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Specification of merger gains in the Norwegian electricity distribution industry

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Abstract

Electricity distribution often exhibits economies of scale. In Norway, a number of smaller distribution system operators exist and thus there is potential to restructure the industry, possibly through mergers. However, the revenue cap regulatory model in Norway does not incentivize firms to merge as merging leads to a stricter revenue cap for the merged company. Thus the regulator compensates the firms in order to create such incentives. The amount of compensation is based on the potential gains of the merger estimated using a data envelopment analysis (DEA) based frontier approach introduced by Bogetoft and Wang (Journal of Productivity Analysis, 23, 145–171, 2005). DEA is however only one of many possible frontier estimators that can be used in estimation. Furthermore, the returns to scale assumption, the operating environment of firms and the presence of stochastic noise and outlier observations are all known to affect to the estimation of production technology. In this paper we explore how varying assumption under two alternate frontier estimators shape the distribution of merger gains within the Norwegian distribution industry. Our results reveal that the restructuring policies of the industry may be significantly altered depending how potential gains from the mergers are estimated.

KEYWORDS: mergers; efficiency estimation; electricity distribution; regulation

JEL CODES: L94; L25; L43; C6

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1. Introduction

The wave of electricity distribution market liberalization in the 1990s attempted to induce competitive market type conditions upon highly non-competitive industries such as electricity generation and distribution. Liberalization was quickly accompanied by an introduction of incentive based regulatory tools to incentivize distribution system operators (DSOs) towards better operating efficiency (see e.g. Jamasb & Pollitt, 2001; 2007). Without regulation such incentives are low as DSOs are generally natural monopolies. The existence of scale economies again has been seen as a prerequisite for a natural monopoly to exist (Filippini, 1998).[1] Mostly academic research has identified that scale economies prevail at least at the lower output levels of electricity distribution (Kwoka, 2005; Kumbhakar et al., 2015). In Norway, similar findings were also reported by the Reiten-committee in a report prepared for the Norwegian ministry of petroleum and energy (OED). The report characterized smaller utilities as being over-represented among the inefficient DSOs (OED, 2014; see also Growitsch et al., 2009). Moreover the report suggested increasing the co-operation and coordination among DSOs. These considerations suggest potential restructuring of the Norwegian electricity distribution industry through mergers to exhaust the potential scale and scope economies (see footnote 1). Of course, the restructuring requires identifying the economically beneficial mergers by measuring the potential gains from mergers.

Incentives to merge also depend on the regulatory model that is used to regulate the DSOs. The typical incentive based mechanisms, such as revenue-cap regulation, usually include a cost efficiency incentive component which requires an estimation of a cost norm, generally using frontier based methods such as *data envelopment analysis* DEA or *stochastic frontier analysis* SFA (see e.g. Bogetoft & Otto, 2011). These methods are used to estimate an efficient cost frontier against which DSOs are compared to assess their cost efficiency. For example, Norway uses DEA to calculate the cost efficiency of DSOs (see e.g. Bjørndal et al., 2010). DEA has been a popular method in efficiency analysis since it is based on minimal assumptions about the production technology. However, one of the key assumptions, namely the convexity of the production possibility set (PPS) has had some unintended consequences for the merger analysis, a situation well illustrated by the Norwegian case. By construction, such convex frontier model identifies the

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[1] Baumol (1977) shows that in a multiproduct context the relevant condition for natural monopoly is *cost subadditivity* for which scale economies is a sufficient condition in the one product case. As electricity distribution is generally modelled as a multi-product industry with outputs such as distributed electricity, number of customers and network length, the incentive to merge is often dictated in terms of *economies of scope*, which implies cost subadditivity in the multiproduct case (see e.g. Bogetoft & Wang, 2005).

merged firm as less efficient than the individual firms which form the merger.[2] This implies that the merged company is able to improve its performance more than its constituent firms. Intuitively this is reasonable as we would expect that there is additional savings potential due to synergies that are beyond the individual improvement potentials.

The unfortunate effect of the above is that the revenue cap for the merged firm would be stricter as it is perceived less efficient. Consequently this creates a strong disincentive to merge. Thus in Norway there is an evident disparity between the likely restructuring needs of the industry and the regulatory disincentives to merge. The Norwegian regulator (NVE) has resolved this issue by applying a compensation scheme to guarantee that mergers with savings potential would take place regardless of the disincentives. In order to determine the appropriate level of the compensation, the regulator has to know the magnitude of the efficiency loss that the merger implies. Since the losses are in practice equal to the extra improvement potential expected from the merger, the amount of compensation can be estimated through the estimation of merger gains.

One of the most popular frameworks to estimate the merger gains is a DEA based approach introduced by Bogetoft and Wang (2005). However, the ways how DEA deals with operating environment, statistical noise and outlying observations make strong assumptions about the nature of the production technology, which might have implications for the estimation of merger gains also. Thus in this study we examine how these modelling choices affect to the presence of merger gains. We follow the framework of Bogetoft and Wang (2005) but augment it with an alternative estimation method and use the stochastic semi-nonparametric envelopment of data (StoNED) in addition to DEA. This method is used by the Finnish regulator to assess cost efficiency of the DSOs (Kuosmanen, 2012). The methods are empirically compared using the data on Norwegian electricity distribution companies. Our results show that the estimator choice and returns to scale assumption have considerable effect to the magnitude of the merger gains and the number of beneficial mergers. Overall the level of gains is rather moderate and the magnitude of scope related gains relative to the scale related gains is found to be small. The operating environment decreases especially the presence of size related effects as company size is generally found to be negatively correlated with the harshness of operating environment.

The paper is organized as follows. In Section 2 some earlier literature about the estimation of merger gains is covered. In section 3 we briefly discuss the Norwegian regulatory model and the associated merger analysis. In Section 4 we introduce the Bogetoft and Wang framework to estimate the merger gains and discuss the different frontier methods that are used to

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[2] The merged firm can be considered as a convex combination of the original firms.

estimate the gains. In Section 5 we present the data and also discuss the operating environment of the merged entities. The results are presented in Section 6, and Section 7 concludes.

