Consolidation of water utilities: lessons from Central and Eastern Europe[*]

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Abstract

We analyze if recent consolidations of water utilities in Central and Eastern Europe had an effect on cost. Unlike a large part of the existing literature we distinguishes economies of scale from consolidation effects. While related, the empirical analysis shows that the former does not guarantee cost savings through consolidations. On the contrary, consolidations appear to have increased unit costs on average. While part of the finding may be explained by diseconomies of scale for large utilities, we show that consolidations altered the supply composition by adding relatively more additional towns compared to consumption or the number of customers. The findings confirm that the structure of the consolidated utilities has a decisive effect for the outcome. Economies of scale alone are not necessarily enough for lower unit cost.

1 Introduction

While municipality size has generally increased in most European countries over the last decades, many Central and Eastern European countries experienced important decentralization tendencies at the beginning of the 1990's. With the decentralization process, previously centralized or regionalized water provision also became a municipal task. Two decades later, many of these countries are now reconsidering their water provision structure and have embarked on a consolidation of utilities. Hungary, Slovakia and Kosovo have already completed the consolidations and are among the countries with the largest average utility size in the region (see World Bank/IAWD (2015)). In addition, Croatia and Romania are in the process of consolidations and authorities in Moldova, Albania, Bulgaria, and Ukraine are evaluating the potential of such a reform. In short, water and wastewater sectors in Central and Eastern Europe are undergoing a profound reform in terms of the structure of the industry.

The approaches to achieve a larger size of operation for utilities differ substantially between countries and range from voluntary aggregations assisted by financial incentives to removing water provision from the local government level altogether. As the reform

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experiences show (see World Bank/IAWD (2015)), most reforms required either mandatory participation backed by the central government or strong financial pressure/incentives.

The motivation for these reforms is varied and ranges from the intent to reap efficiency gains through larger size of operations to regional cross-subsidization of water tariffs. Another dimension that may be important in the underlying context is the fact that many of the top-down consolidations in Central and Eastern European countries were initiated by the central government to facilitate access to European Union financing. Some EU funds are conditional on a minimum size of the applying region. As a result (new) EU member states and accession countries have an incentive to consolidate their utilities regardless of efficiency considerations.[1]

Regarding the economic motivation, and one of the main arguments in favor, the expectation of cost savings is supported by a large number of economic studies since the late 60's. These studies argue that the water sector is characterized by important economies of scale. The main prediction is that average cost will fall with increasing output over substantial parts of the output range. What is surprising, however, is that there are incredibly few studies of actual reforms.[2]. To the best of our knowledge, only two studies tried to quantitatively address the question of water utility consolidation. By far most empirical papers carry out static comparisons of efficiency between small and large utilities at a given point in time.

This neglect is unfortunate as the presence of economies of scale does not per se guarantee that consolidations will lead to lower unit costs. Similar to the question of natural monopoly, overall economies of scale do not fully describe the behavior of costs as the output bundle changes. In terms of water supply, consolidations can differ dramatically with respect to the relative change in the amount of water, the number of customers, or the number of served towns. Hence, even if economies of scale were present over the whole output range - which is not the case - the compositional change due to a consolidation may lead to an increase or a decrease in unit cost. The design of consolidations is therefore not only a question of merging utilities which operate under increasing economies of scale but also needs to consider the whole production environment for potential optimal configurations. As indicated by González-Gómez and García-Rubio (2008), the consolidation of large high density urban utilities with smaller rural utilities of low density may not necessarily deliver the expected cost savings.

Given the consolidation reforms in Central and Eastern Europe we have obtained a panel dataset of more than 300 utilities with roughly 50 consolidating firms from the International Benchmarking Network (IBNet) database. This allows us to address both questions simultaneously: the effect of consolidations and the presence of economies of scale. In addition to adding to the very small literature on the effect of consolidations, we put a lot of emphasis on the choice of comparable utilities. For this reason we run several matching algorithms to ensure that the comparisons between merging and non-merging utilities are meaningful.

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[1] This motivation seems to have been an important driver for some reforms in the region. For instance in the case of Romania, Kruijf et al. (2009) reports that the improved access to EU cohesion funds seems to have been an important driver, also giving local governments an incentive to support the regionalization plans: ... most interviewees indicated that the establishment of the Intercommunity Development Association (IDA) was not such an important change. It was rather a formality that needed to be fulfilled in order to merge water services into one ROC and to get access to EU funds. (See Kruijf et al. (2009, p. 1066))

[2] Also some of the most influential contributions like Kim (1987) or Garcia and Thomas (2001) do not analyze actual consolidations

In the following, we discuss the existing literature on economies of scale and consolidations in the water sector in section 2. Section 3 estimates the consolidation effects whereas section 4 addresses the question of economies of scale. Section 5 discusses and tries to reconcile the evidence from the previous sections in light of our findings. Section 6 concludes.

2 Economies of scale and consolidations in the water industry

There is a huge literature on economies of scale (and scope) in the water sector. Without doubt, this subject has been among the most researched issues in this industry, also because consolidations of water works has been a major policy option in most sector reforms. Since 2008, at least five articles survey the existing literature and try to take stock of what we know from associated research (see González-Gómez and García-Rubio (2008), Abbott and Cohen (2009), Walter et al. (2009), Carvalho et al. (2012), and Saal et al. (2013)).

