# Regulation, Organisation and Efficiency: Benchmarking of Publicly and Privately Owned Utility Companies

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*Paper prepared for the 3rd ECPR Conference, Section 3: Regulation in the age of governance, Panel 3.8 From Monopoly to Market via Regulation: Comparative Perspective on Public Service Utilities, Budapest 8th-10th of September 2005*

**Abstract.** The main purpose of this article is to analyze the efficiency of water supply and district heating in Denmark. Secondly, the purpose is to explain the variation in efficiency – both within each sector and across sectors. I find that the implications of very complex intransparent cost-recovery regulation regimes in the water supply and district heating sectors are widespread inefficiency in the production of both water supply and district heating. The variation in efficiency cannot be explained by ownership, as the property rights theory would state, and only partly by asset specificity as the transaction cost economics would argue. Instead the variation in efficiency is somewhat congruent with the intensity of the interests of constituents as political transaction cost theory suggests.

## 1. Introduction

Over the last decades utility sectors such as telecommunication and energy sectors have been transformed from government owned natural monopolies to liberalised, and in many cases, highly competitive utility sectors. This is partly due to the technological innovation in the utility sectors, and partly due to regulatory reforms and the establishment of new regulatory regimes. Most western economies embark on some form of incentive regulation of liberalised utility sectors, which invariably involves some form of benchmarking of actual versus some form of reference performance (Jamasb & Pollit, 2001: 130). With regard to telecommunication and energy it is widely documented that the liberalisation and deregulation has lead to more competition and lower prices for consumers. However,

[1] The views expressed in this paper are those of the author and do not necessarily reflect the views of the Danish Ministry of Finance.

in most western economies other utility sectors, such as water supply and heating, are still regulated as natural monopolies. This is the case in Denmark where the water and heating sector are regulated by a cost-recovery regime, which implies that suppliers are barred from earning profits. The reason is that the distribution of both water and heat is seen as a truly local phenomenon in Denmark, in the sense that the distribution of both services over long distances is very costly and technically difficult. Thus most companies in both sectors are operating as local monopolies cut of from the right to earn profit. Many publicly owned companies are furthermore operating outside the reach of the political hierarchy, since production and distribution of water and heat is organised in companies owned by the local authorities. Consequently the production of water and heat in Denmark is taking place in a grey zone between the market and the political hierarchy. So, in a time of liberalisation and deregulation in many utility sectors, the aim of this article is to analyse if the organisation and regulation of the water and heating sectors are still best regulated as natural monopolies.

The purpose of the first part of the article is to analyse the efficiency of the Danish water sector and district heating sector by subduing the two sectors to the same form of benchmarking analysis, which is now common in most countries in liberalised, former natural monopolies, such as telecommunication and energy sectors (Jamasb & Pollit, 2001). From a rational institutional perspective the two sectors are expected to be inefficient, since regulation through a cost-recovery regime reduces, if not removes, the incentives of both water and heating suppliers to minimize costs.

The aim of the second part of the article is to explain the variation in efficiency within each sector and between the two sectors. Staying within the broad framework of rational theory it is possible to identify very different explanations. It is frequently stated from the likes of Eggertson (1990), Hart et al (1997) that private providers are more efficient than public providers due to the existence of property rights. Another prominent strand of rational theory, personified by Williamson, states that it is not the ownership, but the degree of asset specificity of the transaction that determines the level of efficiency. This classical dichotomy can, however, be challenged by theories focusing on the strength of interest groups and constituents. Following regulation theory and political transaction cost theory (Stigler, 1971; Peltzman, 1976; Horn, 1995) the reason behind varying efficiency is neither ownership nor asset specificity, but rather the strength of the interest groups and political constituents.

## 2. Organisation and regulation of water supply and district heating

Water and heating supply are the responsibility of municipalities but private suppliers are allowed to operate. The extent of private suppliers varies between the two sectors. In the water sector most suppliers are publicly owned, while most suppliers in the heating sector are private owned companies. In both the water and the heating sector most public suppliers are municipal units within the hierarchy.

But a rather large minority of public owned heating plants are organised as cooperatives between several municipalities (see table 1).

