Water Management in

Denmark

EWUM – Pisa, 12 March 2015

Executive summary

1. Country and sector description;
2. Regulation model based on revenue cap and mandatory benchmarking (Water Sector Act 2009);
3. Analysis of the efficiency of wastewater services through data envelopment analysis;
4. Exploring cost drivers for wastewater utilities;
5. Conclusions and final remarks

Country and sector description

The country

- **High fragmentation**: more than 72 inhabited islands, connected with ferries and/or bridges;
- **Quite simple geography**: flat region, with an atlantic weather;
- 5.6 MIL of inhabitants; 85% of urban population; GDP per capita – 37.315 EUR.
- Well developed **welfare system** and high care of human rights

The water sector

- **low population density**: 129.7 inhabitants per square kilometer (inh/km²) in 2011, greater than the density of Spain (92 inh/km²) and France (103 inh/km²), similar to that of Portugal (114.5 inh/km²), but less than that of Italy (201.5 inh/km²), Germany (229 inh/km²), England and Wales (371 inh/km²) and the Netherlands (494.5 inh/km²) (Eurostat 2011);

- **high level of decentralization**: about 2,800 utilities, with an average population served of 2,059 inhabitants per utility (inh/utility), which is remarkably lower than that of Germany (13,667 inh/utility), Italy (648,352 inh/utility), and England and Wales (2,148,000 inh/utility) (Carvalho et al., 2012);

- **one of highest tariffs in Europe**: the unit price of water and wastewater services to Danish households in 2007–08, including taxes, was 6.70 USD/m³ (OECD, 2010);

- **one of the lowest water loss rates**: the difference between water volumes pumped out and water volumes registered by consumers was only 1.7 m³ per km of pipes per day in 2009; (DANVA, 2010).

High level of decentralization

The Danish water sector comprises a very large number of water companies covering over great diversity in terms of size, type of ownership and organization. The approximately **2.800 water companies** are spread over some **2.500 water** companies and about **300 wastewater** companies.

Over recent years there has been an ongoing consolidation in the water sector. **In 2003 there were 4.155** public entities in the water sector spread over 2.792 water companies and 1.363 waste water companies, while there are currently about 2.500 entities in total.

Not all companies are covered by the regulation system

All the municipally owned water companies are covered by water sector law, while a large part of the private water companies is below the threshold of 200,000 m3 of annual water production and are therefore not covered by the Water Sector Act.

What does “200.000 m3” mean?

In Italy Azienda Servizi Toano sold about 250,000 M3 to no more than 5,000 inhabitants.

The ownership structure: a peculiarity of the Danish WS

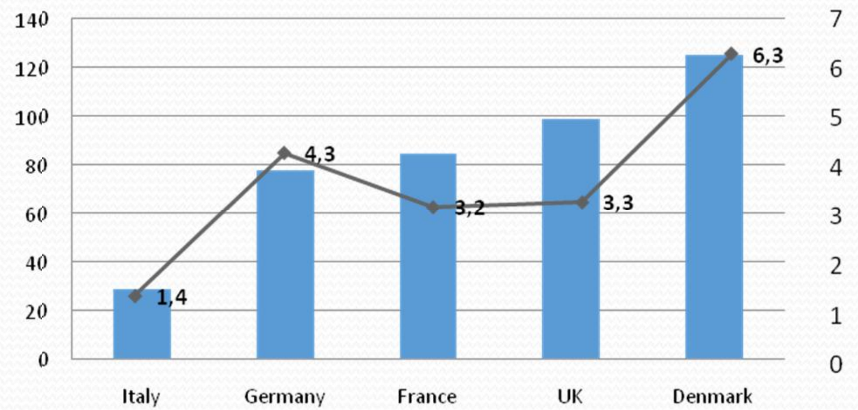
The activities of water supply and wastewater management are mainly divided into two types of ownership: **municipally owned water companies** and private - and thus **consumer owned** - water companies.

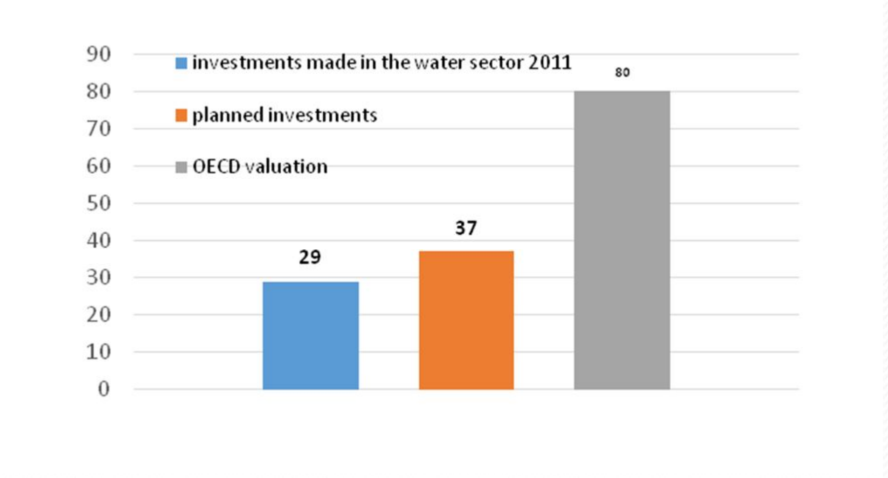
Drinking Water			Waste Water		
Type of ownership	**Companies**	**Share of water production**	**Type of ownership**	**Companies**	**Share of water production**
Municipality	87	About 67%	Municipality	97	About. 98%
Private regulated	135	About 20%	Private regulated	0	-
Private – non regualed	About 2.300	About 10%	Private – non regualed	214	About. 0,5%

The highest tariff and investments in Europe

Danish water utilities account for 1.4% of EU water industry.