Our reading of these surveys is that there are important economies of scale in the industry, which are, however, not unlimited. The evidence appears to be particularly strong in the case of small companies and medium sized companies, much less for large companies. The United Kingdom is given as an example where excessive size might have had negative effects on productivity (see González-Gómez and García-Rubio (2008)). The view that economies of scale decrease with increasing utility size and eventually turn into diseconomies of scale is shared by all five reviews. The studies, however, also note that the estimated optimal utility size appears to vary strongly within and across countries (see Saal et al. (2013)). Abbott and Cohen (2009) notes that the optimal number of connections varies from 100,000 in Fraquelli and Giandrone (2003) to 766,000 in Mizutani and Urakami (2001) and to one million in Fraquelli and Moiso (2005). A similar conclusion is reached in Walter et al. (2009) for output level in m3 of water. As a consequence, the surveys tend to conclude that consolidations are beneficial at least for moderately large utilities.

González-Gómez and García-Rubio (2008) give a very nuanced account regarding the existence of economies of scale by also stressing the role of the overall production environment. According to them, the relevance of customer density and regional dispersion is illustrated in a number of studies. Small density mergers and large geographical service areas might reduce the profitability of a consolidation considerably.

In contrast to the other surveys, the recent literature review by Pollitt and Steer (2012) is mostly critical of what can be concluded from the existing empirical studies. In their review, with a focus on the United Kingdom, they stress that the used definitions of economies of scale and scope are too imprecise to separate the two effects and to evaluate the benefits of integration/consolidation overall. Their main conjecture is that also non-integrated firms may benefit from cooperation and trading in open markets. An argument which is closely akin to the potential benefits of voluntary cooperation between public water utilities as alternative to consolidation. Although most of the presented evidence in Pollitt and Steer (2012) is from other areas such as the energy sector, the authors argue forcefully that it is unclear if advantages from size are not compensated by within-firm transaction costs.

What is surprising when looking at the existing empirical literature is that there are very few true consolidation studies. To the best of our knowledge, the only two quantitative studies of water utility consolidations, analyzing at least a hand full of mergers, are De Witte and Dijkgraaf (2010) and Urakami and Parker (2011). In contrast, virtually all the studies reviewed in the above mentioned survey articles use static ex-ante evaluations. The typical empirical paper uses a cross-section of utilities and infers from the observed variation in water systems configurations (e.g. combinations of i) volume of water, ii) number of customers, iii) number of served cities) how cost changes due to output changes. It is certainly curious that most policy recommendations in favor of consolidations are derived from static comparisons.

Interestingly, the conclusions from the two actual consolidation studies De Witte and Dijkgraaf (2010) and Urakami and Parker (2011) are much less favorable towards utility mergers. The former study is an ex-post evaluation of both the introduced benchmarking system and utility consolidations that occurred after 1997 in the Netherlands. As the goal of their study is also to look at firm specific inefficiency, it uses nonparametric linear programming (FDH) and econometric techniques to assess the impact of these factors on firm performance. The dutch case is interesting as the sector was already highly concentrated before the reforms: The sample period from 1992 to 2007 saw a further decrease in the number of utilities from 20 to 10. Water utilities already had an average production of 69 million m3 to begin with. As a result of the consolidations, this amount increased even further to 111 million m3 on average. Their overall appraisal of the consolidations is ambiguous. While the results varied substantially between nonparametric and parametric, but also between more or less flexible models, no estimation showed a positive and significant effect on scale efficiency. Although not statistically significant, they also find higher average costs after the consolidations. Similar to the case of the United Kingdom (see Saal et al. (2007)), the paper concludes by questioning the benefits of mergers in sectors where the utilities are already large. Moreover from a regulatory standpoint, having too few utilities may represent a drawback.

The consolidation study by Urakami and Parker (2011) differs from the previous one in several respects. Firstly, it has a large sample of several hundreds consolidating utilities. The sample covers Japanese water utilities from 1999 to 2006, which saw a large scale consolidation from 1,958 to 1,602 units. Secondly, Japan other than the United Kingdom or the Netherlands is much more fragmented in terms of water supply and has a large number of utilities of varying size. It might therefore give a more broad account of consolidation effects, considering also small scale units.

The empirical specification involves a translog cost function along with the cost share equations. To evaluate the consolidation effects, also separate estimations for the consolidated and non-consolidated utilities are carried out. Their findings suggest that consolidation had a negative effect on utility costs. While the effect is statistically significant, it is very small, with consolidated utilities being 1.8 percent more productive. Regarding economies of scale, the study finds that on average, both consolidated and non-consolidated utilities are still operating at economies of scale. The authors conclude that benefits from consolidation may not have materialized more clearly because at least some of the mergers involved rural utilities with low density. Moreover, a part of the consolidations in the sample have been very recently, making it hard to evaluate the long-term benefits of consolidation.

What the two existing consolidation studies show is that the particular type of aggregation may matter a lot. Two dimensions appear critical. The initial size of a utility may already be too large and its operation be characterized by diseconomies of scale. The dutch case stressed this fact. Regardless of the initial size, the Japanese case illustrated that

Table 1: Utilities by country

	Consolidated		
COUNTRY_NAME	No	Yes	Total
Albania	30	1	31
Bosnia and Herzegovina	12	1	13
Bulgaria	17	1	18
Croatia	13	1	14
Czech Republic	3	0	3
Hungary	10	7	17
Kosovo	6	0	6
Macedonia, FYR	16	3	19
Moldova	29	0	29
Poland	5	27	32
Romania	7	17	24
Serbia	16	7	23
Slovak Republic	7	0	7
Ukraine	83	0	83
Total	254	65	319

consolidations may also be detrimental to cost efficiency if the absorbed systems are characterized by low density. Particularly large urban utilities might loose economies of density through such mergers.

3 Estimation of consolidation effects

3.1 Data

The main data for our analysis are from the International Benchmarking Network (IBNET) database. IBNET is a data repository initiated and maintained by the World Bank with the objective to improve the service delivery of water supply and sewerage utilities through the provision of international comparative benchmark performance information. Access to detailed utility level data was made available by the Danube Water Program, a World Bank led initiative for water and wastewater services in the Danube region. This leads to a sub-sample of IBNET comprising 14 Central and Eastern European countries.

