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Consolidating the Water Industry: An Analysis of the Potential Gains from Horizontal Integration in a Conditional Efficiency Framework*

Michael Zschille †

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Abstract

The German potable water supply industry is regarded as being highly fragmented, thus inhibiting high potentials for efficiency improvements through consolidation. Focusing on a hypothetical restructuring of the industry, we apply Data Envelopment Analysis (DEA) to analyze the potential efficiency gains from mergers between water utilities at the county level. A conditional efficiency framework is used to account for the operating environment. Highest efficiency improvement potentials turn out to result from reducing individual inefficiencies. The majority of the 84 merger cases is characterized by merger gains, which are decomposed into a technical efficiency effect, a harmony effect and a scale effect. The results suggest to improve incentives for efficient operations in water supply and a consolidation of the industry structure.

JEL-Codes: C14, L22, L25, L95

Keywords: Water Supply, Horizontal Integration, Data Envelopment Analysis, Conditional Efficiency, Nonparametric Estimation

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1 Introduction

1.1 Motivation and industry background

Potable water supply in Germany is the subject of intense political debate. The main focus of this debate lies in the prices charged for the supply of drinking water to the final customers and on how to appropriately regulate the water industry, see Hirschhausen et al. (2009). However, the industry structure itself still lacks appropriate attention. Similar to other countries, like Japan and Portugal, the German water industry is highly fragmented, with 6,211 water utilities in 2007, see Statistisches Bundesamt (2009). In contrast to this degree of fragmentation, by 2007 water industries were consolidated in England, Wales and in the Netherlands. In England and Wales, 22 companies, of which 10 are integrated water and sewerage companies, supply water to the final customers (Bottasso and Conti (2009)). There are only 13 companies in the Netherlands (De Witte and Marques (2010)).

Water supply in West Germany was highly fragmented for political reasons. By West German constitution, potable water provision was the responsibility of municipal governments. Municipalities could decide whether to provide water services on their own or to assign this task to a third party. Municipalities had wide latitude in the structures, including cooperating with other municipalities. These possibilities led to a variety of organizational arrangements. It is common that a utility will supply water and other services, like electricity, natural gas, and other services. These other services might include local public transport and telecommunications. These municipal multi-product companies are usually known as "Stadtwerke" that can either be publicly or privately owned, and in some cases, partially privatized.

In contrast to the structures in West Germany, in the former East Germany 16 water utilities supplied water to all the final customers, divided at a regional level. After reunification, the task of water supply was assigned to local municipal governments. The 16 water utilities were split up into more than 550 utilities, using the West German model (Bundesministerium für Wirtschaft und Arbeit, 2005, p. 5). This was followed with some re-consolidation, such that water utilities in the former East Germany are often organized as a jointly held company serving several municipalities.

However, the former West German water utilities usually provide water and other services to customers only within its municipal territory. In its 2010 biannual report, the German Monopolies Commission (Monopolkommission

(2010)) recommends both incentive-based regulation and a substantial consolidation of the German water industry, since there might be efficiency gains from mergers. Following the report of the Monopolies Commission, the German Federal Government (Bundesregierung (2010)) decided not to regulate the water industry. Even though the federal government will not enforce consolidation, water utilities are encouraged to investigate the potential for mergers with other companies. The issue of industry restructuring and consolidation thus still is of great interest. It is arguable that larger companies might be able to operate more efficiently, better handle the consequences of climate change, as well as find it easier to meet the increasing regulations on water quality and the sustainable use of raw water resources as opposed to smaller companies. Potential merger gains may result from reduced management overhead in the integrated companies as well as the possibility of further optimizations in raw water abstraction and production.

Due to the high importance of water industry restructuring considerations in Germany and other countries, this article makes a contribution to the literature by analyzing the potential efficiency gains from mergers between water utilities using a Data Envelopment Analysis (DEA) approach proposed by Bogetoft and Wang (2005). Especially in the water industry it is necessary to appropriately take the operating environment into account for efficiency analysis. Thus we apply the conditional efficiency framework proposed by Daraio and Simar (2005, 2007) in order to allow for the consideration of structural variables in DEA. Based on the conditional DEA estimates, we then analyze hypothetical cases of horizontal integration between water utilities located within the same county. To validate the results, we further calculate conditional efficiency scores and merger gains including bias corrections according to Simar and Wilson (1998). We contribute to the literature on conditional efficiency approaches and their applications by analyzing the potential efficiency gains from mergers in a conditional efficiency framework. To our knowledge, this article is the first analysis of the potential gains from horizontal integration in the water industry.

1.2 State of the literature

The existence of economies of scale can be used as a first indicator for potential efficiency gains from mergers. Extensive reviews of the empirical literature on scale economies in water supply are provided by Saal et al. (2011b), Abbott and Cohen (2009) and Walter et al. (2009). Most experience in wa-

ter industry restructuring and on the estimation of scale economies originate from England and Wales, where significant structural and regulatory reforms started being implemented in 1989. Saal et al. (2007) find negative scale effects in the productivity growth of water and sewerage companies (WaSCs) over the period between 1985 and 2000. Short- and long-run diseconomies of scale for WaSCs are found in Ballance et al. (2004), while they find constant returns for water only companies (WoCs). The results of Ashton (2003) indicate the existence of slight diseconomies of scale for English and Welsh water companies using panel data for 1991-1996. This result is confirmed by Saal et al. (2011a) for WoCs using an unbalanced panel of 234 observations for the years 1993-2009. In contrast, Bottasso and Conti (2009) find small economies of scale for the English WoCs using panel data from 1995 to 2005. The results show that consolidation might be beneficial especially in densely populated service areas.

Focusing on French water supply, Garcia and Thomas (2001) analyze a sample of 55 water utilities in Bordeaux for the years 1995-1997. Economies of scale are estimated based on a translog variable cost function. For the majority of water utilities in the sample, Garcia and Thomas find economies of scale greater than one, suggesting that mergers between water utilities are beneficial. Garcia and Thomas further show that merging up to 5 water utilities would be most beneficial in the Bordeaux case.