- Turnover 2 BIL €
- Extracted water volume 288 MIL m3
- Wastewater treated 350 MIL M3





The regulation model

The Water Sector Act (2009)

The **water sector act** was adopted in 2009, and the same year the minister for the Environment created the **Water Utility Regulatory Authority**.

The economic regulation in the **water sector act covers**:

1. Comparison of the companies' efficiency (mandatory benchmarking);
2. Determination of annual price caps on companies' prices;
3. Supervision of water companies' internal monitoring system;
4. Guidance of the companies in the rules and how companies must report to the WURA;
5. Contribute to the development of the regulation.

The revenue cap method

From 2009 is set a price limits which work as revenue cap to cover costs.

REVENUE CAP regulation

The revenue cap is calculated considering the costs of last year plus a growth rate given by inflation rate – **efficiency penalty** (e.g.:RPI-X);

PRICE CAP regulation

- Is like revenue cap, even if in this case the risk of a «volume variance» is faced by consumers, while with price cap is faced by the water utility. Price cap is useful when a firm can control volumes and costs are variabile.

The alternative regulation method

RATE OF RETURN regulation

- Revenues are obtained summing up the costs OPEX+Amortization+Depreciation+Taxes+B*RAB, where B is a rate of return, while RAB is the value of net invested capital in fixed assets («regulatory asset base»)
- Partially used in Italy with the so called «Normalized method»

A comparison of three regulation method

Price Cap	Revenue Cap	Rate of Return
• Induce to improve efficiency; • Tariff are kept low.	Like price cap • Risk of volume variance faced by customers	• Increase of investments; • Low risk faced by firms; • No extra profits.
• Authority must carry out an effective control over costs and tariff of water utilities.	Like price cap • Risk of volume variance faced by customers	• Efficiency is not improved, since a cost decrease determines a tariff decrease; • Only a time lag in regulation could improve efficiency; • Utilities too capital intensive

Step 1: Operating costs	
+	Operating costs from the price cap ruling of 2012
-	Possible loss of significant costs
+	Correction for inflation between 2012 and 2013
+	Possible increase of operating costs to the level of efficient operating costs according to the benchmarking model
-	General efficiency penalty (productivity development)
-	Individual efficiency penalty (performance benchmarking)
Step 2 : Corrections from previous years	
+ /-	Settlement of deficit or excess cover (according to the statement in the price cap of 2012)
+/-	Correction regarding compliance with the revenue framework from the price cap of 2011
Step 3 : Budgeted costs	
+	1:1 costs
+/-	Correction of actual expenses for approved 1:1 costs of 2011
+	Operating costs associated with environmental and service goals
+/-	Correction of actual expenses for approved environmental service goals of 2011
+/-	Net financials
+/-	Corrections of actual expenses and income of net financials of 2011
Step 4 : Supplements for investments	
+	Supplements for planned investiments of 2012 and 2013
+	Supplement for implemented investment of 2010 and 2011
+/-	Correction of implemented investments of 2011
+	Supplements for historical investments

The efficiency penalty

1. General, due to any change of technology
2. Specific, due to poor efficiency measured for a firm.

The “firms specific efficiency penalty” is obtained trough a mandatory benchmarking model.

An efficiency potential is estimated for each company, with reference to operating costs. From this item is derived the efficiency penalty, included in the price limit.

Estimation of the efficiency penalty

1. Every year the EP is estimated (there is no time lag, like in UK);
2. A DEA model is used to estimate the frontier of efficient firms
3. **Input** is FADO: controllable operating costs of (T-1,) updated with inflation at the current year (T)
4. **Ouptut** are NVM, AC-NVM, DC-NVM, which represent the modelled costs incurred by every firm under efficient conditions.

Net-Volume-Measures for water firms – The cost drivers

Drillings	Waterworks	Booster stations	Clean water pipes	Plugs	Customers
Amount of pumped up water in m3	Amount of water in m3 with: • No treatment • Regular treatment • Advanced treatment	Number of stations in the categories: • 0-50 m3/t • 51-100 m3/t • 101-200 m3/t • 201-600 m3/t • 601-max m3/t	Kilometers of pipes in the zones: • Country + Town • City • Inner-City	Number of plugs in the zones: • Country + Town • City • Inner-City	Number of meters

Net-Volume-Measures for water firms – The cost equivalent

Cost drivers	Cost equivalent
Drillings	$Y = 1{,}518X_1^{0{,}9321}$
Waterworks	$Y = 0{,}748X_1 + 1{,}613X_2 + 1{,}774X_3$
Booster stations	$Y = 35{,}453X_1 + 56{,}469X_2 + 144773X_3 + 178{,}851X_4 + 440X_5$
Clean water pipes	$Y = 4{,}047(X_1 + X_2) + 85{,}370(X_3 + X_4)$
Plugs	$Y = 135{,}8(X_1 + X_2) + 430{,}2X_3 + 1.208{,}1X_4$
Customers	$Y = 149{,}8X_1$