2. Estimation of merger gains in the literature

According to Resti (1998), the literature on the effects of mergers can roughly be divided into two strands; studies that examine the effect of mergers on the market value, financial performance or the shareholder value of the companies, and studies that examine the effects on the productive efficiency of the companies.[3] In the financial and banking sector mergers have been widely studied from all of the these viewpoints (see e.g. Akhavein et al., 1997; Bruner, 2002; Halkos & Tzeremes, 2013). In the realm of public utilities focus has been on productive efficiency, as maximizing financial performance rarely is the main objective of public service providers. The merger gains have been explored in sectors such as the water sector (De Witte & Dijkgraaf, 2010; Zschille, 2014), healthcare (Kristensen et al. 2010; Peyrache, 2013), and police forces (Simper & Weyman-Jones, 2008). Directly related to this study, Agrell et al. (2015) examined the merger gains in the Norwegian electricity distribution sector during the period 1995-2004. They found rather small merger gains and assigned most of the improvement potential to the internal efficiency increases within the companies. Since we examine hypothetical mergers from a different time period, our study significantly differs from the study by Agrell et al. (2015) who concentrate on the realized mergers using only DEA based approach. Also Bagdadioglu et al. (2007) and Kwoka and Pollitt (2010) have analysed the potential efficiency effects of mergers for distribution utilities. Kwoka & Pollitt (2010) do not find significant merger gains in the US, while Bagdadiouglu et al. (2007) do find such gains within the Turkish distribution sector. In addition Çelen (2013) also studied the effects of mergers on the efficiency of Turkish distribution companies. Çelen identifies merger gains to be present but finds that the merger gains are dependent on the customer base structure of the companies. The efficiency improving effect of mergers declines along with the proportion of residential customers. This seems to imply that the merger gains vary due to the operating environment of the merging firms.

Most of the above studies on public utilities restrict themselves to use only one estimation method to estimate the merger gains. Mostly they apply the Bogetoft and Wang (2005) approach. However, less attention has been paid on how the choice of estimation method and model specification affects the magnitude of the merger gains. There are several concerns of how modelling choices might affect merger gains. First, as Bogetoft and Otto (2011) point out, different

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[3] See also Röller et al. (2000).

estimates of merger gains would be obtained if different frontier estimators of the technology are used. Differences may arise for example if DEA attributes some statistical noise as merger gains. Second, it is important what we assume about the returns to scale properties of the technology. Much of the merger related gains are assumed to come from the movements towards the optimal scale size. As stated in the Reiten report, there are implications that scale inefficiencies are present in the Norwegian DSO sector (see also Kumbhakar et al., 2015). Third, the effect of the operating environment is often neglected in analyses. For example the Bogetoft and Wang framework does not involve any notion of operation environment. It is however widely acknowledged that exogenous factors, so called z-variables, outside the actual production process should be taken into account when assessing the efficiency of firms (see e.g. Saastamoinen, 2013; Growitsch et al., 2012). Otherwise we might suffer from omitted variable bias in the estimation of efficiencies (see Johnson & Kuosmanen, 2011; Wang & Schmidt, 2002). Given that the operation conditions of Norwegian DSOs are challenging, accounting for operation environment is crucial. In this study we examine more closely all these three issues.

3. Norwegian regulatory model and merger gains

The Norwegian power market was deregulated in the early 1990s, a cornerstone being the vertical separation of (competitive) generation and (regulated) transmission/distribution. After a few years of rate of return regulation, distribution and regional transmission were subjected to incentive regulation from 1997 (Bjørndal, et al., 2010). For each electricity network company, the regulator determined a maximum annual revenue, based on the company's own cost, benchmarking results, and some other adjustments of prices and increases in activity. From 2007, the benchmarking was done annually, and revenues were set according to a yardstick formula: $R = \rho C^{*} + (1-\rho)C$, where R is the annual revenue, C is the actual cost, C^{*} is the cost norm found by DEA, and ρ is a factor determining the strength of the incentives in the regulation (presently equal to 0.6).

Since 1997, there has been a continual development of the benchmarking model and the use of its results to calculate company specific cost norms. Presently, the regulator starts with an input oriented DEA model, with three outputs (customers, HV-lines and network stations) and a single input (total cost; i.e. operation and maintenance, capital cost (depreciation and interest), value of lost load (VOLL) and losses), assuming CRS technology. Bootstrapping is used for bias correction. In a second stage, differences in operational environments are accounted for by regressing the DEA scores on five geographical variables, or z-variables (underground cables, HV lines through forest, distance to road, and two composite variables). The independent variables are not the z-variables themselves, but the difference between the z-variables of a company and its peers. The coefficients found in the regression are used to adjust the first stage DEA-results. Finally, the cost norms are calibrated such that the sum of the cost norms is equal to the total sum of costs in the industry. In this way, the company with average efficiency will earn the normal or regulated rate of return.

Another recent addition to the regulation model is the "harmony-effect", compensating companies that merge with a part of the merger gain that is measured in the efficiency analyses. Two firms that merge (in a pure technical manner, i.e. just adding together inputs and outputs) will in most cases get an efficiency score that is lower than the weighted average of the two individual companies. If a merger results in a cost norm that takes out all the synergy effects immediately, the companies may be reluctant to implement any mergers. In order to give incentives to the companies to organize optimally, part of the merger gain is kept by the companies through the harmony ("harmoni-") effect of the regulation model. Effectively the harmony effect is compensated to the firms by the regulator as a one-time lump-sum that is approximated by the discounted future gains over a period of 30 years.

At this point it is good to mention few implicit challenges of the regulatory model. First, we can argue that the regulator is actually compensating something that it should not compensate. In fact, merger gains can be considered something that the merged firm should be able to achieve without any compensation. Second, the compensation compensates the companies but equally well part of the gains from mergers could be compensated directly to consumers. Now it is doubtful whether any gains from mergers in a form of price reduction go to the consumers. Last, the unintended consequence of smaller number of comparators in the benchmark regulation due to mergers might be that DSOs in fact face less pressure in their pricing decision from the regulator's side. It is not however our purpose in this study to make any arguments in favour or against the compensation scheme. Rather we focus on the factors that affect the amount of compensation.

4. Framework to analyse merger gains

In this section we introduce the methods that are used to analyse merger gains. We keep our discussion brief and guide the reader to refer to the original articles as most of the material is well documented in the earlier literature. Rather than replicating the exact formulations of those studies here, we provide a schematic presentation of the basic principles of the Bogetoft and Wang (2005) approach that is used here to estimate and decompose the merger gains. Bogetoft and Wang (abbreviated as BW hereafter) present their framework using an input-orientated model where gains are manifested as potential input reductions. We follow a similar strategy but instead of using physical quantities of inputs we use the total costs as an input measure. In this context the input oriented cost approach is reasonable since the outputs of the DSOs are generally exogenously given and DSOs are minimizing costs instead of maximizing revenue. First we define the merger gains conceptually and then proceed to the specific cost based measurement of them. Lastly we discuss the different methods for cost function estimation used in this study.

4.1 *The conceptual definition of merger gains*

We already discussed in the previous section that the merged firm is generally less efficient in the DEA model than the individual entities forming the merger. This is illustrated in Figure 1, where we have five observed firms (red dots) and the corresponding production possibility set (PPS) with two outputs (relative to costs). Assume now that two firms inside the PPS, namely A and B, merge into company C. As seen, the new firm C is a convex combination of the old existing firms and thus it has a new output profile.[4] It is apparent from the figure that due the convexity of the PPS, point C lies further from the frontier than one of the points A or B. Thus at least one of the companies has a disincentive to merge.

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[4] Figure 1 is similar to the one presented in NVE documents, see NVE (2007) for further details.