Table 1. Organisation of water and heating plants

| | Water plants | | | Heating plants | | |
|---|---|---|---|---|---|---|
| | Public | Private | All water plants | Public | Private | All heating plants |
| Shareholder company | 8 (7.8%) | 1 (1.4%) | 9 (5.2%) | 4 (6.0%) | 5 (2.2%) | 9 (3.0%) |
| Consumer cooperatives | - | 69 (98.6%) | 69 (40.2%) | 24 (35.9%) | 225 (97.8%) | 249 (83.9%) |
| Municipal unit | 93 (91.2%) | - | 93 (54.1%) | 37 (55.2%) | - | 37 (12.5%) |
| Other | 1 (1%) | - | 1 (0.6%) | 2 (3.0%) | - | 2 (0.7%) |
| Total | 102 (100%) | 70 (100%) | 172 (100%) | 67 (100%) | 230 (100%) | 297 (100%) |

According to economic theory, monopoly ownership of the infrastructure in utility sectors is the most efficient form of ownership when the average cost of production increases with the scale of production, which is the case for natural monopolies (Varian, 1996). Since the production of water and heat can be labelled a common good, there is also a welfare economic argument for the public regulation of the market (Rausser, 2000:49). The purpose of such a regulation is, first, to ensure a sufficient level of production, second, to prevent monopolists from exploiting consumers by overpricing their products, and third, to ensure a cost efficient production. There are different models for such regulation. While the regulation of utility sectors such as telecommunication and energy have implemented some sort of incentive regulation, the water and heating sectors in Denmark are still regulated by a cost-recovery regime, implying that the customers must pay no more than the actual cost of production. This means that neither private nor public enterprises are allowed to make profit. So, while the focus in this regulation regime is on preventing monopolists from exploiting consumers, the regime at the same time reduces the incentives for producers to be cost efficient. Since prices reflect the cost of production, the monopolist producers lack an incentive to minimize cost, thereby stimulating a capital intensive production (Averch & Johnson, 1962).

Furthermore, the regulation – and the administrative capacity – in both sectors are rather vague. Though the legislation states that prices should reflect the cost of production, the legislation is unclear with regard to the time limit for the balance between costs and revenue and the size of acceptable deviations. Finally, the rules for price calculation are also rather in-precise. Because of the large number of producers in both sectors, the vague legislation and a limited administrative capacity in the regulation authorities, the relationship between the authorities and producers are characterized by information asymmetry. Consequently the regulatory system fail to give an incentive to maximize efficiency, at the same time as it allows rather the water and heating producers large discretion.

## 3. Measuring efficiency

### *Methodology: Data envelopment analysis*

The analysis of efficiency is carried out as a two-step approach. First, the efficiency of all units within each sector is benchmarked using a so-called data envelopment analysis (DEA). DEA is a productivity analysis tool that ranks units on the basis of a number of inputs and outputs. The result is an efficiency score between 0 and 100, where units scoring 100 points are the most efficient, which the rest are benchmarked against.

Data envelopment analysis uses a linear programming method to search for the optimal combinations of input and output, and uses these best practice observations to identify inefficiency (Charnes et al 1978). The classic model of Charnes et al (1978) was based on the assumption of constant returns to scale, while later models have assumed – some times more realistically – variable returns to scale (e.g. Banker, Charnes & Cooper, 1984). The difference is that the variable returns to scale model takes account for the size of production thereby making sure that only units of the same size are compared on their input-output ratios. This reduces the relevance of economies of scale explanations that otherwise could be a significant influence in utility sectors traditionally characterized by economies of scale (Olatubi & Dismukes, 2000: 47). Therefore, the present analysis assumes variable returns to scale, since this permits the estimation of efficiency scores that are not confounded by scale effects.

The second step of the analysis concerns the identification of causes to the variance in efficiency. This is done by using the efficiency score from the data envelopment analysis in step one as the dependent variable in a regression analysis with a range of political, technical and financial explanatory variables.

### *Measuring efficiency in the water sector*

The first step of the productivity analysis of the water sector is to identify the input and output variables. The input variables are the operating expenditure, which includes administrative expenses and salaries, the number of employees and finally the consumption of electricity. The output variables are the amount of abstracted water and the amount of distributed water. These variables are rather similar, Yet while the amount of abstracted water is an indication of the efficiency of the production, the distribution of water is an indication of the efficiency of the supply of water from plants to households. The output side also includes the number of residents in the distribution area as this variable is expected to be a relevant structural variable.[2] There is a strong correlation between the inputs and outputs, which is important since the efficiency scores depend on the choice of input and output (Thanassoulis, 2000: 438-439). The input and output variables of the analysis are listed in table 2 below. The table also report descriptive statistics for all variables. The descriptive statistics show that there is a rather large variation between the included units.