Data Envelopment Analsys

Efficiency was estimated through a widespread non-parametric tecnique (DEA), which identifies three efficiency score (CRSTE, VRSTE, SE) solving the following linear programming model:

$$Min\ \Phi$$

$$\sum_{j} \lambda_{j} x_{jm} \le \Phi x_{j_0 m} \quad ; m = 1,2,\ldots,M$$

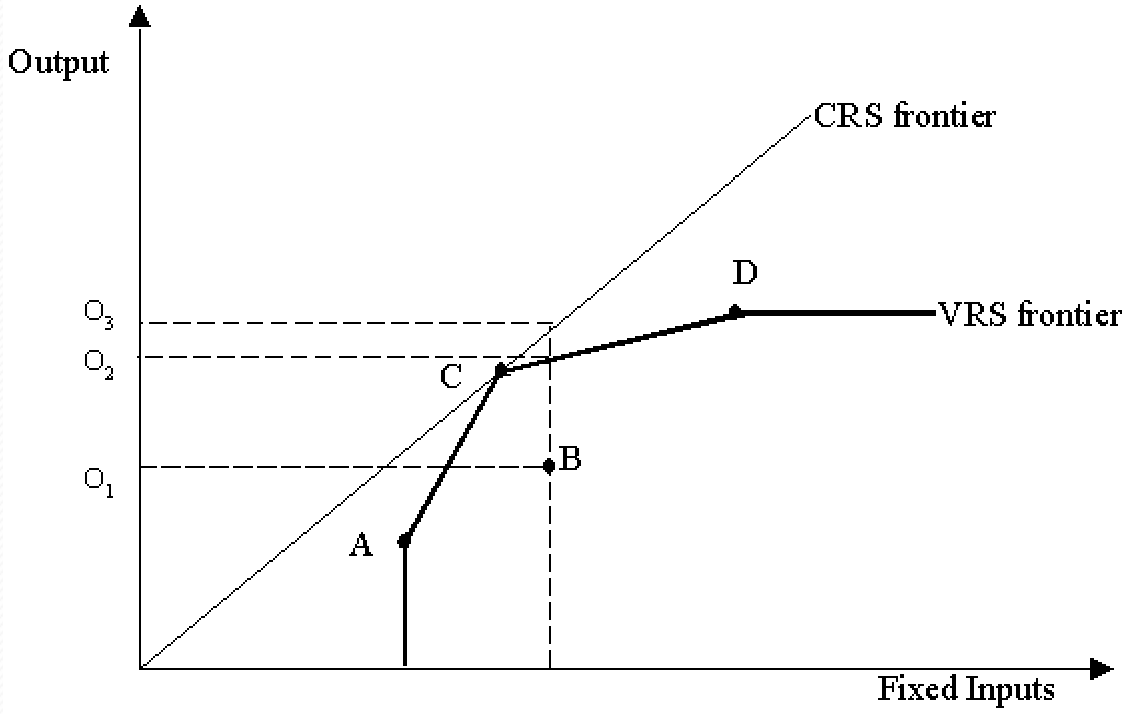
$$\sum_{j} \lambda_{j} y_{jn} \ge y_{j_0 n} \quad ; n = 1,2,\ldots.,N$$

$$\lambda_{j} \ge 0 \ \& \ \sum_{j} \lambda_{j} = 1 \quad ; j = 1,2,\ldots.,J$$

The efficiency frontier with DEA

a) When FADO=NVM: efficient firm, score 1

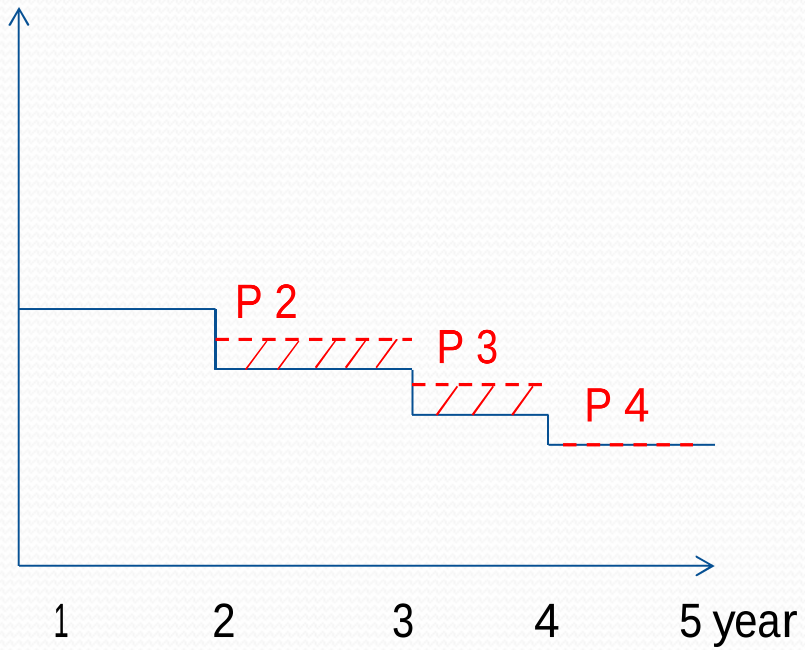
b) When FADO>NVM: not efficient firm, efficiency potential >0



The Water Department thinks that a company should be capable of gaining 25% of efficiency potential in one year; furthermore the maximum efficiency penalty is set at 5%.