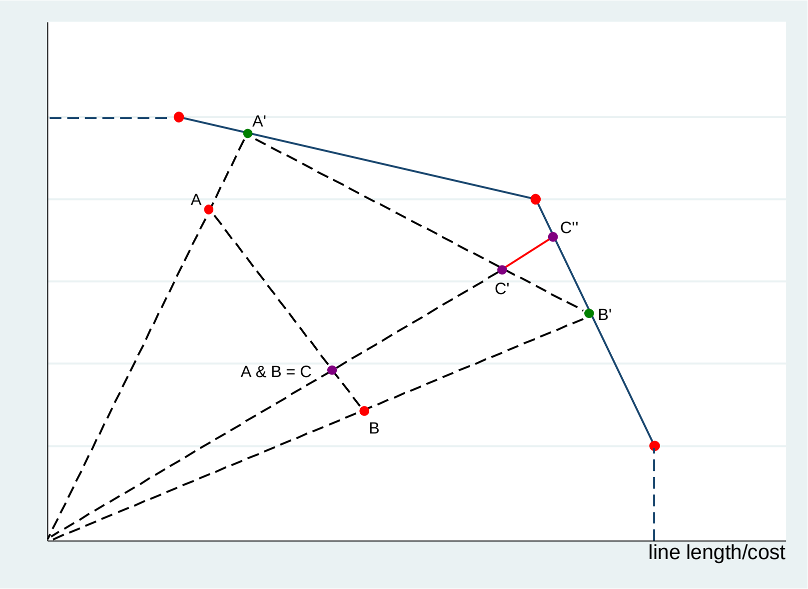

Figure 1: Merger gains and the production possibility set

The total improvement potential of the merger is straightforward to measure as a projection of the merger against the estimated technology. This would be the distance from point C to C". As BW show, the total production economic effect of the mergers can be decomposed into three parts. The true gains of the merger can be evaluated only after we assume that the firms are individually efficient. This individual improvement target BW label as the individual *learning effect* and we would not generally consider these gains as truly being merger gains. This would correspond to the movements of the firms A and B along their corresponding rays to the frontier to points A' and B'. After identifying these efficient projections, we can evaluate the merger of these efficient companies, which would be point C' in Figure 1. The distance of C' from the frontier (C' to C") is then the measure of true merger gains. BW decomposes these remaining gains into size related gains and so called *harmony* gains. In the more familiar economics terms, we can label these as scale and scope related economies. By harmony gains BW and also Bogetoft and Otto (2011) mean reallocations/harmonization in the input mix to produce a larger amount of output.

The full structure of BW decomposition for a specific merger H is presented in Figure 2. Note that the number of firms (elements) in each merger H can differ between mergers, but here we have $|H| = 2$ for all mergers. The overall gains E^H are decomposed into two components, the individual learning LE^H and the remaining learning adjusted gains E^{*H}. The E^{*H} can further be decomposed into harmony (HA^H) and size effects (SI^H).

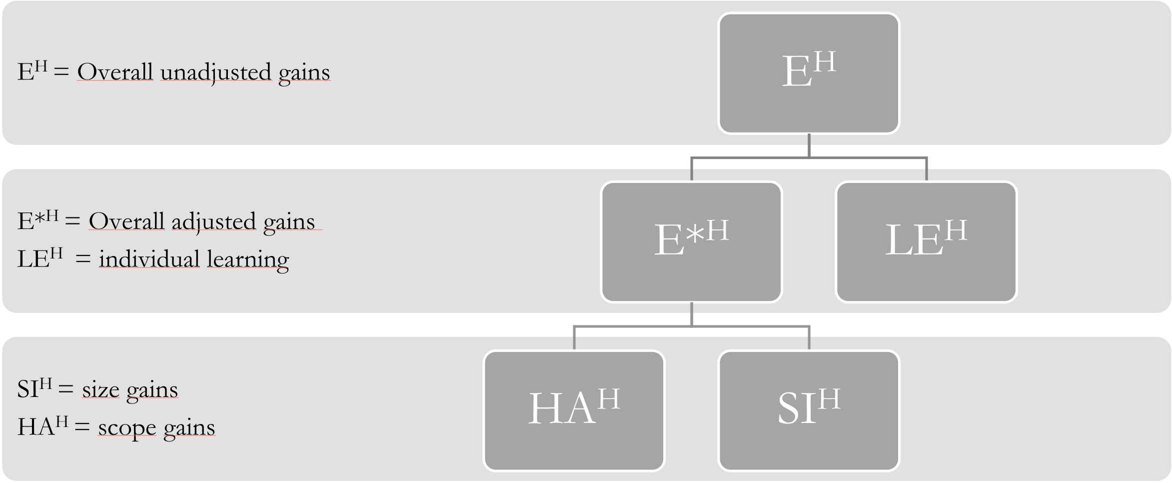

Figure 2: The decomposition of merger gains according to Bogetoft and Wang (2005)

Interestingly the decomposition presented by BW can be seen to coincide with the discussion by Farrell and Shapiro (2001). Farrell and Shapiro (FS hereafter) speak of so called *merger-specificity* when examining the existence of merger efficiencies. They label gains to be merger specific if the gains can only be realized through a merger and are not achievable with some other contractual arrangements or by firms individually. FS point out that scale economies often fail to be merger specific as under certain ideal market conditions, firms would be able to achieve the minimum efficient scale by themselves. Thus a merger is not necessary to achieve these gains. In fact, if we in the BW framework assume that the industry has constant returns to scale, the size effects will vanish as will be shown later. Under CRS, we assume that firms are able (individually) to freely adjust their scale. In the current context however, we need to keep in mind the specific nature of the electricity distribution industry. Firms are considered to be local monopolies operating on a restricted area in which the growth in demand and consequently in size is more or less restricted. Under such conditions, an individual expansion is likely to be unattractive or even infeasible. Thus the most straightforward way to reap the scale economies is through a merger.

FS also discuss synergies, which are often seen as the main measure of merger gains. They define synergies as actions that obviously cannot be achieved without a merger and which involve "*…integration of the parties' unique, hard-to-trade assets.*" Broadly we could interpret the FS synergies as harmonization of assets in the terminology of BW. However this interpretation warrants some caution. DSOs indeed have some hard-to-trade assets, such as networks, that would in principle create some synergies. However, according to FS, no synergies are generally present if the firms' continue to operate like individual units after the merger. This is a likely situation in electricity distribution as significant reorganization of the physical assets of networks after the merger would seem unlikely and merger is often just an aggregation of service areas into one. For example Kwoka (2005) found that increasing the service area alone does not often suffice to reap economies of scale or scope. It is rather the changes in the customer usage (output/number of customers) or customer density (number of customer/network length) that imply some improvements. Anyhow, instead of physical assets most would consider that reorganization in the areas of maintenance, customer service and billing is where we would expect synergies to be present.