Table 2. Descriptive statistics and variable operationalisation

| | Min | Max | Mean | Std. dev. |
|---|---|---|---|---|
| Input variables | | | | |
| - No. of employees | 1 | 188 | 11.7 | 22.3 |
| - Operating expenditure (mill. DKK.) | 276 | 285 463 | 13 650.8 | 32 557.2 |
| - Electricity consumption (MWh) | 48 | 17 360 | 1 036.8 | 2 092.0 |
| Output variables | | | | |
| - Abstraction (m3) | 21 | 63 531 | 2 493.9 | 6 928.8 |
| - Residents | 300 | 499 840 | 30 560 | 59 911.7 |
| - Distributed water (m3) | 100 | 63 531 | 2 757.8 | 6 918.8 |

The assessment of efficiency by using DEA will result in an efficiency measure for each unit between 0 and 100, with the most efficient units being given a score of 100. As shown in table 3 the average efficiency score under the assumption of constant returns to scale (CRS) is 77.4 pct. This means that an average water company should be able to cut almost 23 pct. of its expenditure while keeping the same level of output. Under the assumption of variable returns to scale (VRS) the average efficiency measure is 83 pct. As shown in table 3, respectively 73 production units under the assumption of constant returns to scale and 60 production units under the assumption of variable returns to scale are characterized by some degree of inefficiency in their production of water.

Table 3. DEA analysis under constant and variable returns to scale assumptions

| | Constant Returns to Scale (CRS) | Variable Returns to Scale (VRS) |
|---|---|---|
| Average efficiency score | 77.4 % | 83.0 % |
| Total number of units | 91 | 91 |
| - Number of efficient units | 18 | 31 |
| - Number of inefficient units | 73 | 60 |

[2] The length of the distribution network was originally included as a structural variable. Since the correlation between this variable and the other variables in the model was weak, and the correlation also showed signs of multicollinearity, the length of the network was excluded.

Since there are fewer efficient units under the assumption of constant returns to scale and the average efficiency score is lower than under the assumption of variable returns to scale at least part of the inefficiency is caused by an inoptimale scale of production (scale inefficiency). However, there is still a large part of the inefficiency that cannot be explained by the scale of production. This is termed technical inefficiency, i.e. the inefficient unit should be able to produce a greater amount of output given the level of input. The size of technical respectively scale inefficiency can be measured by comparing the efficiency measures in the CRS and VRS models. If a unit achieves the same efficiency measure in both models, $\theta_{CRS}=\theta_{VRS}$, the unit is producing at the optimal scale and is therefore scale efficient. However, if the score in the VRS-model is higher than in the CRS-model, the production is scale inefficient ($\theta_{CRS}<\theta_{VRS}$), and if the efficiency measure in both models is lower than 100 the production is furthermore technical inefficient ($\theta_{CRS}>\theta_{VRS}$). As shown in table 4 the inefficient units can be divided into 13 scale inefficient, but technically efficient units, 12 technically inefficient but scale efficient units, and finally 48 units that are both technically and scale inefficient.

Table 4. Scale efficiency and technical efficiency

| | Technical efficiency | Technical inefficiency | Total |
|---|---|---|---|
| Scale efficiency | 18<br>$\theta_{CCR}=\theta_{BCC}=100$ | 12<br>$\theta_{CCR}=\theta_{BCC}<100$ | 30 |
| Scale inefficiency | 13<br>$\theta_{CCR}<\theta_{BCC}=100$ | 48<br>$\theta_{CCR}<\theta_{BCC}<100$ | 61 |
| Total | 31 | 60 | 91 |

Note: $\theta_{CRS}$ and $\theta_{VRS}$ are efficiency measures under respectively constant and variable returns to scale assumptions.

Thus the inefficiency revealed in the analysis can only for a minority of the units be explained by inoptimal scale of production. For the majority of the units the inefficiency is simply insufficient output. Thus the analysis clearly demonstrates that there seem to be widespread inefficiency in the water sector. However, the analysis does not explain the variation in efficiency between units. This issue will be addressed later in the article.