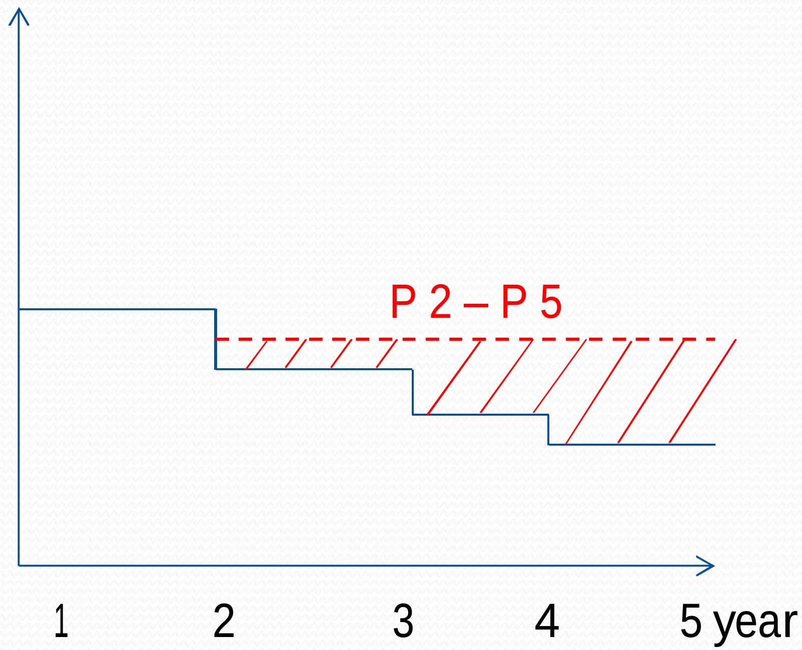
The "time lag" mechanism

In DNM prices are annually updated



The “time lag” mechanism

In UK prices are updated every 5 years



Analysis of the efficiency of danish wastewater utilities

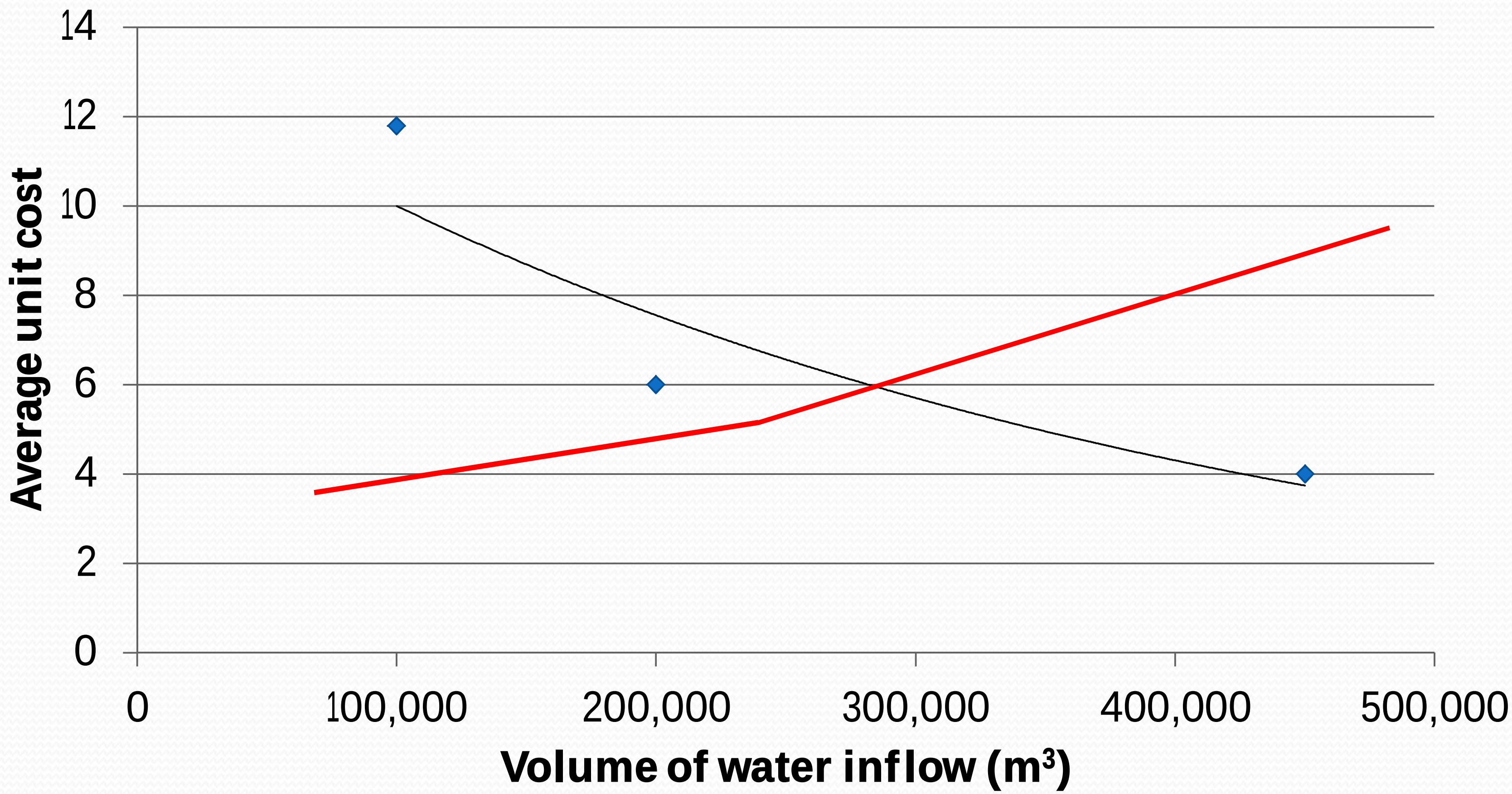
The issue of water utilities efficiency

According to Farrell (1957), the current study is based on the concept of “cost efficiency”: the capability to