3.2. The cost function definition of merger gains

BW defines the merger gains using physical inputs and outputs. Their formulation is in terms of possible input reductions, and an equivalent presentation with output augmentations is straightforward. Here we however examine gains using a total (social) cost function and using cost as a single input. The price/cost regulation of DSOs is often carried out with a cost based benchmarking, where operational or total costs are modelled as a function of the main cost drivers, namely outputs (see e.g. Jamasb & Pollitt, 2001; Korhonen & Syrjänen, 2003; Giannakis et al., 2005; Thakur et al., 2006; Haney & Pollitt, 2009; Bogetoft & Otto, 2011).[5] There are differences among regulators with respect to what type of costs are benchmarked and whether quality considerations are included into benchmarking (Ajodhia & Hakvoort, 2005; Haney & Pollitt, 2009). We believe that the total social cost approach followed in Norway best characterizes all aspects of the network activity (Bjørndal et al., 2010). It accounts for operational and capital related cost, and it includes a quality component. In analysing mergers this definition seems suitable as it allows the cost savings of the merger to be realized in any of the cost components. By using some physical characterization of the technology we would direct the incentives towards the reduction of inputs that were selected into the model, which may not be desirable.

We follow Bogetoft and Otto (2011, p. 274) in defining merger gains. In the set of Equations (1) we have defined all the components of Figure 2 in terms of the cost function, c. H is the number of merging firms in a specific merger, $c(.)$ is the estimated cost function, y is the output vector for firm $k \in H$ and x is the observed cost of firm k.

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[5] Some authors consider that the often used output, network length, should be considered as an input (Neuberg, 1977; Filippini & Wild, 2001). In our view, network length is an output (cost driver) as it alone does not produce anything in the manner of typical inputs, and it serves as a proxy for cost drivers associated with the size of the concession area and the distance between customers.

$$\begin{aligned}
E^{H} &= c\left(\sum_{k\in H} y^{k}\right)\Big/\sum_{k\in H} x^{k} \\
LE^{H} &= \sum_{k\in H} c\left(y^{k}\right)\Big/\sum_{k\in H} x^{k} \\
E^{*H} &= c\left(\sum_{k\in H} y^{k}\right)\Big/\sum_{k\in H} c\left(y^{k}\right) \\
HA^{H} &= c\left(\frac{1}{H}\sum_{k\in H} y^{k}\right)\Big/\left(\frac{1}{H}\sum_{k\in H} c\left(y^{k}\right)\right) \\
SI^{H} &= c\left(\sum_{k\in H} y^{k}\right)\Big/\left(H\cdot c\left(\frac{1}{H}\sum_{k\in H} y^{k}\right)\right)
\end{aligned} \tag{1}$$

A few remarks are in place. First, E^{H} is simply the ratio of the minimum cost of producing the combined output of all merging firms relative to the aggregated observed total cost. Values $E^{H} < 1$ imply potential cost savings due to a merger. This measure is not limited from above to one i.e. it is possible that a merger incurs losses. It is straightforward to see that the overall gains are $E^{H} = LE^{H} \cdot E^{*H}$. Furthermore we could easily show from the formulas above that $E^{*H} = HA^{H} \cdot SI^{H}$. Harmony gains, HA^{H}, are evaluated at the average output profile of the merger. According to BW, this formulation allows us to focus on the actual gains due to changes in the input/output mix without the size effects confounding the examination. Size effects, SI^{H}, are the potential gains if the merged firm operated at full scale instead of average scale. Furthermore, in any convex cost function, harmony effects are always, by construction, less than one. On the other hand size effects can either indicate gains ($SI^{H} < 1$) or losses ($SI^{H} > 1$). Lastly, we highlight one point about the returns to scale and the size measure. If constant return to scale apply, it is necessarily so that $SI^{H} = 1$, as under CRS, $c\left(\frac{1}{H}\sum_{k\in H} y^{k}\right) = \frac{1}{H} c\left(\sum_{k\in H} y^{k}\right)$. Consequently we see that under CRS $E^{*H} = HA^{H}$ since there is no possibility for size related gains.

3.3 Estimation of cost functions

To obtain the measures defined in the previous section we need an estimator of a cost function. Since the merger gains are examined after the individual inefficiencies of the firms are assumed away, we analyse the magnitude of the gains at the cost frontier. BW uses a standard DEA estimator of the technology to estimate the frontier technology. But as Bogetoft and Otto

(2011) show, it is possible to build the same decomposition of the merger gains upon some other frontier estimator such as SFA. Thus in addition to standard DEA, we utilize the StoNED estimator introduced by Kuosmanen and Kortelainen (2012). But before presenting this estimator, we present the general cost function model that forms the basis of our StoNED model. Kuosmanen and Kortelainen (2012) suggested the cost function model given in Equation (2).

$$\ln x = \ln c(\mathbf{y}) + \varepsilon \tag{2}$$

In Equation (2), x is the observed cost, $c(\mathbf{y})$ is the estimated cost frontier that is a function of the outputs $\mathbf{y}$ (input prices are assumed to be the same for all), and ε is the error term which is assumed to include both inefficiency and stochastic noise, which are distributed with the half-normal and normal distributions. These are the routine assumption in the StoNED literature. To ease the notation, we will denote $c(\mathbf{y}) = \phi$. The outputs appear in their original values and the logarithmic transformation concerns only the cost function value at given outputs.

Kuosmanen and Kortelainen (2012) propose to estimate the parameters of interest in the above model with a StoNED procedure which is based on the Convex Nonparametric Least Squares (CNLS) estimator originally suggested by Hildreth (1954). Similarly to DEA, this estimator does not impose any functional form assumptions about the frontier. As DEA, it is based only on certain regulatory conditions of the frontier. In addition it incorporates stochastic noise in the model, similar to SFA. Thus this approach can be seen as a hybrid of the two conventional frontier estimators. In his energy market application of the model, Kuosmanen (2012) presents the following formulation for the operational estimator of the cost frontier shown in the set of Equations (3). The third equality and fourth inequality constraints define the linear piecewise segments of the frontier and guarantee the convexity of the cost frontier. The β-parameters can be interpreted as the marginal costs of the outputs.

$$\min_{\phi,\beta,\delta,\varepsilon} \sum_{i=1}^{n} \varepsilon_i^2 \tag{3}$$

s.t.