### *Measuring efficiency in the district heating sector*

The input variables in the analysis of the efficiency in the district heating sector are the operating expenditure, fuel expenditures and the number of employees. The data is flawed by the absence of information on investments and depreciations, as it was in the water sector. The output variables include the amount of produced district heating, the amount of produced electricity, the number of consumers and the length of the distribution network. Table 5, which contain descriptive statistics for the included input and output variables of the analysis, show that the differences amongst the included production units are rather large. The correlation between the input and output variables need to be strong as the efficiency scores depend on the choice of input and output variables. The multiple regression analysis shows that there is a strong correlation between the chosen inputs and each of the outputs.[3]

Table 5. Descriptive statistics and variable operationalisation

| | Min | Max | Mean | Std. dev. |
|---|---|---|---|---|
| Input variables | | | | |
| - Operating expenditure (DKK) | 294 734 | 257 150 323 | 8 997 683 | 21 183 818 |
| - Fuel expenditure (DKK) | 5 000 | 148 394 000 | 8 038 682 | 13 924 021 |
| - No. of employees | 1 | 90 | 5 | 8 |
| Output variables | | | | |
| - Heat production (Joule) | 16 332 | 17 415 226 | 305 173 | 1 275 933 |
| - Electricity production (kWh) | 568 | 277 012 | 20 441 | 31 978 |
| - No. of hook-ups (Consumers) | 4 | 28 250 | 1 617 | 2 746 |
| - Length of network (km) | 1 | 731 | 36 | 66 |

The data envelopment analysis amongst district heating facilities reveals a widespread inefficiency. The average efficiency score under the assumption of constant returns to scale is 65.8 pct. Under the assumption of variable returns to scale, which is the most conservative estimation of the inefficiency, the average efficiency score increases to 73 pct. Consequently an average district heating company should be able to cut between 27 and 34 pct. of its expenditures while producing the same amount of heat and electricity. On average the district heating sector is therefore more inefficient than the water sector.

Table 6. DEA analysis under constant and variable returns to scale assumptions

| | Constant Returns to Scale (CRS) | Variable Returns to Scale (VRS) |
|---|---|---|
| Average efficiency score | 65.8 % | 73.0 % |
| Total number of units | 210 | 210 |
| - Number of efficient units | 24 | 38 |
| - Number of inefficient units | 186 | 172 |

Part of the widespread inefficiency in the district heating sector illustrated above can be explained by scale inefficiency. However, the scale inefficiency cannot account for the entire inefficiency. There are

[3] The correlation between inputs and outputs is examined by multiple regression and item-item correlation with more or less the same result.

still a large number of production units, whose production is technical inefficient. As shown in table 7 only 24 units are both technical and scale efficient ($\theta_{CRS}$=$\theta_{VRS}$=100). The inefficient units can be divided into 14 scale inefficient, but technically efficient units, 14 technically inefficient but scale efficient units, and finally 158 units which are both technically and scale inefficient. For the majority of the units the inefficiency is not only caused by scale problems. The variation in efficiency between units will be addressed in the following sections of the article.

Table 7. Scale and technical efficiency in the district heating sector

| | Technical efficiency | Technical inefficiency | Total |
|---|---|---|---|
| Scale efficiency | 24<br>$\theta_{CCR}=\theta_{BCC}=100$ | 14<br>$\theta_{CCR}=\theta_{BCC}<100$ | 38 |
| Scale inefficiency | 14<br>$\theta_{CCR}<\theta_{BCC}=100$ | 158<br>$\theta_{CCR}<\theta_{BCC}<100$ | 172 |
| Total | 38 | 172 | 210 |

Note: $\theta_{CRS}$ and $\theta_{VRS}$ are efficiency measures under respectively constant and variable returns to scale assumptions.

## 4. Theoretical explanation of variation

Both the production of water and heat are imbued with inefficiency, as shown previously. From the perspective of rational choice theory this result is to be expected since the cost-recovery regime, the weak regulatory control and the opaque ownership structure of both the water and heating sector provide an inefficient incentive structure. However, the analysis also showed that there is a large variation in efficiency – within and between the two sectors. The question now remains, if and how this variation can be explained. Rational choice theory is divided on this question as different theoretical strands within rational choice institutionalism have different answers.

Alongside the privatisation, liberalisation and deregulation of utilities across most western economies, there has been a debate amongst practitioners as well as in academia on what determines efficiency. This debate has been especially intense between property rights (Eggertson, 1990), Hart et al., 1997) and transaction cost theory (Williamson, 1985). Where property rights theory argues ownership matter, and that private ownership is more efficient than public ownership, transaction cost theory emphasise asset specificity of the transaction. Regulation theory and political transaction cost theory (Stigler, 1971; Peltzman, 1976; Horn, 1995) argue that efficiency is determined by the strength of the interest groups and constituents. Thus staying within the broad framework of rational theory it is possible to identify very different explanations to theoretical expected inefficiency.