The utility coverage by IBNET varies strongly between countries, both in terms of the number of utilities as well as the population living in the service area of the utilities. As the objective of this study is to measure the effect of consolidations, some particular utilities were excluded. The main idea was to restrict the comparisons to cases where utilities consolidate, i.e. increase the number of served towns, and utilities which keep the number of served towns stable. For this reason we excluded utilities which experience a reduction in the number of served towns, even if followed or preceded by an increase. These utilities or parts of them might be integrated into other firms in our sample and could therefore blur the effect we try to identify. The eventual number of covered utilities by country is exhibited in Table 1. The 319 utilities span an unbalanced panel of 1,799 utility-year observations from 1995 to 2013. Summary statistics of the used variables are displayed in Table 2.

Table 2: Summary statistics

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**N**
Consolidation	0.15	0.36	0	1	1799
VC	145835616.83	438794654.24	150082.75	2818238208	1799
Y	42.03	161.09	0.02	2517.75	1799
CD	198.63	343.97	2.09	2507.88	1799
SA	10.68	22.05	1	190	1799
WUPIall	66.76	15.38	28.25	99.93	1727
A_30_TOTAL_POP_WATER_SUPPLY	121.96	193.14	2	1460	1799
A_30A_TOTAL_POP_WASTE	117.14	189.61	2	1257	1799
A_34_TOWNS_SERVED_WATER	6.97	14.92	1	130	1799
A_35_TOWNS_SERVED_SEWERAGE	3.71	8.12	0	88	1799
W_40_POP_SERVED_WATER	110.32	182.56	1	1262.88	1799
X_70_POP_SERVED_SEWERAGE	88.31	163.23	0	1245	1799

3.2 Methodology

To evaluate the effect of consolidations, we first focus on the impact on average cost. We define a consolidation as a situation in which the number of serviced cities or towns increases. The dummy variable 'consolidation' is 1 after a consolidation and 0 otherwise. To keep the analysis focused on consolidation and size effects, we lump water and sewerage systems together. This step is taken to avoid the additional complexity when trying to separate economies of scale and scope and is possibly warranted by the fact that almost all utilities offer both services. As the discussion below will show, the empirical strategy is also designed to control for initial differences in the production structure, including the composition of water and wastewater.

In the spirit of a difference-in-difference approach, we run utility-fixed effects regression to compare the performance change of consolidating firms with non-consolidating firms.[3] Some experimentation with the data has shown that the choice of the control group - e.g. the utilities without consolidation that is used as a comparison - is important for the obtained results. Since we are interested in the counter-factual scenario, how would average cost of a utility change in the absence of a consolidation, not all utilities are suitable for comparison. For this reason, we use different matching techniques to select suitable comparison utilities. In the case of nearest-neighbor propensity score matching we use a set of pre-treatment characteristics to estimate the probability that a utility experiences a consolidation (see Rosenbaum and Rubin (1985)). One or several utilities with similar treatment probability are then chosen as the control group. The variables $x_{k,ict}$ to estimate the probability of a consolidation include important utility characteristics like the population in the service area, the number of towns already served, but also the volume of distributed water and treated sewerage or the performance of a utility in terms of managerial and operating efficiency (WUPI).[4]

Apart from the statistical necessity to balance utility characteristics between treatment and control group, this approach also ensures that the consolidation effects are evaluated in comparison to utilities of similar initial size. As the existing empirical literature has stressed decreasing economies of scale and even diseconomies of scale, matching utilities according to their production structure in size and scope seems imperative.

Since the choice of the matching algorithm is somewhat arbitrary, we use five different samples for the control group. We use i) nearest-neighbor propensity score matching, ii) 4-nearest neighbor propensity score matching, iii) radius matching, iv) all utilities in the sample. The different algorithms i) to iii) represent difference choices in the trade-off between bias and variance (see Caliendo and Kopeinig (2008)). All three algorithms are limited to the utilities on common support. The full sample, iv), is displayed for comparison reasons but should be interpreted with care as the compared utilities differ substantially.

These different subsamples of comparable treatment and control utilities are then used in the generalized difference-in-difference specification:

$$ln(AVC_{it}) = \beta_0 + \beta 1 * Consolidation_{it} + \gamma_i + \eta_t + u_{it} \tag{1}$$

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[3] See Angrist and Pischke (2008) or Wooldridge (2010) for comprehensive approaches to the treatment effect literature.

[4] The water utility performance indicator (WUPI) is a composite indicator based on 10 utility key performance indicators published by the World Bank and IWAD for the water utilities in the Danube Region. For details see World Bank/IAWD (2015).

where $ln(AVC_{it})$ are the average variable cost per m3 for utility i in year t (in natural logs of local currency). The regression also includes utility and time fixed effects which means that the effect of $Consolidation_{it}$ is identified by comparing unit costs over time and between treated and control utilities. According to the previously reviewed literature, we would expect the coefficient $\beta 1$ to be negative, suggesting that consolidations are reducing average cost.

It should be noted that the use of variable cost gives our estimates a short-term interpretation. Capital-stock in terms of the network infrastructure is certainly fixed, a modification infeasible or prohibitively costly (See Garcia and Thomas (2001)). The durability of water pipes is somewhere between 30 and 50 years depending on the situation and the chosen material, which would indicate that the system configuration is fixed for a long time horizon indeed. While a comprehensive analysis of short and long-run cost would still be desirable, this is not feasible with the data at hand. Moreover, in most Central and Eastern European countries, utilities/municipalities do not finance investment themselves but receive investment funding from various external sources: central and regional governments, the European Union, but also international donors like the World Bank (see World Bank/IAWD (2015)). For this reason, changes in capital cost due to consolidations might capture various other factors such as political connections and could therefore mask the underlying technological cost effects, if any. It should still be noted that in the long-term, the overall cost effects might be very different from what is measured here by looking at variable cost, since the structure of the supply system might be adapted to the larger network after a consolidation.