$$\ln x_i = \ln \phi_i + \varepsilon_i \quad \forall i$$

$$\phi_i = \boldsymbol{\beta}_i \mathbf{y}_i \quad \forall i$$

$$\phi_i \geq \boldsymbol{\beta}_h \mathbf{y}_i \quad \forall h,i$$

$$\beta_{h,i} \geq 0 \quad \forall h,i$$

Our choice to use StoNED is due to the fact that this relatively new estimator is applied in the practical regulation by the Finnish regulator to assess the cost efficiency of the DSOs.[6] We believe that comparing methods that are actually used is more relevant from the practitioner's point of view. Moreover, from the methodological standpoint, the similarity of the CNLS/StoNED approach to DEA lend us to better focus to issues of RTS and operation environment. Of course we could apply for example SFA or quantile based frontier estimators. But in these cases the focus would partly be diverged to the specification of the correct functional form or quantile (see e.g. Wang et al. 2014 and references therein). Nevertheless, both CNLS/StoNED and DEA are based on the same basic axioms of production, not on any arbitrary choice of functional form. The difference is that DEA utilizes only the information about the boundary observations. Similar to OLS, CNLS however utilizes all of the observations to estimate an average cost function that is moved to the frontier using the StoNED procedure. Thus DEA reflects the shape of the technology at the boundary, whereas in StoNED the shape of the frontier technology is more dictated by the average behaviour. Given that mergers not only happen between few boundary units, we consider that technology shaped by the average behaviour is a viable choice for the analysis of merger gains. The difference between a DEA and StoNED estimator is illustrated in Figure 3 below.[7] The figure is based on our empirical data which we describe in detail in Section 4. In Figure 3 we have one output and one input, namely the transmitted energy and the total cost of the company and the efficiency towards the frontier is measured to the input direction. Technology in the illustration is estimated using VRS assumption.

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[6] Some recent studies using the StoNED method can be found in Andor & Hesse (2014) and Cheng et al. (2014).

[7] Figure 3 is drawn without using the largest company in the dataset for estimation as for illustration purposes inclusion of that company would distort the figure uninformative. It is however included in our actual estimations (see footnotes 10 and 11).

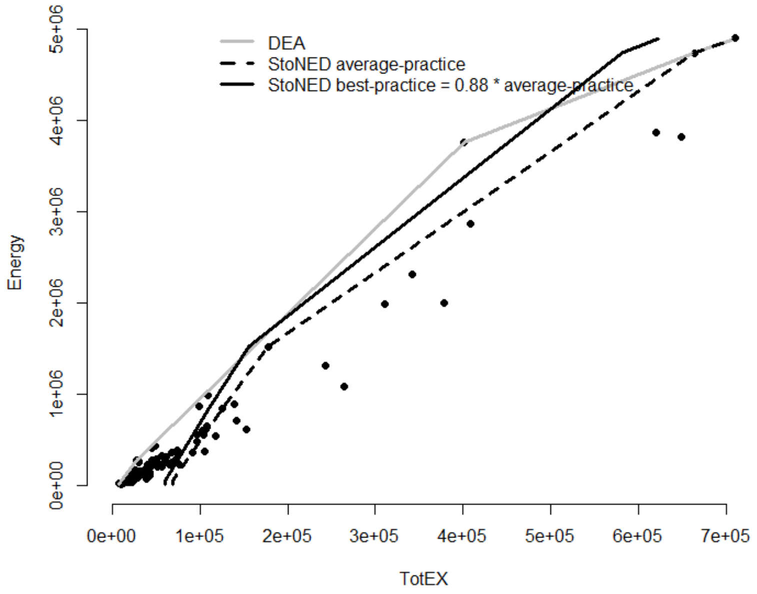

Figure 3: The illustration of DEA and StoNED

We can see from Figure 3 that whereas DEA frontier is strictly defined by the boundary observation, StoNED frontier does not go through all of the boundary points. The best practice StoNED frontier is a constant multiplication of the average practice thus preserving its shape. Although we do not see it so clearly for the smaller companies, the illustration suggests that the behaviour of StoNED is significantly different than that of DEA. Especially about from 100 000 NOK onwards we see that StoNED is effectively flat for a large range of costs, whereas DEA angles heavily due to one outlying observation. This would suggest larger harmony gains in this range when DEA is used. We can also see that in this example, bigger companies seem to drive up the frontier even in StoNED case where all observations can anyhow affect the shape of the frontier.

Concerning this study, one important question is how to incorporate the operating environment into the modelling. Multiple approaches can be found from the SFA literature (see e.g. Kumbhakar & Lovell, 2000). In frontier based merger analysis, environmental variables have been considered by De Witte & Dijkgraaf (2010) and Zschille (2014) who apply the conditional *free disposal hull* (FDH) and DEA estimators introduced by Daraio & Simar (2005, 2007). Merger analysis with DEA could also be augmented with the models of non-discretionary variables, where only a subset of variables can be adjusted by the firms (Bogetoft & Otto, 2011). In the StoNED context Johnson and Kuosmanen (2011) present a straightforward modification of the StoNED framework to include the z-variables. They extend the model specification given in Equation (2) by including the z-variables linearly into the specification and modifying the CNLS estimator correspondingly. This approach is suitable especially when the interest is in the coefficients of z-variables. Since all of the above estimators account for the operating environment in a slightly different manner, we see that we must adopt an approach that can be uniformly applied across methods. Moreover, we want to remain within the basic BW framework as tightly as possible.

We follow the procedure of Barnum & Gleason (2008). Barnum and Gleason suggest accounting for the effect of environment in the outputs via regression, where output is regressed on both inputs and environmental variables. Then the effect of the environmental variables is removed from the observed output, and the new adjusted value of output is obtained. Finally, the benchmarking exercise is done with the new adjusted data.

To adapt the approach of Barnum and Gleason to the cost side we follow a partially linear specification where the log of observed costs is regressed on the log of the outputs and the environmental variables as show in Equation (4). This formulation is consistent with the multiplicative formulation of the cost model presented in Equation (2).

$$\ln x_i = \alpha + \hat{\mathbf{y}}_{\mathrm{i}}'\boldsymbol{\theta} + \mathbf{z}_i'\boldsymbol{\delta} + \omega_i \qquad (4)$$

In Equation 4 the vector $\hat{\mathbf{y}}_{\mathrm{i}}$ represents the logged output values of firm *i*. We have used coefficients θ to separate them from the output coefficients β given in Equation (3). The environmental variables are given by vector **z**, and $\boldsymbol{\delta}$ is the associated coefficient vector which identifies the effects of these variables on the logarithm of total costs. As a second step, we adjust the observed costs to obtain the new adjusted costs, as shown in Equation (5).

$$\tilde{x}_i = \exp\left(\ln(x_i) - \mathbf{z}_i'\hat{\boldsymbol{\delta}}\right) = x_i \exp\left(-\mathbf{z}_i'\hat{\boldsymbol{\delta}}\right) \qquad (5)$$

The last step is to apply the BW framework, either with the DEA or the StoNED estimator, to estimate the technology and the associated merger gains using the new adjusted costs and the original output values. We label this estimation strategy as reverse two-stage DEA or StoNED model. No adjustment is done on the outputs, since we assume that the environmental variables affect to the costs of operation.