Several studies focus on scale economies in Italian water supply, which, similar to the German case, is highly fragmented with around 6,000 water utilities, see e.g. Antonioli and Filippini (2001) or Fabbri and Fraquelli (2000). Using a cross-section sample of 173 water utilities in 1991, Fabbri and Fraquelli (2000) find economies of scale for the majority of observations, while the largest observations are characterized by diseconomies of scale. Arguing that the sample average firm supplies water to about 160,000 inhabitants and that the national average firm serves about 9,000 inhabitants, Fabbri and Fraquelli conclude that most Italian water utilities could benefit from an increase in firm size. In contrast, Antonioli and Filippini (2001) find weak diseconomies of scale for a panel of 32 water distribution companies over the 1991-1995 period. They however point out the drawbacks of the Cobb-Douglas functional form for their estimated variable cost function since scale elasticities are assumed to be constant for all firm sizes.

Using a nonparametric model, De Witte and Marques (2011) and Marques and De Witte (2011) analyze scale economies in the Portuguese water sector based on a sample of about 60 water utilities in 2005. They find that the 2005

number of 300 water utilities should be reduced to 60 water utilities. Optimal firm size is found to lie around a level of 160,000 up to 180,000 inhabitants. For a cross-section sample of 265 water suppliers in 2002, Martins et al. (2011) estimate a short-run total cost function and find economies of scale for all analyzed output levels.

Japan is another example of a highly fragmented water industry. According to Urakami and Parker (2011), more than 17,000 water utilities were under operation in 2005. By estimating a total cost function for 112 water companies in 1994, Mizutani and Urakami (2001) find low diseconomies of scale and significant economies of density, whereas Urakami (2006) and Urakami and Parker (2011) confirm the existence of scale economies.

Kim and Clark (1988) analyze a cross section data sample of 60 US water utilities in 1973. The results indicate weak economies of scale for the smallest utilities which are decreasing with increasing output levels. Further focusing on product-specific economies of scale, they find diseconomies of scale for water delivered to residential customers and economies of scale for water delivered to non-residential customers. For the overall output level, Kim and Clark conclude that there are no significant economies of scale. Bhattacharyya et al. (1995) focus on the impact of ownership on the efficiency of US water suppliers using a sample of 221 water utilities in 1992. They show that private operators could benefit from higher output levels while public operators could benefit from reduced firm sizes. Torres and Morrison Paul (2006) use a cross section sample of 255 water utilities for the year 1996 and find economies of scale in US water supply given that consolidation leads to a higher output density. They argue that a consolidation of smaller utilities is efficient given that economies from an increase in output volumes compensate for diseconomies in the expansion of the distribution network. Garcia et al. (2007) focus on vertical integration in the Wisconsin water industry analyzing a sample of 211 water utilities for the period 1997-2000. They find evidence for scale economies in vertically integrated companies that both produce and distribute water, while they find no evidence for scale economies in pure water production or water distribution companies. They argue that the vertically integrated companies are, on average, significantly smaller than the separated ones, i.e. economies of scale are not exhausted.

Nauges and van den Berg (2010) analyze the scale characteristics of 295 water utilities in 14 developing and transition countries and find increasing returns to scale for 62% of the water utilities. For a sample of 43 Peruvian water utilities over the period from 1996 to 2005, Corton (2011) finds

economies of scale for all water utilities under consideration.

Due to the varying evidence on economies of scale, no general conclusions on optimal firm size can be drawn. Results heavily depend on the analyzed country, on the characteristics of the operating environment and on firm characteristics like the joint provision of water and sewerage services. As a general consensus, the existence of scale economies usually is confirmed for small-scale water utilities up to some threshold level for firm size where economies of scale turn into diseconomies, as shown for example in Fabbri and Fraquelli (2000), Fraquelli and Moiso (2005) or Garcia and Thomas (2001). For the case of Germany, Sauer (2005) shows that the firm size optimum of rural water utilities lies around an output level of 3.592 million cubic meters of water and a network length of 808.8 km with 18,453 connections. On average, optimal firm size is found to be three times larger than under the current market structure. The optimal firm size level derived by Sauer (2005) however is significantly smaller than in empirical analyses for other countries like e.g. for Italy or Portugal. This might be explained by the underlying data sample of Sauer (2005), which only contains information on rural water utilities.

Beside the issue of economies of scale, the scientific literature provides little empirical evidence on the efficiency impact of horizontal integration in the water industry. De Witte and Dijkgraaf (2010) provide a post-merger analysis of the Dutch water sector and do not confirm significant merger economies. They find no significant economies of scale or increased incentives to reduce inefficiencies within the water companies. Ballance et al. (2004) provide an analysis of mergers in the English and Welsh water industry by comparing the cost functions of merged firms and non-merger firms. Applying tests of parameter constancy to the cost functions of both integrated and non-integrated water utilities, significant differences are not confirmed. They find no evidence for a significant decline in costs after a merger. Urakami and Parker (2011) analyze mergers in the Japanese water supply industry and find some positive but small impact of consolidation on efficiency by slowing down cost increases to a small extent.

However, the current literature provides no empirical evidence on the ex-ante analysis of potential merger gains in the water industry. Empirical evidence on the potential efficiency gains from hypothetical mergers so far is only known for other industries like e.g. for electricity supply, hospital services and urban transit, see Bagdadioglu et al. (2007), Kristensen et al. (2010) and Viton (1992), respectively.

The remainder of this article is structured as follows: in Section 2 we describe the DEA approaches used for our analysis, Section 3 presents the data sample and results are shown in Section 4. Section 5 concludes.

2 Methodology

2.1 Data Envelopment Analysis

The analysis of the potential gains from mergers requires the estimation of the underlying technology set of the water utilities. This can be done by either using Stochastic Frontier Analysis (SFA) or Data Envelopment Analysis (DEA). We choose a DEA approach for our analysis. In contrast to parametric approaches, strong *a priori* assumptions on the functional form of the technology set can be avoided. DEA uses linear programming methods to construct a piece-wise frontier around the observations in the sample by assigning weights λ to the peer units. The frontier is then determined by those peer units, i.e. by the efficient observations with an efficiency score equal to one. The efficiency of the remaining observations is determined by the distance of each observation from the frontier. We assume an input orientation to analyze the possible proportional reduction of all inputs while outputs are assumed to remain constant. This is a valid assumption since the demand for water can be regarded as being exogenously given, thus not directly being influenceable by the water utilities.