To allow for the possibility that the effect of the consolidation is not independent of the number of additional towns, we re-run the above model and replace the indicator variable $Consolidation_{it}$ i) by $ln(Served\_towns_{it})$, the natural log of the number of served towns, and ii) by $Consolidation\_size$, dummy variables distinguishing small consolidations with 1-3 towns ($1.Consolidation\_levels$), medium consolidations with 4-14 towns ($2.Consolidation\_levels$), and large ones with more than 14 towns ($3.Consolidation\_levels$).

The additional two specifications, which we also estimate for all four (matched) samples, are:

$$ln(AVC_{it}) = \beta_0 + \beta 1 * ln(Served\_towns_{it}) + \gamma_i + \eta_t + u_{it} \tag{2}$$

$$ln(AVC_{it}) = \beta_0 + \sum_{k=1}^{4} \beta_k * k.Consolidation\_size_{it} + \gamma_i + \eta_t + u_{it} \tag{3}$$

In all specifications, we cluster standard errors at the utility level and robustify for heteroscedasticity.

3.3 Matching results

Before going to the regression results on the effect of consolidation on average unit costs, this section addresses the results from the matching algorithms that are used to identify useful control utilities. The probit regression to obtain the propensity score is exhibited in Table 3. It should be noted that the period t-1, with t indicating the consolidation period, of consolidated utilities is used in the regression. The pseudo-R-squared of the regression is 0.32, indicating that the chosen variables can help determine the probability that a utility consolidates. Although the included regressors try to capture various different production environments in terms of scale and scope, two features turn out most important. Firstly, the performance indicator WUPI (Water utility performance indicator) is a highly relevant predictor, with higher performance increasing the probability of a consolidation. In addition, the number of towns already served with water is positively correlated with further consolidation. It is interesting to see, however, that the squared term is negative, suggesting that the positive relation decreases and becomes negative after a certain point.

A more substantive measure to evaluate if the matching procedures decreased the observed differences between treatment and control group is displayed in Table 4. The first column of the table shows the initial bias between treated and the full control sample. The measure standardized bias is calculated as the difference in means between the two groups, divided by the standard deviation of the variable in the treated group: $(\overline{X}_{treated} - \overline{X}_{control})/\sigma_{treated}$. As can be seen from the first column in the table, this differences are large and statistically significant for a number of variables in the initial sample. The treatment groups is systematically different from the non-treated group. Columns two to four show the remaining bias after the matching procedures. As a rule of thumb, the absolute values of the remaining bias should not only be statistically insignificant but also be below 25 (see Rubin (2001)). All three applied matching techniques live up to this condition, suggesting that at least on observables, treated and non-treated utilities do not differ after the matching approaches.

3.4 Consolidation results

The estimations of the effect of consolidations on unit costs are shown in Table 5. Here we simply regress the variable costs per m3 on the consolidation dummy, which is 1 after a consolidation. The average effect appears to be positive for each the matched samples, with a value around 0.1. However, except the full sample the results are statistically insignificant. It appears that using a dummy to represent consolidations produces too imprecise estimates as shown by the large standard errors. An alternative way at looking at the problem, but putting more structure on the estimation is by differentiating the number of additional towns that are added through a consolidation. The two associated specifications are shown in Tables 6 and 7. In the first case, we replace the consolidation dummy by the natural log of the number of served cities. A consolidation will increase this number. As can be seen now, the effect of adding towns to a utility's service area increases costs: the coefficients are between 0.08 and 0.12, suggesting that an increase in the number of towns by 1 percentage points increases average variable costs by roughly 0.1%. All coefficients are statistically significantly different from zero.

Looking at Table 7 shows that the effects appear largely driven by large consolidations. The coefficients increase monotonically with larger consolidations and are highly statistically significant only for large consolidations. The effects appear very large as consolidations of the largest size are estimated to increase unit costs by more than 15%. The effect for intermediate or small consolidations is considerably smaller and only weakly statistically different from zero. It seems therefore that depending on its size, average costs can increase rather than decrease after a consolidation. This result corresponds to the findings in De Witte and Dijkgraaf (2010), who find that higher average costs after the consolidations of dutch water utilities - even if not statistically significant in their case.

Table 3: Propensity score regression

	(1) scoreyearind
WUPI	0.0458^{***}
	(5.98)
A_30_TOTAL_POP_WATER_SUPPLY	0.00512
	(1.32)
A_30A_TOTAL_POP_WASTE	-0.00682
	(-1.70)
A_34_TOWNS_SERVED_WATER	0.115^{***}
	(4.57)
[1em] A_34_TOWNS_SERVED_WATER^2	-0.00142^{***}
	(-3.32)
A_35_TOWNS_SERVED_SEWERAGE	-0.0424
	(-0.70)
A_35_TOWNS_SERVED_SEWERAGE^2	-0.00114
	(-0.48)
W_40_POP_SERVED_WATER	-0.000405
	(-0.08)
X_70_POP_SERVED_SEWERAGE	0.00167
	(0.61)
_cons	-5.262^{***}
	(-9.27)
N	1400