reduce costs given a certain level of output. It is measured with a cost to cubic meter ratio.

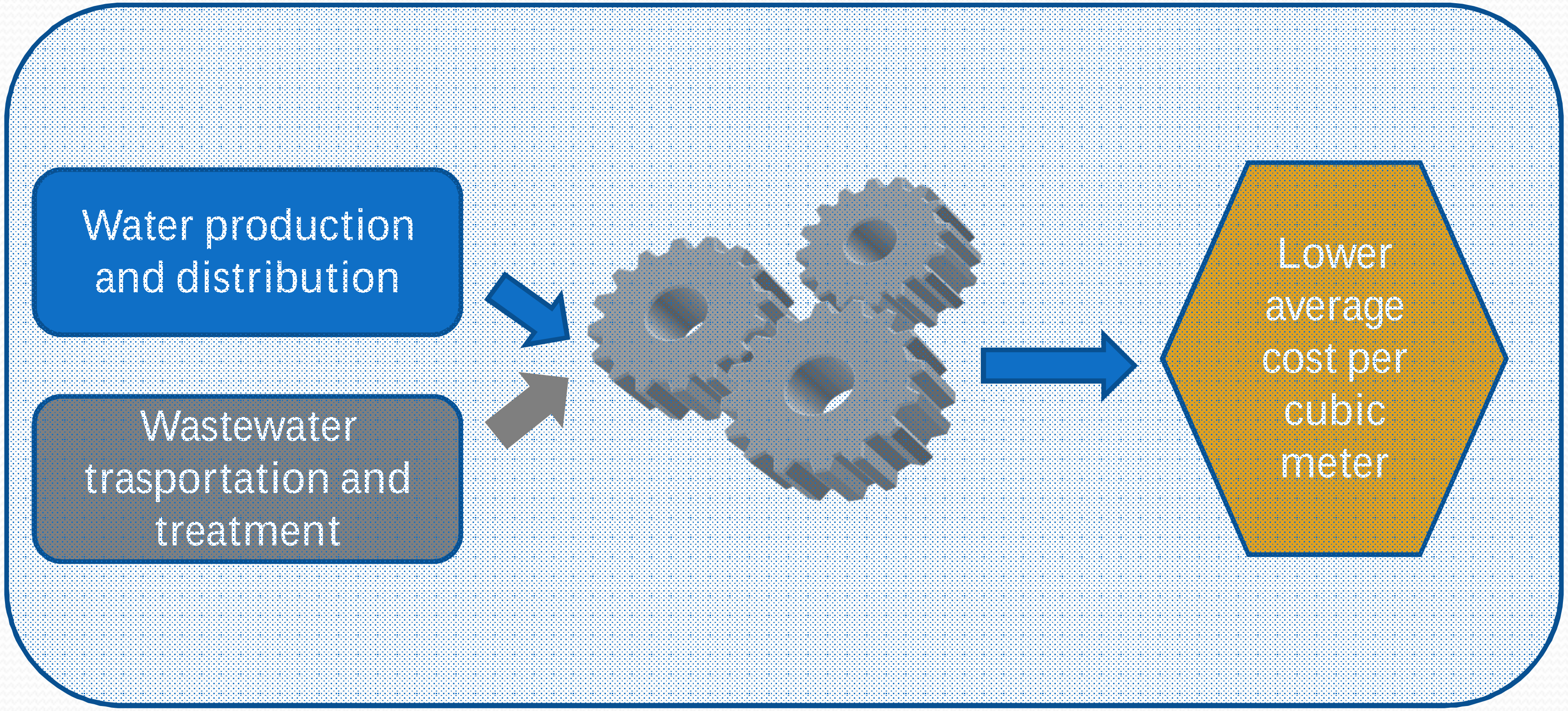
European Environmental Agency (EEA) and Organisation for Economic Co-operation and Development (OECD) has highlighted that operational efficiency is very poor compared to best practices.

Efficiency represents a way to realize investments, along with fund raising or tariff increases.