We further assume a non-decreasing returns to scale (NDRS) technology for our analysis. Following standard microeconomic theory, the NDRS assumption implies that an up-scaling of firm sizes is always possible while down-scaling is not. Under constant returns to scale (CRS) it is always possible to scale firm sizes either up or down, the smallest water utilities in the data sample however would usually be evaluated as being less efficient than under a NDRS assumption. The NDRS assumption thus leads to more conservative efficiency estimates as compared to the CRS case. It is furthermore arguable that a further down-scaling of the small water utilities in the data sample as being possible under a CRS assumption would make no economic sense given the already high fragmentation of German water supply. On the other hand, the assumption of variable returns to scale (VRS) would highly restrict the possibilities for analyzing merger gains through strictly bounding the DEA technology set since an up- or down-scaling of firm sizes

is not always possible. Given the small-scale structure of the water utilities in Germany and the existence of larger water utilities in other countries like in the UK or the Netherlands, an expansion of the technology set from VRS to NDRS thus seems reasonable.

The DEA linear program for the determination of the Farrell (1957) efficiency score for each observation i under the assumption of NDRS is given by

$$\begin{aligned} \widehat{\theta}^{i}_{DEA}(x,y) = \ inf\{\theta|\ y^i \leq & \sum_{k=1}^{K} \lambda^k y^k; \\ \theta x^i \geq & \sum_{k=1}^{K} \lambda^k x^k; \\ & \sum_{k=1}^{K} \lambda^k \geq 1,\ \lambda \in \mathbb{R}^K_+\}, \end{aligned} \tag{1}$$

with x denoting a p-dimensional vector of inputs, y a q-dimensional vector of outputs, λ a set of weights and $k = \{1, \ldots, K\}$ the full set of observations.

2.2 Accounting for the operating environment

Water operations heavily depend on the operating environment and on the characteristics of a service area. Examples include the differences between rural and urban areas as well as the availability and characteristics of the raw water resources. Thus considering the operating environment is fundamental when analyzing water utilities to ensure that water utilities are only compared to other water utilities in similar operating environments. The literature provides different approaches for the consideration of environmental variables in DEA. In most applications multi-stage approaches are used, including the calculation of standard DEA efficiency scores in a first step, a regression analysis of the efficiency scores on structural variables in a second step and different approaches to account for the relevant structural variables in the following steps.[1] Daraio and Simar (2005, 2007) argue that typical multi-stage approaches rely on a separability condition between the input and output space used in DEA and the space of environmental variables z,

[1] A short overview of possible approaches to incorporate the operating environment into DEA is given in Coelli et al. (2005).

i.e. that the DEA frontier is not influenced by the structural variables. To overcome this separability condition, Daraio and Simar suggest estimating the DEA technology set by conditioning on the characteristics of the operating environment of each individual observation. This approach requires the smoothing of the z-variables through the estimation of a Kernel function. Daraio and Simar (2005) recommend using a Kernel function with compact support, i.e. a Kernel function $K(.)$ with $K(u) = 0$ if $|u| > 1$ with $u = \frac{|z_i - z_k|}{h}$. Here, z_i denotes the vector of structural variables of the decision making unit (DMU) under consideration, z_k the structural variables of all other observations and h the selected bandwidth. We estimate an *Epanechnikov* Kernel for this purpose. This procedure guarantees that only those observations are selected into the set of possible peer units of a DMU that lie within the neighborhood around z_i.[2]

While Daraio and Simar (2005) introduce the concept of conditional efficiency measures for the order-m and Free Disposal Hull (FDH) cases, the framework is extended to the DEA case in Daraio and Simar (2007). The conditional DEA technology set under the assumption of non-decreasing returns to scale is defined as

$$\begin{aligned} \widehat{\Psi}^z_{DEA} = \{(x,y) \in \mathbb{R}^{p+q}_+ \mid y \leq & \sum_{\{k|z_i - h \leq z_k \leq z_i + h\}} \lambda^k y^k; \\ x \geq & \sum_{\{k|z_i - h \leq z_k \leq z_i + h\}} \lambda^k x^k; \\ & \sum_{\{k|z_i - h \leq z_k \leq z_i + h\}} \lambda^k \geq 1,\ \lambda \in \mathbb{R}^K_+\}. \end{aligned} \tag{2}$$

As shown in equation 2, only those observations are used for the construction of the DEA frontier for DMU i that lie within the chosen bandwidth h around z_i. Efficiency scores $\theta^i_{DEA}(x, y|z)$ for each observation i can then be derived from this technology set.

Based on the conditional efficiency approach, Daraio and Simar (2005, 2007) propose using a graphical analysis to illustrate the impact of the en-

[2] According to De Witte and Marques (2010), we use the Mahalanobis transformation for the decorrelation of the z-variables. The bandwidth h is chosen by using the likelihood cross-validation principle based on a k-nearest neighbor (k-NN) approach and, following the suggestion by Daraio and Simar (2005), expanded by the factor $1 + n^{-\frac{1}{(p+q)}}$ to account for the dimensionality of the input vector x and the output vector y and for the sparsity of points in higher dimensional space.

vironmental variables on efficiency. They suggest to nonparametricly regress the ratio $\frac{\widehat{\theta}^i_{DEA}(x,y|z)}{\widehat{\theta}^i_{DEA}(x,y)}$, i.e. the ratio between the conditional and the unconditional efficiency scores, on an environmental variable z. A scatter plot including a smooth nonparametric regression line can be used to illustrate the efficiency-impact of the variable under consideration. An increasing regression line indicates an unfavorable impact of the z-variable on efficiency, since efficiency is greater when conditioning on the environmental variable. A decreasing regression line indicates a favorable impact on efficiency. For our analysis, we thus calculate efficiency scores conditional on each of the environmental variables, while neglecting the impact of the remaining variables in each case and calculate the ratio between the conditional and the standard, unconditional DEA efficiency scores.