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4: Matching Bias Reduction

	Initial bias	NN PSM bias	4-NN PSM bias	Radius bias
WUPIall	155.8***	-11	-0.4	9.7
A_30_TOTAL_POP_WATER_SUPPLY	36.3**	-5.1	5.7	7.9
A_30A_TOTAL_POP_WASTE	30.8**	-7	4.4	6.2
A_34_TOWNS_SERVED_WATER	60.6***	6.6	0.2	9.2
A_34_TOWNS_SERVED_WATER^2	16	4.8	-1.3	6.8
A_35_TOWNS_SERVED_SEWERAGE	24.3	-2.7	4.2	15.2
A_35_TOWNS_SERVED_SEWERAGE^2	-3.4	-5.2	1.3	5.4
W_40_POP_SERVED_WATER	39.5***	-9	4.3	5.9
X_70_POP_SERVED_SEWERAGE	39.4***	-11.3	3.6	6

Table 5: Consolidation effect 1

	(1) AVC	(2) AVC	(3) AVC	(4) AVC
Consolidation	0.0675	0.0439	0.0398	0.163***
	(0.0504)	(0.0492)	(0.0484)	(0.0609)
N	629	865	1860	1901
Sample	NN PSM	4-NN PSM	Radius Matching	Full Sample

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6: Consolidation effect 2

	(1) AVC	(2) AVC	(3) AVC	(4) AVC
ln(Served_towns)	0.143***	0.125***	0.136***	0.188***
	(0.0443)	(0.0461)	(0.0488)	(0.0513)
N	624	854	1769	1808
Sample	NN PSM	4-NN PSM	Radius Matching	Full Sample

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 7: Consolidation effect 3

	(1) AVC	(2) AVC	(3) AVC	(4) AVC
1.Consolidation_size 1-4	0.0174	0.0150	0.0141	0.0386
	(0.0297)	(0.0296)	(0.0292)	(0.0325)
2.Consolidation_size 4-14	0.0722^{*}	0.0673^{*}	0.0650^{*}	0.117^{**}
	(0.0394)	(0.0373)	(0.0361)	(0.0478)
3.Consolidation_size 14+	0.207^{***}	0.195^{***}	0.188^{***}	0.278^{***}
	(0.0575)	(0.0552)	(0.0557)	(0.0708)
N	629	865	1860	1901
Sample	NN PSM	4-NN PSM	Radius Matching	Full Sample

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

4 Estimation of economies of scale

The obtained results appear somewhat in contradiction to a large part of the empirical literature showing that there are economies of scale over a substantial output-range. Although diseconomies of scale have been found in a number of studies for water utilities, the rather clear cost-increasing effect of consolidations found in the previous section is surprising. For this reason, we now compare these results to typical economies of scale estimations. This allows us to do two things: Firstly to compare the consolidation results with the standard measure in the literature to evaluate mergers, economies of scale. While not the same, the presence of economies of scale are typically used to justify or promote consolidations. Secondly, we can evaluate weather the dataset at hand is peculiar in a systematic way that drives these results. While there is no a priori reason to believe so and the matching approach should have taken care of most comparability issues, it might be reassuring to see how the dataset and the consolidations behave in a standard multi-product cost function setting.

We therefore follow the existing literature that studies economies of scale in the water sector (see Caves et al. (1980), Caves et al. (1984), Garcia and Thomas (2001) for classical contributions or Nauges and van den Berg (2008) for a study using IBNET data) and apply a cost function approach.[5] Importantly, to allow for a flexible data generating process, we estimate a translog function (see (see Christensen et al. (1973))) that explains (total) variable cost as a function of Y the volume of water and wastewater, CD the number of customers of a utility and SA the number of served towns:

$$\begin{aligned} ln(VC_{it}) = \beta_0 + \beta_1 * ln(Y_{it}) + \beta_2 * ln(CD_{it}) + \beta_3 * ln(SA_{it}) + \\ \beta_4 * ln(Y_{it})ln(Y_{it}) + \beta_5 * ln(CD_{it})ln(CD_{it}) + \beta_6 * ln(SA_{it})ln(SA_{it}) + \\ \beta_7 * ln(Y_{it})ln(CD_{it}) + \beta_8 * ln(Y_{it})ln(SA_{it}) + \beta_9 * ln(CD_{it})ln(SA_{it}) + \\ \gamma_i + \eta_t + u_{it} \end{aligned} \tag{4}$$

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[5] Our approach differs from most studies in the sense that we estimate the cost function without input prices, do not impose cross-equation restrictions and do not estimate a system by adding cost share equations.

Table 8: Translog cost function

	(1) VC	(2) VC	(3) VC	(4) VC
Y	0.203^{**}	0.199^{**}	0.232^{**}	0.140^{***}
	(0.0836)	(0.0889)	(0.0955)	(0.0432)
CD	0.689^{***}	0.604^{***}	0.402^{**}	0.541^{***}
	(0.164)	(0.175)	(0.171)	(0.140)
SA	0.0788^{**}	0.0992^{*}	0.138^{**}	0.233^{***}
	(0.0321)	(0.0514)	(0.0650)	(0.0755)
c.SA#c.SA	0.0107	0.00543	0.0140	-0.0294
	(0.0136)	(0.0149)	(0.0135)	(0.0210)
c.CD#c.CD	0.292^{**}	0.267^{**}	0.274^{***}	0.0544
	(0.115)	(0.111)	(0.0912)	(0.0489)
c.Y#c.Y	0.0297	-0.00984	-0.00666	-0.0312^{**}
	(0.0551)	(0.0548)	(0.0424)	(0.0151)
c.Y#c.CD	-0.224	-0.134	-0.137	0.0240
	(0.161)	(0.155)	(0.119)	(0.0417)
c.Y#c.SA	0.0809^{*}	0.0668	0.0828^{*}	-0.00232
	(0.0413)	(0.0457)	(0.0457)	(0.0288)
c.CD#c.SA	-0.125^{**}	-0.138^{*}	-0.148^{**}	-0.0576
	(0.0611)	(0.0738)	(0.0644)	(0.0582)
_cons	-0.110	-0.119	-0.0186	0.0541
	(0.102)	(0.111)	(0.150)	(0.118)
N	624	856	1776	1815

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The flexibility comes from the addition of squared and interaction terms of the three 'output' variables Y, CD, and SA. Due to these terms, all variables are demeaned which gives the coefficients from the translog estimation the interpretation of an at the means evaluation. Like in the regressions on consolidation, we add utility and time fixed effects and cluster standard errors on the utility level.