### *Property rights theory / Theory of incomplete contracts*

In accordance with the Coase theorem, the property rights theory stresses the importance of ownership of assets, i.e. residual control rights, in the case of incomplete contracts (Hart & Moore, 1990; Hart, Shleifer & Vishny, 1997; Hart, 2003)[4]. The fundamental difference between private and public ownership concerns the allocation of residual control rights, as a public provider will have weaker incentives than a private provider to engage in quality improvements and cost reductions. Though consumer-cooperatives do not fit into the dichotomy of traditional property rights theory, Hansmann (1996) and Hart & Moore (1998) have expanded the property rights theory in order to include the special ownership structure of consumer-cooperatives. Compared to a private enterprise the production of consumer-cooperatives is inefficient. This is due to excessive consummation by certain groups of consumers and a far more complex objective for the management (maximizing the pay-off of the median consumer) relative to the objective of the management of a private company (profit maximizing) (Hart & Moore, 1998: 4). Nevertheless the incentives to engage in cost reductions or quality improvements are stronger in consumer-cooperatives than in public entities, as consumers will gain from a more efficient production through lower prices (Hansmann, 1996: 46-49). This lead to the following hypothesis:

> $H_{1a}$: Private owned utility companies, including consumer-cooperatives, will be more efficient than public owned utilities.

### *Transaction cost economics*

Though the transaction cost economics acknowledges that the incentive structure of the market is stronger than that of public ownership (Williamson, 1985: 29), this theoretical strand does not focus on ownership when trying to explain the differences in efficiency between enterprises. Rather the focus of the transaction cost economics is primarily on the specificity of the asset of the transaction. Thus the costs of production, and of transactions, depend on the asset specificity. The consequence of high asset specificity is that hierarchical solutions, i.e. public ownership, become more attractive because of the increased certainty for the actors involved in the transaction associated with hierarchical governance structures. In contrast, when transactions are characterized by low asset specificity, market solutions become more efficient since the assets can easily be reused (Williamson, 1996:108). Since the water and heating sector are associated with large investments in infrastructure and in production facilities, which

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[4] Ownership, however, does not matter when it is possible to sign a complete or comprehensive contract (Hart, Shleifer & Vishny, 1997).

are difficult to use for other purposes, both sectors are characterized by high asset specificity. Hence the production and supply of water from public enterprises are expected to be more efficient than from private enterprises. This expectation is contrary to that of property rights theory. In short transaction cost economics lead to the following hypothesis:

> $H_{1b}$: Due to the high asset specificity connected to the production and distribution of water and heat, public owned utility units will be more efficient than public owned utility companies.

Since the asset specificity of each transaction depends on the market structure, i.e. on the level of competition, efficiency will also tend to vary with the level of competition within each network area. Water and heating enterprises within areas with a relatively high degree of competition are therefore expected to be more efficient than enterprises in areas with little competition:

> $H_2$: Since competition influences the asset specificity, the efficiency will depend on the degree of competition.

### *Political transaction cost theory*

The transaction cost economics were initially developed to analyze make-or-buy decisions in the private sector, though Williamson insists that the theory is equally applicable to the public sector (Williamson, 2000). Political transaction cost theory, here represented by Terry Moe and Murray Horn, have, however, questioned whether politicians and other decision makers in the public sector are interested in minimizing the economic transaction costs. The argument is, that politicians may be more interested in getting re-elected by trying to maximize their votes, thus making efficiency and cost-effectiveness a secondary consideration (Moe, 1990:119; Horn, 1995:8-10).

As a result, politicians may try to ensure that the private benefits of their political constituents surpass their costs (Moe, 1990: 128; Horn, 1995: 10)[5]. Thus, the intensity of their constituents and of their interests are expected to be of relevance to the efficiency of the production (Peltzman, 1976; Moe, 1990: 130-131). Concentrated interests are expected to be more influential on politicians than more dispersed interests. This indicates that the size of industrial interests, and thereby concentrated interests, in the constituency influences the efficiency. But the politicians are also

[5] Moe (1997:471) describes this part of his theory as an institutional version of the interest group theory associated with the so-called Chicago school, represented by Stigler (1971), Peltzman (1976) and Becker (1983).

expected to be aware of the voters, and the number of consumers are therefore also expected to influence the efficiency. This may be summarized by the following hypothesis:

$H_3$: The intensity or concentration of constituents affects the efficiency.

The main emphasis of the different theoretical strands with regard to explaining variation, and the empirical implications hereof, are summarized in the table 8.