2.3 Detection of influential observations

Since DEA is usually sensitive to outliers or extreme observations in the data, a profound validation of the data is necessary. Banker and Gifford (1988) and Banker and Chang (2006) propose using the *super-efficiency* concept for this purpose. For each observation i, the idea of the super-efficiency approach is to solve the linear program given in equation 1 by only using all observations $k = (1, \ldots, K)$ other than i, i.e. $k \neq i$, as possible peer units. The observation i under consideration is thus not included into the reference set, i.e. DMU i can obtain an efficiency score greater than one and is evaluated as being super-efficient in this case. For the detection of potential outliers, Banker and Chang (2006) propose using different threshold values for the super-efficiency scores and to delete all observations with efficiency scores greater than the chosen threshold value. We choose a graphical analysis for this purpose and look at the distribution of the super-efficiency scores by plotting histograms to detect all extreme observations. This procedure is sequentially repeated until no obvious outliers remain.

As for the standard DEA approach, the results of the super-efficiency approach also depend on the operating environment. We thus extend the idea of the standard super-efficiency approach to the *conditional super-efficiency* case. The frontier for observation i is thus determined only by observations other than i that lie within the chosen bandwidth around z_i and thus face a similar operating environment. Similar to the standard super-efficiency approach, outliers are determined based on a graphical analysis. By sequen-

tially repeating this procedure, all obvious outlying observations are removed from the sample. In each step, bandwidths for the environmental variables are re-optimized and adjusted for the reduced sample size.

2.4 Potential merger gains

Based on the estimated conditional DEA frontier, it is possible to analyze hypothetical cases of horizontal integration between water utilities in more detail. Considering a merger of J firms out of the full set of observations $k = \{1, \ldots, K\}$ into the integrated firm denoted by DMU^J, Bogetoft and Wang (2005) propose a simple direct pooling of the inputs x and outputs y of the individual firms to be merged. We thus obtain an integrated firm DMU^J that uses $\sum_{j \in J} x^j$ units of input to produce $\sum_{j \in J} y^j$ units of output.

Following the notation of Bogetoft and Wang (2005), the input-oriented Farrell efficiency measure of the integrated company is then defined as

$$E^J = \min\{E \in \mathbb{R}_+^{p+q} | (E \sum_{j \in J} x^j, \sum_{j \in J} y^j) \in \widehat{\Psi}_{DEA}^{*,\,z}\}. \tag{3}$$

The underlying DEA technology set is denoted by $\widehat{\Psi}_{DEA}^{*,\,z}$. For the analysis of hypothetical cases of horizontal integration, we use the technology set estimated before any merger as the reference set. As indicated by the superscript z, the conditional pre-merger technology set from equation 2 is used for this purpose.[3] The efficiency of the merged entity, E^J, represents the *potential overall gains from merging.* It is the simple efficiency evaluation of a hypothetical DMU using the sum of inputs of the pre-merger firms to produce the sum of the pre-merger outputs. A merger is assumed to be beneficial for $E^J < 1$. A value of $E^J = 0.9$ e.g. indicates a potential for input savings of 10% through merging the companies in J. For $E^J > 1$, a merger is assumed to have a negative impact on efficiency.[4]

[3]In our analysis we focus on hypothetical mergers between water utilities located in the same *Landkreis*, the German equivalent of a county. For the application of the conditional efficiency approach, structural variables are re-calculated for the integrated companies.

[4]Given the assumption of NDRS for the underlying technology set, the overall merger gains E^J will always be lower or equal to one in a standard DEA framework. Due to the application of the conditional efficiency framework in our analysis, the set of peer units for a merged water utility is likely to be different as compared to the individual pre-merger companies due to the re-calculation of environmental variables. It is thus possible that newly integrated companies lie outside the NDRS technology, i.e. it is possible to achieve overall merger gains greater than one.

The potential overall gains from merging still include inefficiencies of the individual firms from before merging that can not be attributed to a merger. Thus we need to project the individual companies onto the efficient pre-merger DEA frontier $(\widehat{\theta}^j_{DEA}(x, y|z)x^j, y^j)$ using the conditional efficiency scores of the individual companies. The performance of the merged entity is then determined by the sum of the efficient individual input quantities and the sum of the initial output quantities:

$$E^{*J} = \min\{E \in \mathbb{R}^{p+q}_+ | (E \sum_{j \in J} \widehat{\theta}^j_{DEA}(x, y|z)x^j, \sum_{j \in J} y^j) \in \widehat{\Psi}^{*,\,z}_{DEA}\}. \tag{4}$$

The performance measure E^{*J} represents the *corrected overall potential gains from merging*. As before, a merger is evaluated as being beneficial for $E^{*J} < 1$ and costly otherwise.

The framework of Bogetoft and Wang (2005) allows for the decomposition of the potential merger gains according to

$$E^J = LE^J * HA^J * SI^J \tag{5}$$

with LE^J denoting a learning effect, HA^J a harmony effect and SI^J a size effect. The learning or technical efficiency effect in this decomposition represents efficiency improvement potentials resulting from individual inefficiencies and is calculated as

$$LE^J = \frac{E^J}{E^{*J}} \tag{6}$$

with $0 < LE^J \leq 1$ since $E^J \leq E^{*J}$. Such efficiency improvements usually can not be attributed to a merger. Thus, it is more meaningful to represent the potential gains from horizontal integration by the corrected merger gains E^{*J} and the corresponding decomposition into the harmony and the scale effect.

The harmony effect, sometimes referred to as the scope or synergy effect, aims to represent the potential efficiency gains from a reallocation in the mixture of inputs and outputs within a merged firm as compared to the pre-merger firms. Individual firms use different combinations of inputs and outputs, with reallocation becoming possible in a merged company. Combining such different production plans might enable to reach a higher output level with the given inputs or, vice versa, to reduce the input quantities while holding the output level constant.

The harmony effect HA^J is defined as

$$HA^J = \min\{HA \in \mathbb{R}_+^{p+q} | (HA \sum_{j \in J} \alpha \widehat{\theta}^j_{DEA}(x, y|z) x^j, \sum_{j \in J} \alpha y^j) \in \widehat{\Psi}^{*,\,z}_{DEA}\}, \quad (7)$$

where α denotes a vector of weights. In most applications, $\alpha = \frac{1}{J}$. In this case, the harmony effect is determined by the arithmetic average of the efficient input quantities within the merged unit and the average output quantities. Firm size after a merger is thus assumed to remain unchanged here while only the change in the mixture of inputs and outputs is considered. This assumption holds for the case of similar pre-merger firm sizes. In the case of differing pre-merger firm sizes however, scale effects might to some extent be captured by the harmony effect. Different weights α, e.g. based on a measure of firm size, can be used to avoid the inclusion of scale effects in the harmony measure. Efficiency gains resulting from the harmony effect might also be realized without any merger through the cooperation of individual companies.