Methods somewhat similar to the approach of Barnum and Gleason have been suggested by Fried et al. (1999; 2002). These methods conduct an ordinary benchmarking first, then identify the effects of the environment on the observed slacks, and finally adjust input/output accordingly in order to run the benchmark process again. The current practice of the

Norwegian regulator is to adjust the obtained efficiency scores for the environment (see Amundsveen et al., 2014). Simar and Wilson (2007) have criticized the use of such two stage methods as they are not generally adequately defining the underlying data generating process. Also the underlying correlation between the efficiency scores in the first stage suggests biases in the second stage estimates of the environmental effects. We see that these problems are not equally apparent in the Barnum and Gleason approach as the order of the steps is reversed. Of course, we still need assume that our environmental variables are separable from the outputs since the adjustment is done only on costs and not on outputs. In the context of electricity distribution this seems a reasonable assumption as outputs are usually exogenously determined by the demand and thus it is rather the cost that is affected by the environment.[8] Moreover, using this approach we avoid somewhat ambiguous determination of the environment for the merged company. Considering any convex (weighted) combination of the environments is not appropriate as pointed out already by Ruggiero (1998). At least the weighting would be arbitrary as it would not be clear what weights to use.

5. Data

The data includes 123 Norwegian DSOs. With the exception of a few certain special distribution areas, these companies cover the whole of Norway. We have observations from the time period 2004-2012. We use however the averaged data over that period, thus the final sample includes 123 observations. Note that the computational burden of the CNLS estimation procedure increases significantly when the number of observations increase (see e.g. Lee et al. 2013). Computational tools to execute CNLS estimation with a high number of observations have been developed (Lee et al., 2013). Nevertheless, we see that there are at least two compelling reasons to use averaged data in the present context. First, it is not meaningful to consider merging the values of inputs and outputs from different years. Thus pooling data over all years and estimating one pooled frontier is not appropriate. It would be possible to estimate yearly frontiers and consider merger gains separately for each year. Since mergers can happen only once and the aim is to identify the potentially beneficial mergers over the whole period, such examination would not be highly informative. Second, averaging likely reduces the effects

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[8] The Norwegian regulatory model is somewhat more elaborate than many of the usual two-stage approaches. It utilizes the information from the first benchmarking stage in the second stage by using the differences in the environments between the firm and its reference companies in the first stage. Moreover the regulator applies a bootstrap approach to account for the serial correlation bias of the second stage.

of stochastic noise in the data, as discussed for example by Kuosmanen et al. (2013). It is more reasonable to study the merger gains under circumstances where all merging parties operate on their average input/output profile. Averaging reduces the effects of a single year of unexpected costs and sudden demand shocks.

5.1 *Input/output and operating environment data*

Our model specification is the same than the one used by the Norwegian regulator for which details can be found from Amundsveen et al. (2014). The single input is the total cost of the distribution company. It is measured in 1000 Norwegian kroner (NOK) and it is adjusted to the price level of 2012. The total cost includes five different components: operation & maintenance, value of lost load, thermal power losses, capital depreciation, and return on capital. We have three different outputs, namely the number of customers, the length of high voltage (HV) lines measured in kilometres, and the number of network stations. The model omits the transmitted energy as an output since it is highly correlated with the number of customers, creating multicollinearity.

Two of the five z-variables used are composite indices (*geo1* & *geo2*) in which the larger figures correspond to a harsher operating environment. The detailed description of the individual components of these indices can be found in Amundsveen et al. (2014). The distance to road (*distance*) is measured in meters, and it describes the average distance of the network lines to the closest road in meters. The variable *forest* describes the share of overhead HV lines affected by coniferous forest and the variable *under* is the share of underground lines in the HV network.

The z-variable adjustment discussed earlier leads to new environment adjusted cost data (*adjtotex*). It is noteworthy that the environment adjustment leads to smaller total cost values for all but one company.[9] The summary statistics of all the variables are given in Table 5.1. Recall that the data is averaged over the period which is why the customer number is not necessarily a whole number. The main observation from the summary statistics is that the company size is positively skewed as medians of the cost and outputs are significantly smaller than the means.

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[9] The correlation between the original total costs and the environment adjusted costs is almost perfect (0.9986).

Table 5.1: Summary statistics of the original data, n=123

	Mean	**Sd**	**median**	**min**	**max**
totex	92208.3	185344.4	33156.9	7829.4	1525695.3
adjtotex	79073.4	155582.9	27377.9	5119.6	1249879.7
customers	22222.9	58088.6	6302.8	994.0	536733.2
HV lines	789.3	1323.2	318.9	54.8	8390.2
stations	995.3	1879.0	365.4	56.7	13399.3
distance	227.79	208.57	142.87	70.37	1056.44
under	0.34	0.18	0.31	0.06	0.86
forest	0.12	0.10	0.12	0.00	0.39
geo1	0.01	1.49	-0.44	-2.06	4.72
geo2	0.00	1.52	-0.46	-0.64	11.86

5.2 *Merger data*

In this study we focus on pairwise mergers between two DSOs which share geographical borders with respect to their service areas. We have constructed a 123×123 binary matrix indicating whether the companies are neighbours or not (1 = yes, 0 = no). From this matrix it is straightforward to build the required merger matrix where each firm involved in a specific merger is identified. In total, there are 295 possible pairwise mergers. Note that when VRS is assumed in the DEA model, some of the mergers may be infeasible in terms of their size when compared to the original technology, as pointed out by BW. Since the size related gains cannot be computed for such mergers, the overall adjusted gains cannot be evaluated for these mergers either. A total of 11 such mergers were identified in our estimation.[10] However, harmony gains are computable even in these 11 mergers, as by construction the average company that forms the basis for evaluating the harmony gains is still within the technology. Thus we report harmony gains also for these mergers.[11] Similar problem does not occur in the case of StoNED since due to the noise term as the frontier does not need to exactly envelope all of the observations.

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[10] These 11 mergers involved one specific company, namely the largest company in the data set. Since this company in the VRS case is by construction part of the frontier, merging it will automatically lead to a company size that is not included to the original technology estimated using the original unmerged firms. Omission of the largest company from the estimation does not solve the problem, since similar problem would occur with the second largest company of the original dataset (which would now be the largest one). Furthermore such omission is not reasonable since the mergers should be evaluated against an existing technology and obviously all companies should be able to affect the estimation of the technology.

[11] Thus there are 295 mergers to be examined in all CRS models and in when the HA measure of DEA VRS model is examined. When SI and E* measures of VRS DEA models are studied, there are 284 mergers for which these measures can be reported.

The input and output data for a merged company is the direct summation of the costs and the outputs of the merging companies as is seen from the set of Equations (1). The summary statistics of merged costs and outputs are presented in Table 5.2. Also summary data for the *adjtotex* of mergers is presented. In this case it is the aggregation of environment adjusted costs of the merging companies. We can see that on average the merged companies are rather big compared to the original companies since the mean cost and outputs are about three times higher now.