Table 8. Summary of common framework and diverging implications

| | **Property Rights** | **Transaction cost economics** | **Political transaction cost theory** |
|---|---|---|---|
| **Common assumptions** | Actors are rational and opportunistic | | |
| **Diverging arguments related to efficiency** | Ownership | Asset specificity | Institutional design<br>Concentration of constituents |
| **Empirical implication** | Private enterprises are expected to be more efficient than public owned. | Public ownership is expected to be more efficient than private ownership.<br>The efficiency is, however, also expected to vary according to the degree of competition within each utility network. Enterprises within areas with competition are expected to be more efficient than enterprises within areas with little competition. | Public enterprises are expected to be more efficient than political-administrative structures.<br>The concentration of constituents and of their interests is supposed to influence the efficiency of production. |

## 5. Operationalisation of variables

As demonstrated above, both sectors seem to be permeated with inefficiency. The analysis of the variation in inefficiency takes its starting point in the different theoretical strands mentioned in the introduction: the significance of ownership ($H_{1a}$), asset specificity ($H_{1b}$), competition ($H_2$), and intensity of constituent ($H_3$). Before testing these hypothesises in a multivariate regression analysis, the dependent and independent variables are operationalised.

### *Dependent variable*

The dependent variable is the efficiency measure of the production units. Since the variable returns to scale model (VRS) only reports the technical inefficiency, this model will be used in the following analysis instead of the constant returns to scale model (CRS). Furthermore, the variable scale assumption gives a more conservative estimation of the efficiency, thus giving the inefficient units the benefit of the doubt. Finally, looking at it from a policy perspective, at least in the long run the scale of production *is* variable.

THowever, the productivity analysis above – under either scale assumption – does not differentiate between the most efficient units, which constitute a problem in the following regression analysis below. The problem can be solved by calculating a so-called super-efficiency score, according to Andersen & Petersen (1993). The super-efficiency score is a ranking of the efficient units, i.e. the units with an efficiency measure of 100. The score, which is higher than 100, thereby ranks the efficient units without affecting the inefficient units.

### *Independent variables*

The independent variables are variables attached to each of the theoretical expectations mentioned above: ownership ($H_{1a}$), asset specificity ($H_{1b}$), competition ($H_2$) and intensity of constituents ($H_3$). The analysis will also control for the significance of several structural variables. The relevant structural variables are described below in relation to the analysis of the variance in each sector.

Ownership of utility plants is measured by a dummy variable. The private owned plants are expected to be the most efficient production units, according to property rights theory. But if the foundation for the analysis instead is transaction cost economics the expectation would be that the publicly owned plants are more efficient than the privately owned plants, because of the high asset specificity characterising the production and distribution of water and heat.

Transaction cost economics would also suggest that the degree of competition is of critical relevance, since competition influences the mutual interdependence in a transaction, hence also affecting the asset specificity of the transaction. Though both the water and heating sector are characterised by limited competition - there rarely are several plants within the same distribution area - the mere existence of comparable units exposes production units to a latent or indirect competition pressure (see Bendor, 1985). The market structure, i.e. the number of production units and their market share, within the same distribution area is expected to influence the efficiency of the production. According to transaction cost economics the correlation between competition and efficiency is stronger for privately owned units than for publicly owned (Williamson, 1996: 104). Hence, the degree of competition is expected to have a stronger influence on the efficiency of privately owned water plants than publicly owned water and heating plants. The degree of competition is operationalised as the market structure of the respective sector.

According to political transaction cost theory the efficiency is also influenced by the intensity of the constituents' interests. The constituents can be divided into two groups: industries where water respectively heat is a major production factor, and households with a more dispersed interest. Within both groups of constituents, the strength of the constituents' interest may vary. Thus the demand for efficient production, and thereby lower prices for consumers, is expected to be a function of the intensity of industries and households interest. The independent variables are listed and operationalised in table 9 along with the expected correlation with efficiency.

Table 9. Variable operationalisation

| Variables | Operationalisation | Expected correlation |
|---|---|---|
| **Hypothesis:** | | |
| H1 – Ownership | Dummy-variable for ownership structure (public owned=0; private owned=1) | +/- |
| H2 – Competition | Market structure index | - |
| H3a – Intensity of industrial interests | Number of companies within industries, where water/heat is a major production factor, located in the area | + |
| H3b – Intensity of household interests | Heat: Share of households in the local area connected to the district heating network<br>Water: Share of production of water distributed to households | + |

## 6. Explanation of variation between water companies

As demonstrated, the water sector seems to be imbued with inefficiency. The analysis of the variation in inefficiency takes its starting point in the different theoretical strands described above: the significance of ownership ($H_{1a}$), asset specificity ($H_{1b}$), competition ($H_2$), and intensity of constituent ($H_{3a}$ & $H_{3b}$). Along with these variables a set of structural variables are also included in the regression analysis. The structural variables are the length of the distribution network, the measured loss of water in the pipelines, the average age of the pipelines, the maximum storage capacity of the production facilities and the number of summer residents in the area. The last variable may seem curious, but it is included since summer resident areas are often very thin populated, which increases the cost of distributing water or heat. The dependent variable is the efficiency scores calculated under the assumption of variable returns to scale.