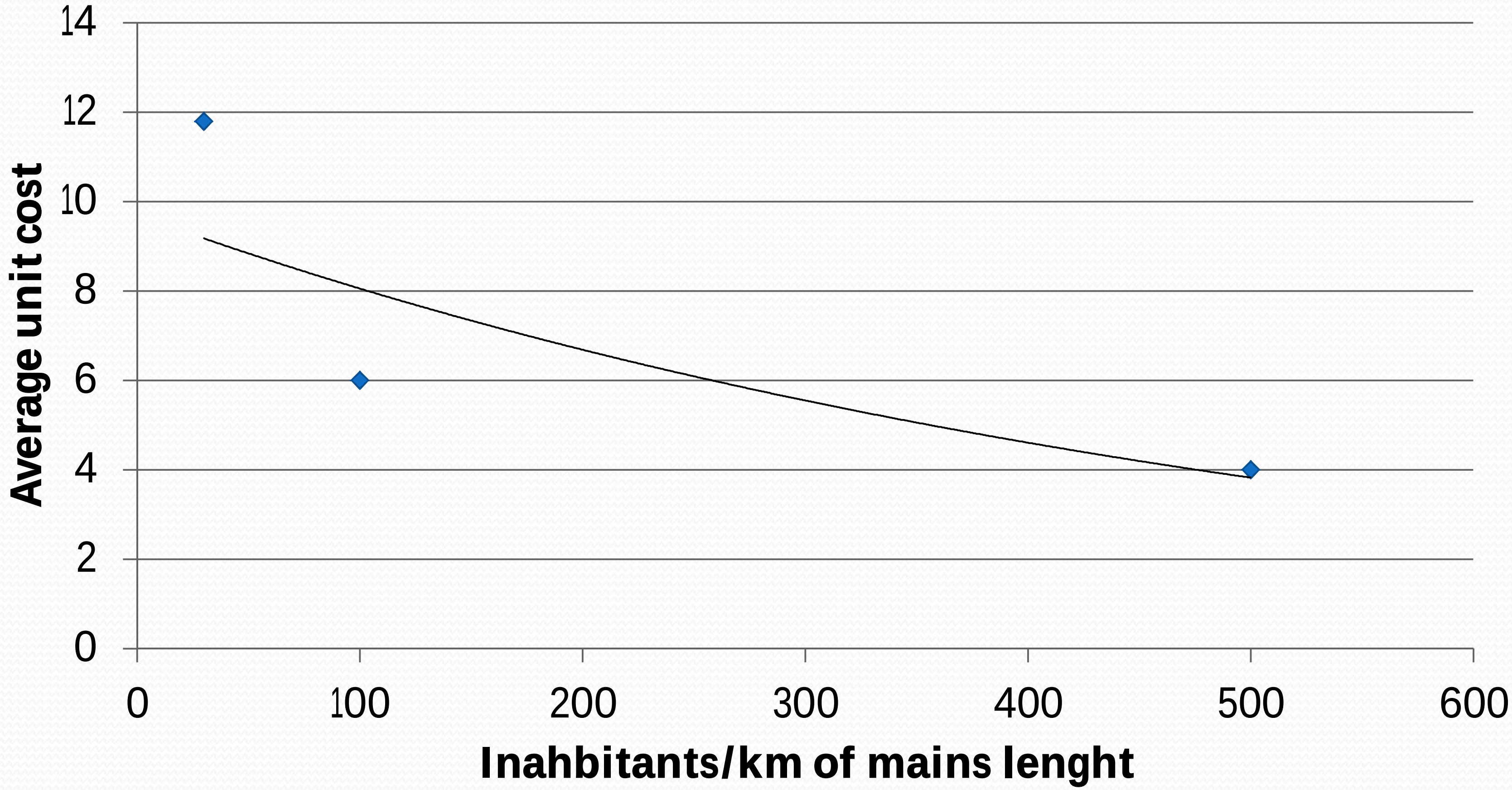
(Dis)Economies of scale



Economies of scope



Economies of density



Research method – data collection

- Analysis of 62 Danish water utilities (44 provide only wastewater services, 18 water and wastewater services)
- The dataset was made of 372 observations concerned this items (DANVA Report 2011):

Input:

Costs for transportation; treatment; and customer handling

Output:

- Water inflow

Environmental variables:

- Lenght of sewers
- Population served
- Wastewater (W) or Water and Wasteater utilities (WW)

The data availability

Denmark has experienced a voluntary banchmarking since 1999, through the support of the national association of water utilities (DANVA)

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From 2011, a price cap mechanism was applied and, from 2012, these were based on benchmarking results (similar to the Portuguese and Dutch experience).

Research method –
1) the measure of efficiency

Efficiency was estimated through a widespread non-parametric tecnique (DEA), which identifies three efficiency score (CRSTE, VRSTE, SE) solving the following linear programming model:

$$\begin{aligned}
&Min\ \Phi \\
&\sum_{j} \lambda_{j} x_{jm} \leq \Phi x_{j_0 m} \quad ; \ m=1,2,\ldots,M \\
&\sum_{j} \lambda_{j} y_{jn} \geq y_{j_0 n} \quad ; \ n=1,2,\ldots.,N \\
&\lambda_{j} \geq 0 \ \& \ \sum_{j} \lambda_{j} = 1 \quad ; \ j=1,2,\ldots.,J
\end{aligned}$$

Research method – 2) the determinants of efficiency

Linear regression model based on a tobit censored function:

$$\text{DEA SCORES} = \beta_0 + \beta_1\text{SIZE} + \beta_2\text{DID} + \beta_3\text{CD} + \varepsilon$$

where:

SIZE = population served

DID = mono or multi-utilities (dummy)

CD = pop. served to kilometers of sewer length

Descriptive statistics (1)

	Max	Min	Mean	SD
Wastewater utilities				
Operating costs (€)	19,771,389	715,700	5,359,130	3,989,746
- *Transport costs (€)*	10,979,867	0	2,126,053	1,784,065
- *Treatment costs (€)*	11,621,835	0	2,840,626	2,487,343
- *Customer handling costs (€)*	2,520,971	0	392,450	467,605
Sewage volume treated (m3)	11,812,097	626,287	3,113,549	2,026,060
Sewer length (km)	2,496	55	819	494
Population served (no. people)	533,875	8,486	61,470	84,074
Population density (pop/km of network)	3849	16	146	498

Descriptive statistics (2)

	Average Operational Costs (€)	Average Mains/Sewers Length	Average Population Served	Average Volume of Water Sold	Average Cost per Cubic Meter (€)
Wastewater utilities					
Large	8,330,558	1,040	129,845	4,967,923	1.7
Medium	4,045,923	736	37,099	2,329,990	1.7
Small	4,236,822	711	17,466	2,232,819	1.9
Mono-utility	5,472,094	820	58,699	3,770,914	1.5
Multi-utility	5,691,005	816	67,937	4,042,910	1.4
Very high density	4,947,081	536	116,984	6,314,824	0.8
High density	7,619,117	1,080	77,028	4,345,716	1.8
Low density	3,661,513	725	31,036	1,983,021	1.8
Very low density	5,923,359	934	20,833	2,766,490	2.1

Main results - SIZE

Utility size exerts contrasting results:

1. Large firms achieve optimal structure (SE),
2. but the small and medium ones own the skill to perform better (VRSTE);
3. The effects on SE and VRSTE neutralize each other when CRSTE is considered

Tobit regression	CRSTE	VRSTE	SE
Size	-0.047	-0.271***	0.237***
Water&Wastewater	0.091*	-0.007	0.061
Density	1.17***	3.29***	-0.165

***, ** and * indicate 1%, 5% and 10% significance levels, respectively

Main results – Degree of Investments Diversification

The policy of the majority of Danish local government to keep water and wastewater services separated seems to penalize performance.

Tobit regression	CRSTE	VRSTE	SE
Size	-0.047	-0.271***	0.237***
Water&Wastewater	0.091*	-0.007	0.061
Density	1.17***	3.29***	-0.165