The results from estimating equation 4 are shown in Table 8. As the variables are in natural logarithms, a percentage interpretation arises. The magnitude of the coefficients varies somewhat over the columns (i.e. different matched samples) but remains qualitatively very similar. A one percentage point increase in output (Y) increases cost by 0.2%. A one percentage point increase of customers increases cost between two and three times as much whereas the percentage change increase of costs associated with a percentage change increase in the service area is around 0.1. The positive coefficient on the number of towns also suggest that keeping output and customers fixed, a system with more towns is more expensive to operate than a situation with less systems.

More interesting than the sheer magnitude of the coefficients is an overall measure of economies of scale. As described in the associated literature (see Filippini et al. (2008)) a number of different size effects such as economies of output density, economies of customer density, and economies of scale can be calculated from the obtained cost elasticities.

For our specific case of water provision, economies of scale measure the reaction of costs to a proportional increase in output, number of customers and service area. This yields:

$$E_S = \left(\frac{\delta VC}{\delta Y} + \frac{\delta VC}{\delta CD} + \frac{\delta VC}{\delta SA} \right)^{-1} \tag{5}$$

where SA is the service area. In this case, customer density and output per customer are held fixed. As noted above, the coefficients in translog are evaluate at the sample means. To account for the fact that the cost effect of increasing the scale of operations likely depends on the initial size of the utility, we re-estimate the previous translog regressions at various percentiles of the empirical size distributions: the 10th, 25th, 50th (median), 75th, 90th percentiles. In each case we set all three variables - Y, CD, SA - to the respective percentile.

Table 9: Translog cost function

	(1) p10 Y=3,CD=26,SA=2	(2) p25 Y=7,CD=76,SA=2	(3) p50 Y=18,CD=181,SA=9	(4) mean Y=14,CD=167,SA=9	(5) p75 Y=39,CD=385,SA=28	(6) p90 Y=66,CD=26,SA=50
NN-PSM	1.41	1.13	1.03	1.03	0.95	0.86
	(0.20)	(0.05)	(0.02)	(0.02)	(0.02)	(0.02)
4-NN-PSM	1.47	1.14	1.08	1.08	1.01	0.92
	(0.25)	(0.06)	(0.03)	(0.03)	(0.03)	(0.03)
Radius	1.62	1.20	1.06	1.07	0.96	0.85
	(0.27)	(0.06)	(0.02)	(0.02)	(0.02)	(0.02)
Full Sample	1.03	0.99	1.16	1.16	1.33	1.40
	(0.04)	(0.03)	(0.04)	(0.04)	(0.12)	(0.23)

Standard errors in parentheses

The results in Table 9 exhibit the common decreasing returns to scale pattern, showing increasing returns to scale for firms smaller and medium sized firms whereas large and very large firms may already operate in the region of diseconomies of scale. This is very similar to a number of studies on economies of scale in the water sector. In the underlying sample the point of constant returns to scale is somewhere between the 50 and 75 percentile.

5 Reconciling economies of scale and consolidation effects

The previous empirical sections have shown two things: Firstly, that there are important economies of scale in the analyzed water and sanitation sectors, at least up until a certain threshold. Secondly, the analyzed consolidation cases, which also directly enter the calculation of the measure of economies of scale, reveal unit cost increases through consolidations. At first sight, the two findings appear inconsistent and one might be surprised to find such contradictory results based on the same data.

Given the previous discussions, two potential reasons arise why the consolidations might not have decreased unit cost. To start with, the results on economies of scale have confirmed the findings in the existing literature that large utilities may already operate at diseconomies of scale. Our estimates in Table 9 suggest that diseconomies start somewhere before the 75th percentile ($Y=39,CD=385,SA=28$). As displayed in Figure 1, some of the consolidating utilities have already been operating well beyond this point, but not all of them. The distribution of the graph also shows that a sizable number of the utilities should be considered small and medium sized, hence not yet affected by economies of scale. As a result, the diseconomies of scale argument relating to the initial size of the consolidating utilities is a only a partial explanation for the observed increase in average costs after mergers.

The second potential source of increasing unit costs due to consolidations relates to the type of consolidation. Particularly system/town heavy consolidations with low density rural areas may be detrimental from a cost perspective. To capture this density effect, we compare the average number of customers per served town before and after the consolidations. Figure 2 shows the associated results in a box plot graph. It is obvious that the aggregations have strongly decreased density. While the median was roughly 50 thousand customers per town before, it was less than 10 thousand customers per town after the consolidations. This shows impressively that the typical consolidation in our sample involved adding many towns and systems relative to the number of customers and therefore also volume.

In terms of relative change, we also find that the average aggregation increased output by 2 percent, customers by 3 percent and the number of towns by 40 percent (or 5 cities).[6] In line with the translog regressions in Table 8, adding systems while keeping output Y constant will increase both overall but also average cost. This interpretation is also consistent with the conclusion in Urakami and Parker (2011) that consolidations in sparsely populated rural systems may be at the cost of economies of density.

On a more general note, the results also show that one should use economies of scale results very carefully for policy recommendations regarding utility consolidations. The interpretation of economies of scale as a proportional increase in overall scale, i.e. in output,

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[6] These figures were obtained by regressing the relative changes per year per utility on a consolidation dummy with 1 after the consolidation and zero otherwise.