The third effect is the size or scale effect. Based on the idea of returns to scale it is arguable that firms can produce outputs more efficiently at larger scale. It is aimed to represent savings potentials from operating at the full scale of a merged firm rather than at the average scale. The size effect SI^J is defined as[5]

$$SI^J = \min\{SI \in \mathbb{R}_+^{p+q} | (SI * HA^J \sum_{j \in J} \widehat{\theta}^j_{DEA}(x, y|z) x^j, \sum_{j \in J} y^j) \in \widehat{\Psi}^{*,\,z}_{DEA}\}. \quad (8)$$

Even with a harmony effect equal to one, there might be potential for efficiency improvements through operating at a larger scale.

3 Data description

The analysis is based on data from the Statistics of German Waterworks published by Bundesverband der Energie- und Wasserwirtschaft (2008) and is a cross-section sample for the year 2006. The original data sample includes 1,096 water utilities. Due to missing or erroneous data, the sample reduces to a set of 651 observations, including pure water production companies,

[5]Using the basic decomposition of the overall merger gains given in equation 5, the scale effect can also be calculated as a residual of the other effects, i.e. as $SI^J = \frac{E^{*J}}{HA^J}$.

pure water distribution companies and integrated utilities that both produce and distribute water. In our analysis we focus on vertically integrated water utilities that both produce and distribute water; other types of utilities are excluded. The final sample includes 364 companies. We allow for a low share of water input purchased from other water utilities, e.g. to meet peak demands, of up to 20% of total water input to ensure the comparability of the water utilities in our sample. The 364 water utilities in our data sample deliver water to around 20.45 million inhabitants as compared to the total number of inhabitants in Germany of about 80 million people. Final water deliveries of the considered companies sum up to about 1.14 billion cubic meters, whereas final water deliveries for entire Germany summed up to about 4.54 billion cubic meters in 2007, see Statistisches Bundesamt (2009). The sample contains both small and large companies and also the largest German water utilities. The data sample can thus be characterized as being representative. In addition to water supply, utilities sometimes also provide other services like electricity or natural gas supply. In our analysis, we only focus on the drinking water services provided by the utilities.[6]

Table 1 shows the summary statistics of the data sample. Similar to other applications in the literature like e.g. by De Witte and Marques (2010), we assume a simple production model where the *length of the entire network* in a service area and the *number of employees* represent capital and labor inputs. The number of employees is not available in full-time equivalents and the impact of part-time employment is thus not captured by our model. Since the share of part-time employment in Germany usually is low, we assume the number of employees in the water utilities to be comparable. For the representation of the main activities of water utilities, the output measures in our model are *final water deliveries* defined as the sum of water supplied to residential and non-residential customers and *bulk water supplies* as the amount of water supplied to other water utilities. We furthermore take the number of *connections to final customers* into account to ensure that water companies supplying water in areas of low per-capita water demand are not discriminated.[7]

[6]All variables used in our analysis only represent the drinking water activities of the companies. We are however aware of possible scope effects between the services provided by multi-utilities. Given our model specification, this might only be the case for labor input, e.g. due to a shared management overhead. We assume this effect to be small.

[7]Thanassoulis (2000) similarly recommends to focus on the main activities of water utilities and thus to use water quantities, connections and network lengths as output

Since we allow for a low share of purchased water input, the amount of own water production could be included as an additional output to differentiate between utilities with complete own water production from those water utilities with a share of purchased water input of up to 20% as discussed earlier. The amount of own water production is highly correlated with the amount of water delivered to final customers (Pearson correlation coefficient of 0.9984), the variable would thus not have any additional explanatory power in our model. With the aim of reducing the dimensionality problem of DEA, we thus neglect the amount of own water production as additional variable in our model.

[Table 1 about here.]

In addition to the input and output measures, several structural variables that are assumed to have an influence on firm performance are considered. We only consider exogenous structural variables that are not influenceable by the firms' management. The network length usually is an important variable to proxy the capital input of a water utility. It can however also be regarded as an output variable beside the water output and the number of connections to control for the size of a service area and different densities of supply. Since we include the network length on the input side rather than on the output side, we define the variable *output density* to control for different densities in the service areas. It is calculated as the sum of water deliveries to final customers and to other water utilities over the length of the entire distribution network. Following the empirical evidence in the literature, we presume a positive impact on efficiency. Examples are, among others, Picazo-Tadeo et al. (2009), García-Sánchez (2006) or Tupper and Resende (2004).

To control for network quality, we define the *share of water losses* as the difference between total water input and total water output over total water input. It is arguable that the share of water losses is endogenous since water losses can be influenced by investments into network infrastructure or better maintenance. As argued by Coelli and Walding (2006), pipe bursts and water losses also depend on other factors like for example the type of soil in a service area. We thus assume water losses to be exogenously given.[8]

measures. Since network lengths are assumed to be a proxy for capital input in our model, the variable is not included as an output measure.

[8] A similar assumption on the exogeneity of water losses in the short run is made in Zschille and Walter (2012).

At the mean, the share of water losses for the water utilities in our sample is around 12%, whereas it is about 10% for entire Germany based on aggregated statistical information provided by Statistisches Bundesamt (2009), including all German water utilities.[9]

Beside network quality, the consideration of water quality could be of interest. Based on the given data sample it is not possible to define an appropriate measure for the quality of the delivered water. Given the strong regulations on the quality of drinking water in Germany, the consideration of a measure for water quality however appears to be negligible. In order to control for differences in the source of water, we take the *share of groundwater input* in total water input into account. Groundwater usually is of good quality and requires less treatment to meet the regulations on drinking water quality than surface water. However, groundwater abstraction increases pumping needs versus the use of surface water, see Filippini et al. (2008). Meanwhile, Coelli and Walding (2006) argue that capital costs for groundwater usage are lower than for the use of storage water. We presume a positive impact of the share of groundwater usage on efficiency. With a mean level of around 83%, the share of groundwater input of the utilities in our sample is significantly higher than the national average of 62%, see Statistisches Bundesamt (2009).[10]

4 Results

In the first step of our analysis we calculate standard DEA efficiency scores to evaluate the performance of the water utilities in our data sample.[11] The first row of Table 2 reports the summary statistics of the standard, unconditional efficiency scores for the full sample. The results show a low mean efficiency

[9] As indicated by the minimum value of the share of water losses, the sample includes observations with very low shares of water losses of below 1%, which is unrealistic from an engineering perspective. Since we however can observe a continuum of water utilities with similarly low losses, we do not remove such observations from the data sample.