Table 5.2: Summary statistics of the mergers, n=295

	mean	**Sd**	**median**	**min**	**max**
totex	272568.52	357092.70	119980.20	23129.49	2146201.01
adjtotex	232546.47	298292.91	106428.08	18288.89	1817971.56
customers	70399.01	115755.85	23161.44	3110.00	677192.89
HV lines	2210.23	2402.79	1248.11	172.56	14902.56
stations	2874.63	3539.71	1393.56	232.33	22777.78

6. Results[12]

We have separated our examination of the results into three parts. We start by examining the effect of changing the estimator of the cost functions from DEA to StoNED. After that, we analyse how the assumption about the returns to scale affects the magnitude of merger gains. Lastly, we examine whether accounting for z-variables in our estimations has any effect. Our examination is more from the overall industry perspective and we do not single out any particular mergers. As a consequence we focus to overall patterns over all firms rather than to the gains/losses in individual mergers.

Since our interest is in the possible merger gains, we focus to the mergers for which the values of E*, HA and SI are below one. It is however important to keep in mind that significant size related losses for some mergers are in fact found in all VRS models. Moreover, we only focus on the adjusted overall gains and its components (E*, HA, SI) as these can be considered the true gains due to merger. Thus we exclude the learning effect from our examination. We explore the results in two different ways. We examine both the magnitude of the gains and the number of beneficial mergers. In the latter case we consider different threshold levels for the mergers to be counted as beneficial. The threshold varies between 0.1% and 5% which in terms

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[12] The results have been obtained by using R software with the package 'Benchmarking' for the DEA estimations (see details in Bogetoft and Otto 2015). The StoNED/CNLS results are obtained with the standard StoNED/CNLS formulation and using GAMS software for the optimization. Codes and details are available for example in Johnson and Kuosmanen (2015).

of the gain measures means values between 0.999 and 0.95, where the latter value corresponds to larger gains.

Lastly, we introduce notation for the tables and figures. The DEA models are named as 'DEA' and StoNED models as 'STO'. RTS assumption is indicated by 'C' or 'V', referring either to constant or variable return to scale. If the model name includes 'Z' it means that the z-variables have been accounted for. Thus, for example 'DEA-CZ' refers to the constant returns to scale DEA model with environment adjustment.

First we examine the most beneficial and unbeneficial mergers. In Table 6.1 we have tabulated the minimum, maximum, and the 5% percentile points of the E*, HA, and SI in a percentage form. These statistics correspond to the best, the worst and the best 5% of the mergers. Recall that the lower the measures are, the higher cost saving potential the mergers yields. By construction, in CRS cases the values of E* are the same than HA values since all SI values in these case are 100%. For the sake of completeness we however report HA and SI values for CRS models also.

Table 6.1: The gains in the best mergers

	DEA-C	**STO-C**	**DEA-CZ**	**STO-CZ**	**DEA-V**	**STO-V**	**DEA-VZ**	**STO-VZ**
E*								
min	93.11 %	96.31 %	90.76 %	96.37 %	75.70 %	84.50 %	85.68 %	87.80 %
max	100.00 %	100.00 %	100.00 %	100.00 %	231.25 %	223.57 %	204.05 %	210.28 %
Best 5%	97.14 %	99.14 %	97.42 %	98.87 %	85.73 %	90.22 %	91.01 %	92.53 %
HA								
min	93.11 %	96.31 %	90.76 %	96.37 %	91.72 %	96.84 %	92.56 %	96.19 %
max	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %
Best 5%	97.14 %	99.14 %	97.42 %	98.87 %	94.46 %	98.44 %	94.71 %	98.24 %
SI								
min	100.00 %	100.00 %	100.00 %	100.00 %	75.73 %	84.50 %	86.04 %	88.00 %
max	100.00 %	100.00 %	100.00 %	100.00 %	231.25 %	223.57 %	204.05 %	210.34 %
Best 5%	100.00 %	100.00 %	100.00 %	100.00 %	87.33 %	90.56 %	91.69 %	93.20 %

We see that the magnitude of the gains in the best mergers varies significantly given the different model specifications. Note that different models do not necessarily identify the same mergers to be the most beneficial. For example, some mergers might have large size related gains or losses which affect their overall gains in the VRS case. Overall, the magnitude of the gains of the best 5% of the mergers is approximately 1%-3% in CRS models. In the VRS case we see larger gains as the gains of the best 5% of mergers vary from about 7.5% to 14%. The best mergers (minimum) achieve gains in the range of approximately 4%-24%. Generally these gains are due to large size related gains as the harmony effects are clearly lower than the size gains, suggesting some significant scale economies being present. However, in the VRS case there are also some very large size related diseconomies present (values above 100%), which in many cases might offset the positive harmony effects. This in contrast would suggest disintegration gains. The harmony gains that we find are similar to what Agrell et al. (2015) found. For size gains, we instead find larger effects than they did. Agrell et al. however reported the average gains instead of the gains at the end of the distribution.

The figures in Table 6.1 however are not very informative about the overall level of gains in the industry since they only reflect the level of gains in the best mergers. Thus in Table 6.2 we have presented the median of E*, HA, and SI for each model specification. We report median instead of the mean since the mean was found to be distorted upwards due to some large size related losses of some individual mergers. Anyhow our medians are rather close to the means presented in Agrell et al. (2015). If the median in the table is below 100% we can be certain that at least 50% of the hypothetical mergers have some gains present. Note that here we examine the whole distribution of gains and losses, not only the gains side of it. The most striking observation in the table is the large difference in size gains between DEA and STO when VRS is assumed. This reason for this will be discusses in the next section.

Table 6.2: The median of E, HA and SI*

	MEDIAN		
	E*	**HA**	**SI**
DEA-C	99.85 %	99.85 %	100.00 %
STO-C	100.00 %	100.00 %	100.00 %
DEA-CZ	99.85 %	99.85 %	100.00 %
STO-CZ	100.00 %	100.00 %	100.00 %
DEA-V	99.77 %	98.71 %	101.49 %
STO-V	97.43 %	99.97 %	97.72 %
DEA-VZ	100.04 %	98.81 %	101.85 %
STO-VZ	98.31 %	99.85 %	98.57 %

6.1 Effects of the frontier estimator

Next we compare the effect of the estimator choice to merger gains. We should compare only between the models with the same RTS assumption and z-variable specification as both factors individually can affect the gains. In Table 6.1 we saw that StoNED produces smaller harmony gains than the corresponding DEA based estimator. This suggests that the StoNED frontier is less curved implying that the angles (kinks) between the two intersecting frontier segments are smaller than in DEA. Given that CNLS based estimator goes through the cloud of points instead of boundary points, this smoother behaviour is quite expected. However, DEA may attribute statistical random noise as a merger gain since it assumes away the noise from the data. Thus it may overestimate the magnitude of the gains.