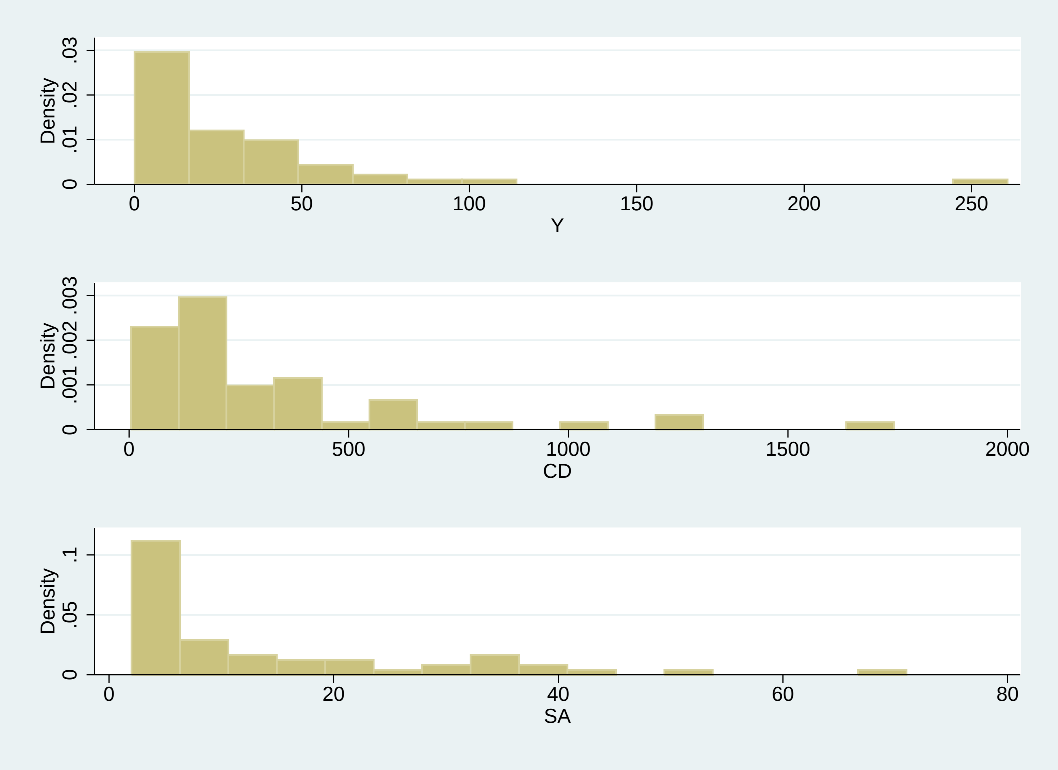

Figure 1: Size distribution before consolidation

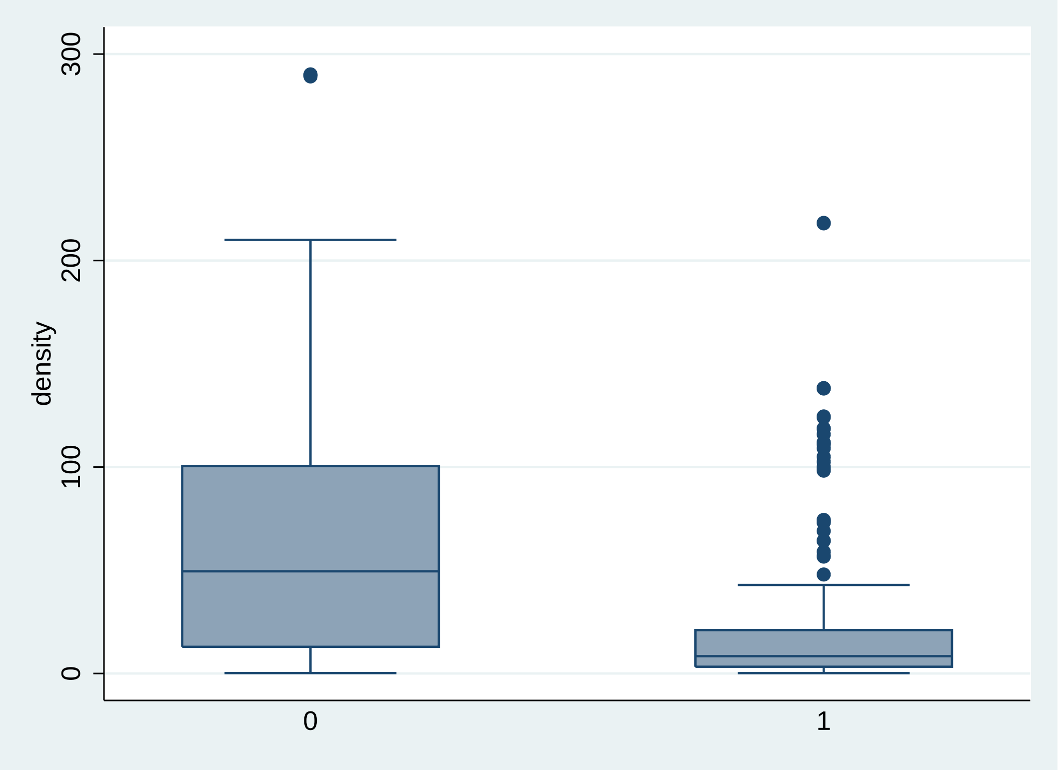

Figure 2: Density before and after consolidation

customers and served towns, does not seem to capture well the real-world consolidations in our sample.