Table 10. Structural and technical variables in relation to the production of water

| Structural variables | Operationalisation |
|---|---|
| Length | Length of pipeline (km) |

| | |
|---|---|
| Loss | Measured loss of water in the pipelines ($m^3$) |
| Age | Average age of the pipelines (years) |
| Capacity | Maximum storage capacity ($m^3$) |
| Summer residents | Number of summer residents in the area |

The regression analysis confirms that competition, industrial interests and the length of the distribution network influences the efficiency of water production. It can therefore be concluded that the higher the market concentration the more efficient is the prodution of water. This correlation is also found if the data set is divided between publicly and privately owned utility entities though the correlation is not markedly stronger for private entities compared to public ones. The analysis also demonstrate that entities operating in municipalities with strong industrial interests are more efficient than entities operating in municipalities with little or no industrial interest. Thus the intensity of industrial interest influences the efficiency of water production. In contrast the interests of household are not important. Finally, only one of the structural variables, the size of the distribution area, is significant. However, the correlation between the length of the distribution network and the efficiency of the production is reverse to the expected: the longer a distribution network the higher efficiency. In sum, the three significant variables explain 40 pct. of variation (see table 11), as expected by transaction cost economics and political transaction cost.

The remaining structural variables do not influence the efficiency. Hence the variation in efficiency cannot be explained by the age of the pipelines, the maximum storage capacity of the production facilities, the number of summer residents or the loss of water in the pipelines. Ownership is also rejected as significant explanations of the variation in efficiency. There is no significant difference between the efficiency of private and public water production, in opposition to the expectations of property rights theory.

In conclusion the variation of efficiency can best be explained by the incentives created by the existence of competitors, along with the incentives that the pressure from concentrated and intense industrial interests creates. The most efficient production facilities are located in areas with competition and with a strong industrial pressure for an efficient production. The analysis thereby confirms hypothesis $H_{3a}$. Hypothesis $H_2$ can only be partially confirmed, since the analysis also showed that there is no difference in the influence of competition on private respectively public production of water. At the same time, neither ownership nor household interest, are of importance, thereby rejecting hypothesis $H_{1a}$ and $H_{3b}$. However, the analysis also showed that there is a large part of the variation in efficiency which cannot be explained by the included variables.

Table 11. Explanation of variance in the efficiency of water production and distribution

| Significant variables | Standardized Beta-coefficient | Level of significance |
| --- | --- | --- |
| Competition | -0.414 | 0.000 |
| Industrial interests | 0.326 | 0.002 |
| Length of network | 0.357 | 0.001 |
| Explained variation (adjusted $R^2$) | 0.400 | |

## 7. Explanation of variation between heating companies

The analysis above indicated that the district heating sector is even more inefficient than the water sector. As with the water sector, the analysis of the variation in efficiency in the district heating also takes its starting point with the theoretically deduced explanations: the significance of ownership ($H_{1a}$), asset specificity ($H_{1b}$), competition ($H_2$), and intensity of constituent ($H_{3a}$ & $H_{3b}$).

A set of structural variables is also included in the regression analysis: cogeneration, choice of fuel, capacity, age of pipelines and the number of summer residents. These variables may be more significant than in the analysis of the water sector due to the heating sector's more complex production process. In the heating sector many producers are so called common heat and power plants, where the producers are able to utilize the fuel when turning primary energy (process heat recovery, fossil fuels, biogas, pellets etc.) into both thermal and electric energy (Energistyrelsen, 2003), Thus the production of common heat and power plants can be expected to be more efficient than regular heat plants. The choice of fuel may also influence the efficiency of the production, since it is impossible for most producers to substitute between fuel types in the short run. Thus dummy variables for gas, oil, coal and biogas are included. A third structural variable included is the maximal capacity of the production facility. A high maximal capacity indicates an inefficient overcapitalisation of the production facility. The age of the distribution pipelines is also included as a structural variable. Old distribution pipelines may be less efficient than newer pipelines, but since all costs under the cost-recovery regime are pushed on to the consumer, the old and inefficient pipeline may well be cheaper. Finally, the number of summer residents in the distribution area is included as an indicator of the density of the distribution area. The dependent variable is the efficiency scores calculated under the assumption of variable returns to scale.