[10] One explanation might be our focus on vertically integrated companies with own water production and distribution. Such vertically integrated utilities usually use groundwater abstraction, while surface water resources like e.g. reservoirs or rivers water are usually used by larger bulk water supply companies, which are not part of our final sample.

[11] All calculations are conducted using the statistical software *R* with the additional packages "Benchmarking" version 0.18 by Bogetoft and Otto (2011), "FEAR" version 1.13 by Wilson (2008) and "np" version 0.40-3 by Hayfield and Racine (2008).

level of 58.77%, thus indicating large potential for efficiency improvements. Looking at potential outliers, four utilities are excluded from the sample when applying the super-efficiency procedure. Mean efficiency weakly increases to 60.74%, the minimum efficiency score remains unchanged. Super-efficiency scores however are likely to be influenced by the operating environment. Thus we again use the full set of 364 observations for the following conditional efficiency analysis.

[Table 2 about here.]

Figure 1 shows three nonparametric regression plots illustrating the impact of the considered structural variables on efficiency. The first plot of Figure 1 indicates a positive impact of the variable *output density* on efficiency. For low output densities, the ratio of conditional to unconditional efficiencies is higher than one and efficiency is thus higher when accounting for output density, underlining that additional inputs are required in low-density areas, thus leading to efficiency disadvantages. This result indicates significant returns to density for water utilities supplying water in rural areas, which are decreasing with increasing density. A similar impact on efficiency is found for the *share of water losses*. For the *share of groundwater usage* we find a weak negative impact on efficiency. In contrast to the presumption of an efficiency-enhancing impact of a higher share of groundwater input, there seem to be disadvantages from only using groundwater resources as compared to e.g. reservoir or river water. Given our model specification, using only groundwater resources might lead to more labor input in order to cover the demand for water as compared to using surface water, where it is easier to abstract greater amounts of water. Table 2 shows that controlling for structural variables in DEA leads to a significant increase in efficiency. At the mean, efficiency increases from 58.77% to 87.24%.

[Figure 1 about here.]

We apply a conditional super-efficiency approach for the detection of potential outliers in the data sample. Table 2 reports the conditional efficiency scores obtained after the conditional super-efficiency analysis. Due to the sequential deletion of super-efficient observations in the sample, the number of observations is reduced to 353 in total. The set of 11 deleted observations also includes the four water utilities that are deleted in the unconditional super-efficiency case. As compared to the conditional efficiency scores before

outlier detection, we find a low increase in the mean efficiency level from 87.24% to 88.2%. The minimum efficiency score however increases significantly after outlier detection.

Having determined the conditional DEA technology set, we then turn to the analysis of hypothetical mergers between neighboring water utilities. We focus on mergers between water utilities that are located within the same *Landkreis*.[12] Thus we analyze cases of horizontal integration between all water utilities within one county for which data is available. However, it is not possible to cover all water utilities within one county. In total we consider mergers of 227 water utilities into 84 hypothetical new companies. While the input and output measures for the merged companies are obtained by direct pooling of the individual pre-merger input and output quantities, we recalculate the structural variables for each of the merged entities.

The counties under consideration are spread across Germany. Most are, however, located in the federal states of Bavaria, Hesse, Lower Saxony and Rhineland-Palatinate. We can only analyze few merger cases in the former East Germany since the water utilities located in this area are already larger than water utilities in the former West German territories, and already deliver water at a county level in some cases. Table 3 provides the summary statistics for the potential merger gains for all 84 cases of horizontal integration. In 82 out of the 84 cases a merger between the water utilities would be beneficial when looking at the potential overall gains E^J. Since those results still include the individual inefficiencies within water utilities before merging, we only consider the projections of the individual water utilities and calculate the corrected potential gains E^{*J}. The merger gains drop down significantly after correcting for individual inefficiencies. In 21 merger cases we find potential losses from a merger as indicated by values of E^{*J} being greater than one. At the mean we find low potential merger gains of 4.1%. In cases of such low efficiency gains it is of course arguable that the costs of restructuring are likely to be greater than the potential gains from integration. Given the general small-scale structure of German water supply as compared to other countries, real merger gains are likely to be greater.

[Table 3 about here.]

After calculating overall gains from merging, we provide the decomposition into the learning effect, the harmony effect and the scale effect. At

[12] A *Landkreis* is the German equivalent of a county as defined by the *NUTS 3* code of the *NUTS*-classification (*Nomenclature des unités territoriales statistiques*).

the mean, around 13% of the overall merger gains E^J could be realized by improving efficiency within the individual water utilities. The learning effect thus inhibits the greatest potential for efficiency increases versus harmonization and scale effects. Such efficiency improvement potentials are usually not attributable to a merger since efficiency could be improved by, for example, sharing best practices between individual water utilities.

Significant potentials for efficiency increases arising from a harmonization in the individual production plans of the different water utilities, as indicated by the harmony effect, are only found in a few cases. At the mean, less than 3% of the input quantities could be saved by reallocating the inputs in the integrated companies. We can further only find weak scale effects for most merger cases. At the median, there are already no efficiency gains from an increase in firm size.

Due to the different sizes of the firms prior to merging, scale effects might to some extent be captured by the harmony effect, thus resulting in lower estimates for the scale effects shown in Table 3. We therefore use the number of connections to customers as firm-size related weights α when pooling the inputs and outputs for the considered merger cases (cf. equation 7). Table 3 reports the weighted results for the harmony and scale effects. Using weights, the potential gains resulting from the harmony effect turn out to be lower, while the efficiency improvement potentials from the scale effect increase.

