMSO, London.

Martimort D., P. de Donder, E.B. de Villemeur, 2002, An Incomplete Contract Perspective on Public Good Provision, report for the Ministry of Economic Affairs and the Ministry of Finance of the Netherlands.

Masten, S.E., and K.J. Crocker, 1985, Efficient Adaption in Long-Term Contracts: Take-or-Pay Provisions for Natural Gas, *American Economic Review* 75, 1083-1093

Micheal, S.C., 2000, The effect of organizational form on quality: the case of franchising, *Journal of Economic Behavior & Organization* 43, 295-318.

Mikkers, M. and V. Shestalova, 2003a, *Competition and Reliability of Supply in Public Utilities*, CRI Technical Paper 15, CRI, Bath University, UK.

Mikkers, M., and V. Shestalova, 2003b, Regulating Natural Monopolies: Effects and Remedies, *The Utilities Journal* 6, 38-39.

Milgrom, P. and J. Roberts, 1986, Price and Advertising Signals of Product Quality, *Journal of Political Economy* 94, 796-821.

Ministry of Economic Affairs, 2000, Publieke Belangen en Marktordening: Liberalisering en Privatisering in Netwerksectoren, policy note.

NRC Handelsblad, 2003, NS-Akkoord over Prijs Treinkaartje. Newspaper article, July 17, 2003.

OCFEB, 2002, Welvaart en de Regulering van Netwerksectoren, Report for the Ministry of Economic Affairs and the Ministry of Finance of the Netherlands.

Ofgem, 2003a, *Open Letter on Developing Network Monopoly Price Controls and the Next Price Control Review of the Electricity Distribution Network Operators (DNOs)*, consultancy report.

OECD, 2000, *Promoting Competition in the Natural Gas Industry*, DAFFE/CLP(2000)18, Paris

OECD, 2001, *Structural Separation in Regulated Industries*, policy report, Directorate for Financial, Fiscal, and Enterprise Affairs.

OECD, 2002, *Flexibility in National Gas Supply and Demand*, Paris

Ofgem, 2003b, *2001/200,2 Electricity distribution and quality of supply report*.

OfWat, 2003, The Completed Acquisition of Northumbrian Water Limited, consultation paper. http://www.ofwat.gov.uk.

Pollitt M., 1995, *Ownership and Performance in Electric Utilities*, Oxford, Oxford University Press.

Propper, C., S. Burgess and K. Green, 2004, Does competition between hospitals improve the quality of care? Hospital death rates and the NHS internal market, *Journal of Public Economics*, 88, 1247-1272.

Roemer, J. E. and J. Silvestre, 1992, A Welfare Comparison of Private and Public Monopoly, *Journal of Public Economics* 48, 67-81.

Saal, D., D. Parker, 2000, The Impact of Privatisation and Regulation on the Water and Sewerage Industry in England and Wales: A Translog Cost Function Model, ABS working paper no: RP0103, Aston Business School, UK.

Saal, D.S, and D. Parker, 2001, Productivity and Price Performance in the Privatized Water and Sewerage Companies of England and Wales, *Journal of Regulatory Economics* 20, 61-90.

SEO, 2003, "Gansch het Raderwerk Staat Stil": De Kosten van Stroomstoringen, consultancy report for TenneT.

Shen, Y.C., 2002, The effect of hospital ownership choice on patient outcomes after treatment for acute myocardial infarction, *Journal of Health Economics* 21, 901-922.

Shen, Y.C., 2003, The effect of financial pressure on the quality of care in hospitals, *Journal of Health Economics* 22, 243-269.

Shires, J., and J. Preston, 1999, Getting Back-on Track or going off the Rails? An Assessment of Ownership and Organizational Reform of Railways in Europe, paper presented at the 6th International Conference on Competition and Ownership in Land Passenger Transport, Cape Town, South Africa, 20-23 September 1999.

Shleifer, A., 1985, A theory of yardstick competition, *RAND Journal of Economics* 16, 319-327.

Shleifer, A., 1998, State versus Private Ownership, *The Journal of Economic Perspectives* 12, 133-150.

Shleifer, A., R.W. Vishny, 1997, A Survey of Corporate Governance, *The Journal of Finance* 52, 737-783.

Steiner, F., 2000, Regulation, Industry Structure and Performance in the Electricity Supply Industry, OECD Economics Department Working Papers 238.

Stelzer, I.M., 2002, A Review of Privatisation and Regulation Experience in the UK, in Robinson, C. (ed.), *Utility Regulation and Competition Policy*, Edward Elgar Publishing Limited, Cheltenham, UK.

Stratix, 2002, Risico-Analyse Discontinuïteiten Telecommunicatievoorzieningen, consultancy report for the Department of Economic Affairs of the Netherlands.

Svensson, J., 1998, Investment, property rights and political instability: Theory and evidence, *European Economic Review* 42, 1317-1341.

Tangeras, T., 2003, Yardstick Competition and Quality, mimeo, Research Institute of Industrial Economics, Stockholm, Sweden.

Ter-Martirosyan, A., 2003, The Effects of Incentive Regulation on Quality of Service in Electricity Markets, George Washington University, working paper.

Teulings, C., A. Bovenberg, and H. van Dalen, 2004, Privatisering of de Kunst van het Loslaten, *ESB* 89, 28-31.

TILEC, 2003, Op Weg Naar een Vrije Postmarkt, consultancy report for TPG Post.

Tilley, B. and T. Weyman-Jones, 1999, Productivity Growth and Efficiency Change in Electricity Distribution, working paper.

TK, 2004, Toezicht doelmatigheid waterleidingbedrijven, Netherlands Ministry of Housing, Spatial Planning and the Environment, BWL/2004021847.

Valletti, C. and T. Cambini, 2003, Investments and Network Competition, CEPR discussion paper 3829.

Van Damme, E., R. Aalbers, A. Gielen, and J. Sylvester, 2003, Privatisation in the Netherlands, paper presented at the CESifo Conference Centre, Munich.

Vass, P., 2002, Competition and restructuring in the UK water industry, *Journal of Network Industries*, 3, 77-98.

VEWIN, 2001, Water in zicht 2000: bedrijfsvergelijking in de drinkwatersector, Vereniging van Waterbedrijven in Nederland, Rijswijk.

Vickers, J and G. Yarrow, 1988, Privatization: An Economic Analysis, MIT Press.

Wallsten, S.J., 2000, Telecommunication Privatization in Developing Countries, Stanford University and World Bank, mimeo.

Wilson, R., 2002, Architecture of Power Markets, *Econometrica* 70, 1299-1340.

WSTB, 2002, Privatization of water services in the United States: An assessment of issues and experience, The National Academy of Sciences.