Table 12. Structural and technical variables in relation to the production of heat

| **Structural variables** | **Operationalisation** |
| --- | --- |
| Cogeneration | Dummy variables for regular heat plants and common heat |

| | |
|---|---|
| | and power plants |
| Choice of fuel | Dummy variables for the type of fuel (gas, oil, coal and biogas) |
| Capacity | Maximum storage capacity (Joule) |
| Age | Average age of the pipelines (years) |
| Summer residents | Number of summer residents in the area |

The regression analysis confirms that cogeneration, the choice of fuel, competition and household interests influence the efficiency of the heat production. As expected, the analysis shows that common heat and power producing plants are significantly more efficient than regular heat plants. The analysis also showed that heat plants that use bio fuel are less efficient than heat plants using other energy sources. However, there are fewer negative externalities in the shape of $CO_2$ emission, related to the production of heat, when the plant is using bio fuel.

The analysis also demonstrates that the amount of competition is significant. But the correlation between competition and efficiency contradicts the expectations; the less competition, the higher efficiency of heat production. There are no difference between the influence of competition on private and public heat plants,. Finally, the analysis shows that plants operating in areas with strong household interests are more efficient than plants operating in areas with no or only little household interest. Thus the intensity of constituents, in this case household interests, influences the efficiency of heat production.

Based on the analysis it can also be concluded that the remaining theoretically deduced explanations are irrelevant: there is no significant correlation between the intensity of industrial interests and ownership on one hand, and the efficiency of heat plants on the other. In contrast to the expectation in political transaction cost theory there is no significant difference between the efficiency in areas with vague respectively strong industrial interest. And in contrast to the expectations from property rights theory there is no significant difference between the efficiency of private and public heat plants. None of the remaining structural variables, age of pipeline, maximum capacity and summer residents, influence efficiency. In sum, the four significant variables explain only 24 pct. of variation (see table 13).

Table 13. Explanation of variation in the production and distribution of district heating

| Significant variables | Standardized Beta-coefficient | Level of significance |
|---|---|---|
| Cogeneration (dummy) | 0.189 | 0.017 |
| Competition | 0.157 | 0.012 |
| Household interests | 0.163 | 0.000 |
| Bio-fuel (dummy) | -0.307 | 0.000 |
| Explained variation (adjusted $R^2$) | 0.243 | |

The analysis shows that the variation of efficiency can best be explained by the incentives created by the existence of strong household interests along with a number of technical factors such as the choice of fuel and co-production of heat and electricity. However, the analysis shows that heat plants exposed to limited competition are more efficient than heat plants which are more exposed to competition. The analysis thereby confirms hypothesis $H_{3b}$ about household interest. The remaining hypothesis – $H_{1a}$ about ownership, $H_{1b}$ about and asset specificity, $H_2$ about competition and $H_{3a}$ about industrial interest – are rejected. But there is also a large part of the variation which the included variables cannot explain.

## 8. Conclusion

Both the water and the heating sector are characterized by inefficiency in Denmark, the heating sector more so than the water sector. Within each sector, part of the variation in efficiency is explained by the interests of the constituents and asset specificity besides a few technological factors. However, asset specificity does not have the expected significance in the heating sector. Ownership does not have any influence on efficiency, which is partly due to the cost-based regulation in both sectors. Thus the analysis has shown that the arguments inherent in the property rights theory have no relevance in the analysed utility sectors in Denmark, while the performance of the transaction cost economics is rather mixed. The strongest arguments are present in the political transaction cost theory.

Though it is not possible to compare the statistical results between the two sectors, the analysis seems to suggest that the variation in efficiency and the degree of inefficiency is highest in the district heating sector.

The difference in efficiency between the water and heating sectors can be partly explained by the technological factors characteristic of each sector. One possible explanation is that generation of heat is more complex than abstraction of water, resulting in greater variation in efficiency. The difference between the water and heating sector is also caused by variation in the strength of the relevant constituents. The relevant constituents in the heating sector, consumers, constitute a rather diffuse interest grouping. In contrast the industrial interests in the water sector constitute a rather concentrated interest, which facilitates collective action towards decision makers. And since the industrial constituents in the water sector represent a more intense group of constituents, they are expected to be more influential on decision makers.

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