***, ** and * indicate 1%, 5% and 10% significance levels, respectively

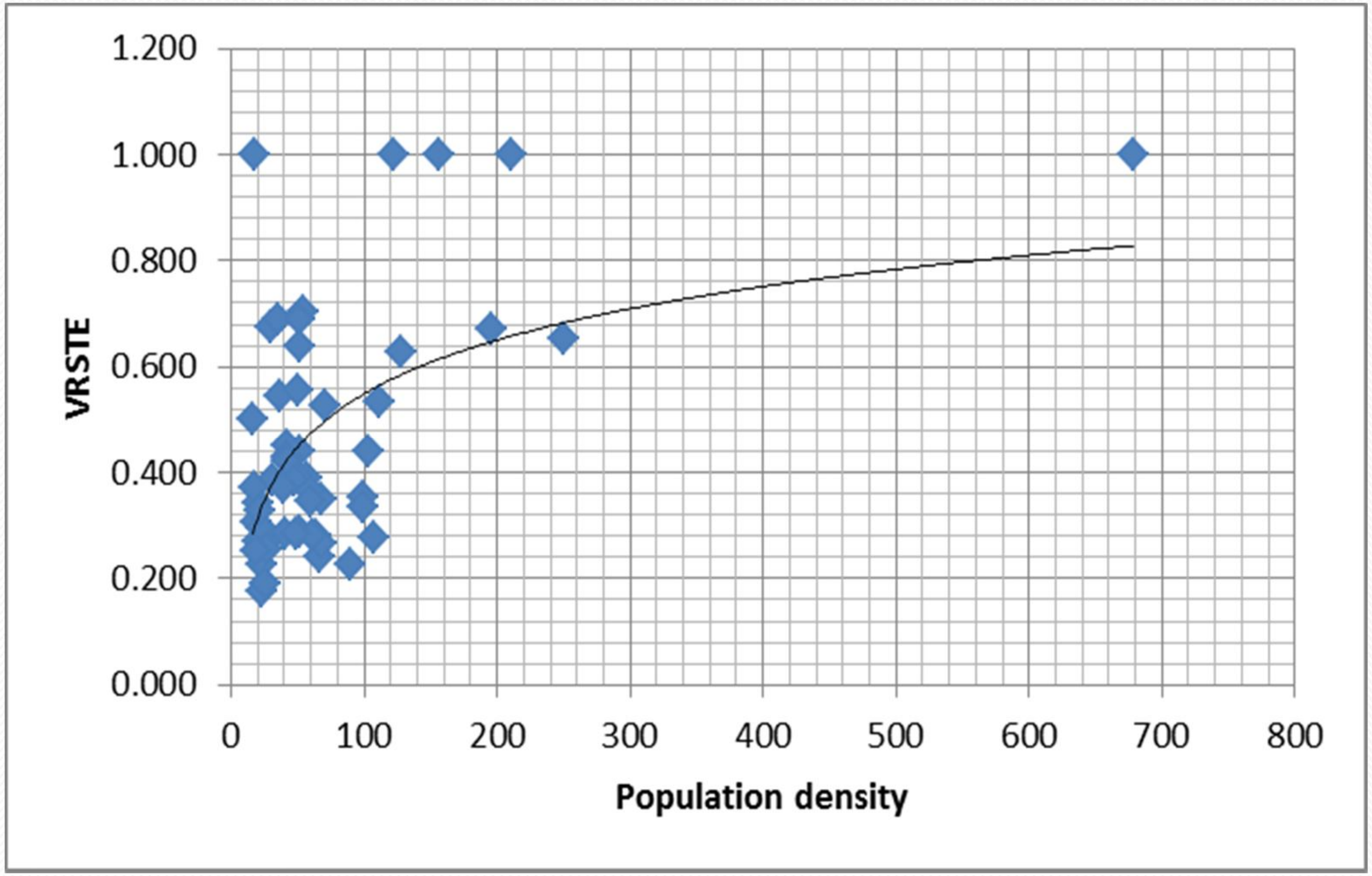
Main results – Customer Density

Firms operating in Very High Density areas achieved the best standard of global efficiency (CRSTE) and show a good capability to purchase and consume input to treat a cubic meter of water

Tobit regression	CRSTE	VRSTE	SE
Size	-0.047	-0.271***	0.237***
Water&Wastewater	0.091*	-0.007	0.061
Density	1.17***	3.29***	-0.165

***, ** and * indicate 1%, 5% and 10% significance levels, respectively

The relationship between population density and VRSTE



Discussion and conclusion (SIZE)

- As regard SIZE, results conflicts with Guerrini et al. (2013); one reason could be the different characteristics of the observed utilities (Italian firms are 7 times greater and operate in water and wastewater segment);
- However the conclusion are similar: global efficiency (CRSTE) is not affected by size;

PRACTICAL IMPLICATIONS

Strategies that aim to extend the area served by wastewater utilities (such as covering new areas or merging with other companies) do not yield cost savings.

Discussion and conclusion (DID)

- Prior studies show the existence of economies of scope when firms invest in business related to the water sector (gas/energy/urban waste); while conflicting results arise when water and wastewater segment are observed (Marques & DeWitte, 2011; Tania & Marques, 2011; DeWitte & Marques, 2011);
- Weak relationship between the integration of water and wastewater segment and efficiency are demonstrated in this study

PRACTICAL IMPLICATIONS

The policy of merger and acquisition of utilities could be followed but it is not strictly recommended

Discussion and conclusion (CD)

- Literature on economies of density is quite scarce, but is consistent in demonstrating the presence of cost savings when firms operate in high densely area (Guerrini et al., 2013; Filippini et al., 2008; Nauges & Van den Berg, 2008; Torres & Morrison-Paul, 2006).

PRACTICAL IMPLICATIONS

A policy of merger and acquisition of firms operating in high densely areas allows to reduce the average costs. Population density should be carefully included in the Danish benchmarking model.

Exploring cost drivers of wastewater utilities

The data collection

DANVA benchmarking reports of 2011, 2012 and 2013.

Variable	Measure	Abbreviation
Transport costs (€)	Unit cost per cubic metre in DKK	TRANS
Treatment costs (€)	Unit cost per cubic metre in DKK	TREAT
Customer handling costs €)	Unit cost per cubic metre in DKK	CH
Completed investments (€)	Unit value per cubic metre in DKK	CI
Volume of water inflow to treatment plants	Cubic metre	VOLIN
Total organic impact	Population equivalent (PE)	OI
Treatment plants above 30,000 (PE)	Number of plants	TP
Population served	Number of inhabitants in the area served	PS
Length of sewers	Kilometres	LS
Population density	Population served/length of sewers	PD
Scope of operations	Mono- or Multi-utility	SO

Three regression functions

- TRANS = f(PD; SO; VOLIN; CI)
- TREAT = f(PS; TP; SO; CI; OI)
- CH = f(SO; PS)

Main results

transport costs	RE	
population density	-0.0042746**	
multi-utilities	-0.9563856**	
volume of inflow to treatment plants	-0.000	
completed investments (DKK)	0.0008659	
Hausman test	Prob>chi2 =	0.9523
treatment costs		FE
population served		0.000
treatment plants above 30 PE		-.0103243
multi-utilities		0.452088
completed investments (DKK)		-0.0064169
total organic impact (PE)		0.000
Hausman test	Prob>chi2 =	0.0000
customer handling costs	RE	
population served	-0.000	
multi-utilities	-0.252655**	
Hausman test	Prob>chi2 =	0.1424

Conclusions

National water authorities should include environmental variables such as ***population density*** *in the benchmarking model adopted for tariff setting.*

Firms could then pursue policies of ***mergers and acquisitions*** *regarding other wastewater utilities operating in high density areas.*

Furthermore, they could promote the ***installation of mini treatment plants*** *in rural and isolated areas, thus reducing or eliminating the cost for wastewater transportation, which is the variable most affected by density.*

Finally, ***a vertical integration strategy must be pursued****, since this reduces transportation costs via the joint provision of water and wastewater services and lightens the burden of the administrative area.*