Since the estimates of the merger gains are likely to be influenced by the low number of observations of large companies, we account for this sparsity of observations of large companies by running a conditional DEA with bias corrections based on bootstrap methods as proposed by Simar and Wilson (1998).[13] We maintain the assumption of an underlying NDRS technology. Results are reported in the lower part of Table 3. Using bias corrections, the overall merger gains E^J indicate greater efficiency improvement potentials as compared to the results without bias corrections. Those effects however are again merely based on learning effects and only to a small extent on pure merger gains. The extent of the harmony and scale effects is found to be similar to the results without bias corrections.

Figure 2 provides boxplot illustrations of the overall merger gains with bias corrections and the corresponding decomposition for different groups of firm sizes. We divide the sample of 84 integrated companies into four

[13]For a detailed description of the methodology for calculating bias corrected efficiency scores in DEA, we refer to the article by Simar and Wilson (1998).

groups based upon the quartiles of the amount of water delivered.[14] The two plots in the left part of Figure 2 indicate that there are strong overall gains from merging based on strong learning effects. Without using weights for the decomposition of merger gains, at the median the potential harmony gains turn out to be the lowest for the group of smallest water utilities and higher for the other groups, while scale effects are only found for the group of smallest utilities. Using weights, we merely find losses from the harmony effect and gains resulting from the scale effect for all groups, which are the lowest for the group of largest utilities. In contrast to the summary statistics in Table 3, group-specific median-values indicate potential efficiency gains resulting from the scale effect for all four groups of observations.

[Figure 2 about here.]

5 Interpretation of results and concluding remarks

In this article we provide the first analysis of the potential gains from horizontal integration in the potable water sector. While merger gains in the water industry have so far only been analyzed on an ex-post basis, we provide new insights into a hypothetical restructuring of the industry. Similar to other network industries, water supply heavily depends on the characteristics of the operating environment. Applying a conditional efficiency approach, we take different structural variables into account in our analysis and contribute to the scientific literature by analyzing the potential gains from mergers within a conditional efficiency framework. For the detection of potential outliers or extreme observations in the data, we extend the basic idea of the super-efficiency approach to the conditional super-efficiency case.

Investigating the hypothetical consolidation of the German water industry at the county-level, we find substantial gains from horizontal integration in the majority of the cases analyzed. The decomposition of the potential overall gains from mergers shows that the technical efficiency effect turns out to be the main source for efficiency gains. Highest efficiency improvement potentials for the water utilities thus result from technically more efficient

[14] Calculated as the sum of water delivered to final customers and the amount of bulk water supplies.

operations rather than from mergers and corresponding changes in market structures. Having corrected for individual inefficiencies, pure merger gains exist in the majority of cases but are found to be low. Using firm-size related weights for the decomposition of the corrected merger gains, weak or even negative harmony effects are found for most merger cases while scale effects turn out to be weakly positive in most cases. Scale effects are found to be the highest for the group of smallest water utilities. Despite the application of a bootstrap procedure for the calculation of bias corrected efficiency scores, the mostly low merger gains and the correspondingly low harmony and scale effects might be explained by the low number of sufficiently large observations in the data sample. Best practices of large firms in the sample are thus likely to underestimate the true best practices in the entire industry. Regarding the small-scale industry structure of German water supply, the given data sample further might not cover the full range of possible firm sizes when estimating the DEA technology set. The empirical evidence in the literature on the existence of returns to scale in water supply across different countries suggests that optimal firm size for water utilities is usually reached at higher output levels. Our results however are in line with the empirical evidence in the literature indicating low merger gains in water supply across different countries based on post-merger analyses, see e.g. Urakami and Parker (2011), De Witte and Dijkgraaf (2010) or Ballance et al. (2004).

Since scale effects are found to be low or negative in some cases, the necessity of mergers is questionable. Major efficiency gains result from the technical efficiency effect and there might be possibilities to realize those efficiency improvement potentials through arrangements other than a merger, e.g. through sharing best practices between companies. However, if technical inefficiencies in a water utility are a result of mismanagement, a merger could lead to better management abilities and improved performance. In addition to reducing inefficiencies in the individual water utilities, potential scope effects could result e.g. from a simple cooperation between different companies.

Further extensions of the model and a more detailed data set could improve the quality of our results. First, more observations of large-scale water utilities would be beneficial to ensure the appropriate definition of the DEA technology set for larger units. Since the number of larger water utilities in Germany is low and the majority of the large-scale observations already is contained in the data sample, the consideration of water utilities from other countries might be beneficial. The results presented here can only give an

indication of the potential efficiency gains from consolidation in the water industry. Second, the consideration of additional variables to control e.g. for water treatment and water or service quality could improve the results. Results might also change when relying on a cost model rather than on a production model. Since consolidation at the county level is found to increase efficiency in most cases, an analysis of consolidation at a regional level according to the former east German model would be of interest. Such an approach however is restricted by data availability and missing peer units since today even the largest German water utilities are usually smaller than the former East German utilities. Beside horizontal integration, an analysis of efficiency gains from vertical integration e.g. between water production, distribution and retail services might be of interest.

Regarding the international evidence on scale economies in water supply and the high fragmentation in Germany as compared to water industries in other countries, consolidation in Germany is likely to result in increased efficiency. However, mergers decisions are made by the firms involved, since merger effects also depend on other characteristics of the water utilities that are not covered by our model, like, for example, firm culture. One important factor is that the political circumstances of a water utility must allow for consolidation. Municipal governments usually prefer to control local utilities and are likely to discourage consolidation efforts.

We have so far neglected the impact of mergers on market power. In competitive industries, mergers lead to greater market power for the integrated company and can thus result in negative welfare effects. In water supply, however, utilities are defacto local monopolies with strong market power by definition. De Witte and Dijkgraaf (2010) further point out that mergers lead to a reduced number of companies that can be analyzed in benchmarking studies for regulatory purposes, thus meaning that the impact of best practices might be underestimated. Since we analyze a hypothetical consolidation of the water industry at the level of the more than 400 German counties, a sufficiently large number of companies for benchmarking purposes would be maintained.

We show that there are substantial inefficiencies in the German water sector. While mergers can contribute to a reduction of those inefficiencies, the greatest improvement potentials rely on technical efficiency effects that do not necessarily require a merger of different companies. Regarding policy recommendations, more incentives are necessary to reduce the high inefficiencies in German water supply in combination with a consolidation of the

smallest utilities.