6 Conclusion

This study tries to make the point that the effect of consolidations varies gravely, depending on its design and the technological and geographical circumstances. We find that the consolidations analyzed in this paper tend to have increased unit costs. Importantly, only part of the result can be explained by the fact that the utilities operated under diseconomies of scale already before the consolidation. In general, our estimations suggest that despite economies of scale being present over a considerable output range, consolidations were detrimental from a cost perspective. We read this finding as evidence that economies of scale capture the expected effects of consolidations only imperfectly. While the former assume a proportional increase in output, customers and the number of served systems, the average consolidation observed here was much more system heavy. In contrast output and customers increased by a relatively smaller amount. To summarize, the consolidations had a strongly negative effect on customer density, which is likely responsible for the unit cost increase.

Although we have little information on whether consolidations typically follow this pattern, it would be desirable if future research could shed light on the issue. Even if due to data limitations the effects of consolidations cannot be measured directly, already a description of the consolidation design and process could prove highly insightful. A promising case for such an exercise would be Italy, which in the aftermath of the Galli law also aggregated its highly fragmented water supply system on the regional level.

7 References

References

Abbott, M. and Cohen, B. (2009). Productivity and efficiency in the water industry. *Utilities Policy*, 17(3):233–244.

Angrist, J. D. and Pischke, J.-S. (2008). *Mostly harmless econometrics: An empiricist's companion*. Princeton university press.

Caliendo, M. and Kopeinig, S. (2008). Some practical guidance for the implementation of propensity score matching. *Journal of economic surveys*, 22(1):31–72.

Carvalho, P., Marques, R. C., and Berg, S. (2012). A meta-regression analysis of benchmarking studies on water utilities market structure. *Utilities Policy*, 21:40–49.

Caves, D. W., Christensen, L. R., and Tretheway, M. W. (1980). Flexible cost functions for multiproduct firms. *The Review of Economics and Statistics*, pages 477–481.

Caves, D. W., Christensen, L. R., and Tretheway, M. W. (1984). Economies of density versus economies of scale: why trunk and local service airline costs differ. *The RAND Journal of Economics*, pages 471–489.

Christensen, L. R., Jorgenson, D. W., and Lau, L. J. (1973). Transcendental logarithmic production frontiers. *The review of economics and statistics*, pages 28–45.

De Witte, K. and Dijkgraaf, E. (2010). Mean and bold? on separating merger economies from structural efficiency gains in the drinking water sector. *Journal of the Operational research Society*, 61(2):222–234.

Filippini, M., Hrovatin, N., and Zoric, J. (2008). Cost efficiency of slovenian water distribution utilities: an application of stochastic frontier methods. *Journal of Productivity Analysis*, 29(2):169–182.

Fraquelli, G. and Giandrone, R. (2003). Reforming the wastewater treatment sector in italy: Implications of plant size, structure, and scale economies. *Water Resources Research*, 39(10).

Fraquelli, G. and Moiso, V. (2005). Cost efficiency and scale economies in the italian water industry. *Higher Education and Research on Mobility, Regulation and the Economics of Local Services (HERMES), Working Paper*, 8.

Garcia, S. and Thomas, A. (2001). The structure of municipal water supply costs: application to a panel of french local communities. *Journal of Productivity analysis*, 16(1):5–29.

González-Gómez, F. and García-Rubio, M. A. (2008). Efficiency in the management of urban water services. what have we learned after four decades of research. *Hacienda Pública Española/Revista de Economía Pública*, 185(2):39–67.

Kim, H. Y. (1987). Economies of scale in multi-product firms: An empirical analysis. *Economica*, 54(214):185–206.

Kruijf, J. V., Dinica, V., and Augustijn, D. (2009). Reorganization of water and waste water management in romania: from local to regional water governance. *Environmental Engineering & Management Journal (EEMJ)*, 8(5).

Mizutani, F. and Urakami, T. (2001). Identifying network density and scale economies for japanese water supply organizations. *Papers in Regional Science*, 80(2):211–230.

Nauges, C. and van den Berg, C. (2008). Economies of density, scale and scope in the water supply and sewerage sector: a study of four developing and transition economies. *Journal of Regulatory Economics*, 34(2):144–163.

Pollitt, M. G. and Steer, S. J. (2012). Economies of scale and scope in network industries: Lessons for the uk water and sewerage sectors. *Utilities Policy*, 21:17–31.

Rosenbaum, P. R. and Rubin, D. B. (1985). Constructing a control group using multivariate matched sampling methods that incorporate the propensity score. *The American Statistician*, 39(1):33–38.

Rubin, D. B. (2001). Using propensity scores to help design observational studies: application to the tobacco litigation. *Health Services and Outcomes Research Methodology*, 2(3-4):169–188.

Saal, D. S., Arocena, P., Maziotis, A., and Triebs, T. (2013). Scale and scoe economies and the efficient vertical and horizontal configuration of the water industry: a survey of the literature. *Review of Network Economics*, 12(1):93–129.

Saal, D. S., Parker, D., and Weyman-Jones, T. (2007). Determining the contribution of technical change, efficiency change and scale change to productivity growth in the privatized english and welsh water and sewerage industry: 1985–2000. *Journal of Productivity Analysis*, 28(1-2):127–139.

Urakami, T. and Parker, D. (2011). The effects of consolidation amongst japanese water utilities a hedonic cost function analysis. *Urban Studies*, 48(13):2805–2825.

Walter, M., Cullmann, A., von Hirschhausen, C., Wand, R., and Zschille, M. (2009). Quo vadis efficiency analysis of water distribution? a comparative literature review. *Utilities Policy*, 17(3):225–232.

Wooldridge, J. M. (2010). *Econometric analysis of cross section and panel data*. MIT press.

World Bank/IAWD (2015). Water and wastewater services in the danube region: A state of the sector. Regional Report, International Bank for Reconstruction and Development/The World Bank. Available online at `http://sos.danubis.org/files/File/SoS_Report.pdf`; visited on May 24th 2015.