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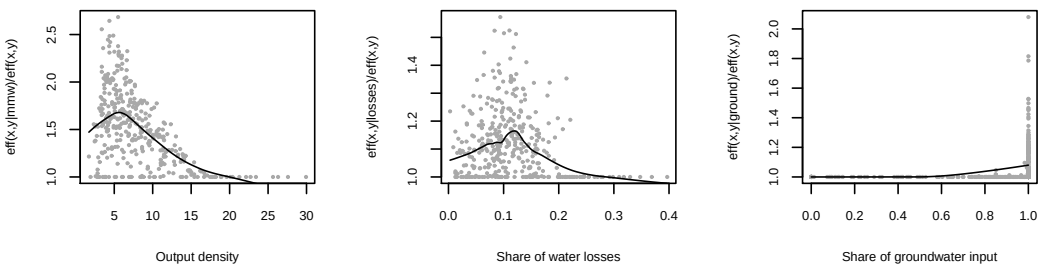

Figure 1: Effect of z-variables on DEA frontier

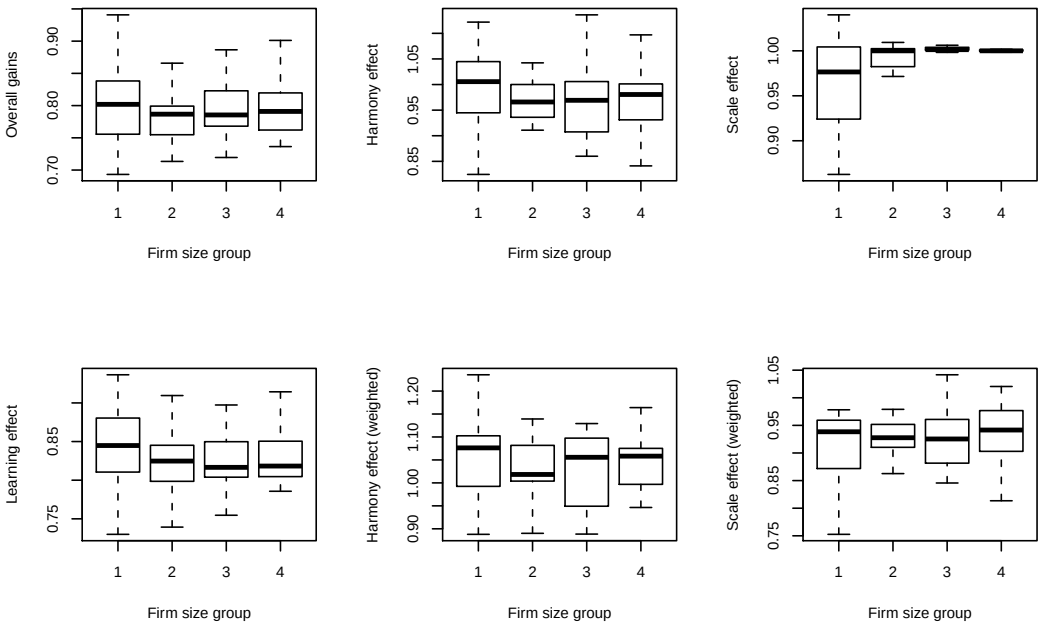

Figure 2: Merger gains and decomposition with bias corrections for different firm sizes by quartiles

Table 1: Descriptive statistics

	Min.	Median	Mean	Max.	Std. dev.
Network length *net* [km]	21.00	164.50	329.68	7,858.00	600.80
Employees *labor* [number]	2.00	10.00	29.85	2,326.00	139.97
Connections *con* [number]	911.00	5,437.00	10,837.61	262,000.00	22,751.33
Final water deliveries *wdel* [1000 m^3]	89.00	1,154.50	3,144.41	197,900.00	12,720.40
Bulk water supplies *bws* [1000 m^3]	0.00	1.00	264.21	14,670.00	1,130.43
Water produced *wprod* [1000 m^3]	99.00	1,344.00	3,697.09	217,890.00	14,337.20
Output density *dens* [ratio]	1.70	6.98	8.14	29.93	4.63
Water losses *losses* [ratio]	0.00*	0.11	0.12	0.40	0.06
Groundwater usage *ground* [ratio]	0.00	1.00	0.83	1.00	0.31

* Zero due to rounding.

Table 2: Summary of efficiency scores

	Obs.	Min.	Median	Mean	Max.	Std. dev.
Standard DEA						
full sample	364	0.2346	0.5445	0.5877	1.0000	0.1874
after outlier detection	360	0.2346	0.5652	0.6074	1.0000	0.1929
Conditional DEA						
full sample	364	0.3148	0.8571	0.8724	1.0000	0.1047
after outlier detection	353	0.3834	0.8676	0.8820	1.0000	0.1012

Table 3: Summary of potential merger gains and decomposition

	Symbol	Min.	Median	Mean	Max.	Std. dev.
DEA-NDRS						
Overall gains	E^J	0.3596	0.8248	0.8337	1.0703	0.0922
Corrected gains	E^{*J}	0.7978	0.9582	0.9592	1.1362	0.0740
Learning effect	LE^J	0.4238	0.8743	0.8714	1.0000	0.0924
Harmony effect	HA^J	0.8064	0.9699	0.9761	1.3356	0.0833
weighted	HA^J_w	0.7948	0.9833	0.9912	1.4698	0.1004
Scale effect	SI^J	0.7357	1.0000	0.9839	1.0000	0.0375
weighted	SI^J_w	0.7327	0.9852	0.9718	1.2472	0.0679
DEA-NDRS with bias-corrections						
Overall gains	E^J_b	0.3381	0.7891	0.7908	0.9722	0.0842
Corrected gains	E^{*J}_b	0.7862	0.9663	0.9670	1.1668	0.0764
Learning effect	LE^J_b	0.4014	0.8266	0.8197	0.9364	0.0816
Harmony effect	HA^J_b	0.7997	0.9762	0.9814	1.3789	0.0871
weighted	$HA^J_{b,w}$	0.8453	1.0470	1.0530	1.7570	0.1219
Scale effect	SI^J_b	0.7374	1.0003	0.9868	1.0400	0.0396
weighted	$SI^J_{b,w}$	0.6384	0.9294	0.9237	1.1655	0.0712