In terms of size gains StoNED produces smaller gains for the best mergers as we saw in Table 6.1. This implies less potential improvement through scale economies since the increasing returns part of the STO-V/STO-VZ frontier would be less steep than the corresponding segment in DEA frontiers. On the other hand, in Table 6.2 we saw that there seems to be more beneficial mergers in the StoNED models than in DEA since the median of StoNED is lower. Thus StoNED generally identifies more mergers to have some size related gains than DEA, but the magnitude of these gains is smaller in StoNED. These two results are not in conflict though, because we need to make a difference between the number of beneficial mergers and the magnitude of the merger gains.

Next, in order to get a view of how many mergers are beneficial, we investigate the number of beneficial using bar graphs which plot the number of beneficial mergers with the given magnitude of gains. In Figure 4 we have plotted the number of mergers (vertical axis) that have harmony gains greater than or equal to the given threshold (left panel CRS, right panel VRS). The threshold values of HA are given on the horizontal axis. Obviously, the higher the threshold, the fewer mergers are found to have as high gains. Moreover, mergers with high gains are always a subset of a group with a lower threshold. Thus the bars of similar colour decrease in height along the threshold values. In Figure 5, the similar plotting is done for SI where we do not have the CRS results since SI is always one in this case.

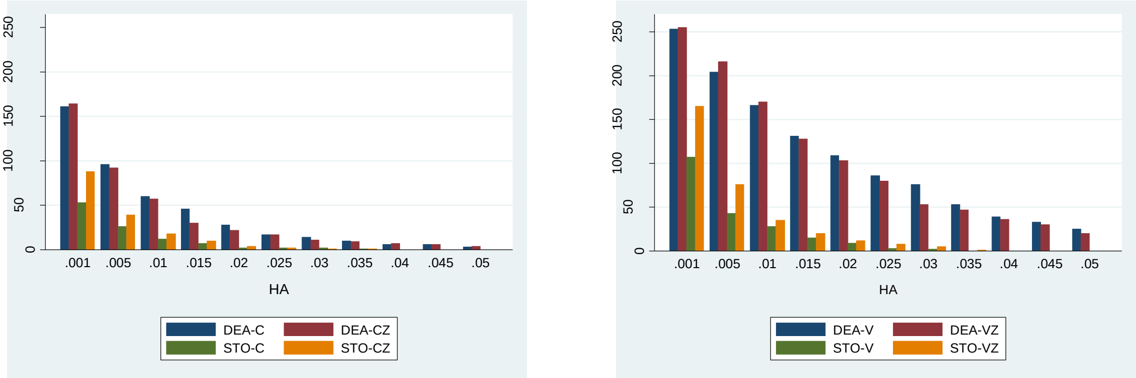

Figure 4: The effect of frontier estimator on harmony gains

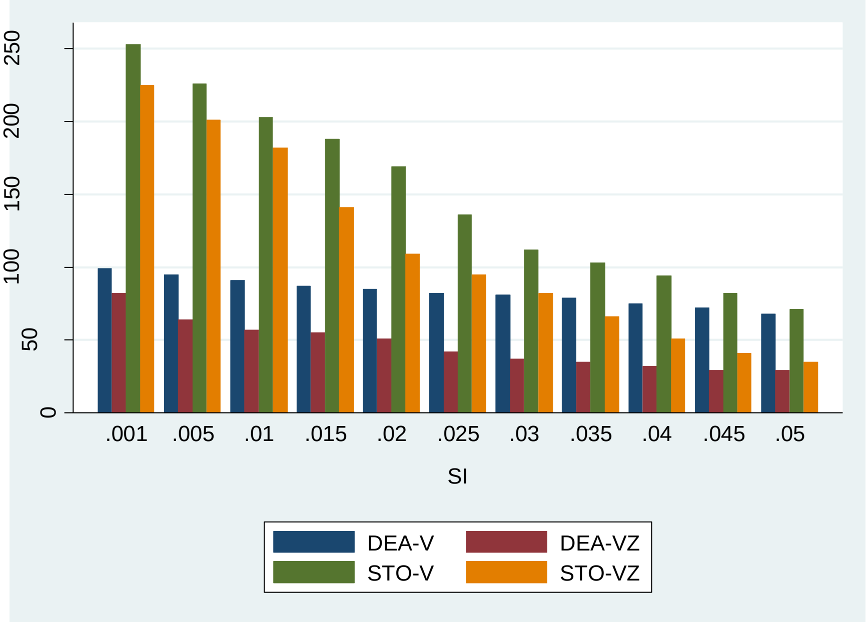

Figure 5: The size related gains under different frontier estimators

Figures 4 and 5 imply similar conclusions that were already observed from the earlier results. Clearly the number of beneficial mergers in terms of HA is higher across all thresholds in DEA than in StoNED due to curvature. One reason for this smoother behaviour of StoNED might be that it produces more separate piecewise linear frontier segments, which may smooth out most of the largest angles in kinks. Of course, more segments mean more kinks and thus in principle more possibilities for the existence of harmony gains. But due the smoothness, these gains are often virtually non-existent for most mergers. Indeed, as Table 6.2 points out, the median for harmony gains in STO-models is practically 100% in all cases. In fact, even the 25% percentile is very close to 100%, which is why we see so few beneficial mergers in Figure 4 for STO-models as the thresholds are large compared to the potential gains.

StoNED however produces higher number of mergers to have size gains. This is also possibly explained by the higher number of frontier segments of StoNED. If indeed StoNED produces more segments, then it is likely that there are also more of IRS segments presents. On the other hand, if there is only one IRS segment of StoNED present, it may just expand further than the corresponding DEA IRS segment, thus covering more observations. Also, when using DEA (with or without z-variables), the number of beneficial mergers in terms of SI is relatively stable over all threshold values. This implies that most of the merger gains when estimated with DEA are rather large in magnitude. This suggests that the IRS part of the DEA frontier has larger returns to scale than corresponding IRS segment of StoNED frontier.

6.2 Effects of the RTS assumption

Table 6.1 showed that for the best 5% of the mergers, the VRS models produce greater harmony gains than the corresponding CRS models. The VRS frontier is always a tighter envelopment of the data than the CRS frontier and thus it is basically a more curved frontier. More curvature means that the amount of harmony gains is larger for some mergers. The best 5% of the mergers seem to have larger gains in the VRS models also in terms of E* since for some mergers the size effect increases the overall learning adjusted gains E*. Generally size gains contribute much more to E* than harmony gains. Of course size effect can be also negative. In fact, size effects act as an additional source of variation in E*. Thus we would expect that the variation in E* is larger in VRS case than in the CRS models. We examine this in Table 6.3, reporting the standard deviations of all gain measures for each model specification.

Table 6.3: The standard deviation of E, HA and SI*

	STANDARD DEVIATION		
	E*	**HA**	**SI**
DEA-C	0.0108	0.0108	0.0000
DEA-V	0.1308	0.0185	0.1377
STO-C	0.0042	0.0042	0.0000
STO-V	0.1438	0.0055	0.1431
DEA-CZ	0.0113	0.0113	0.0000
DEA-VZ	0.1011	0.0168	0.1072
STO-CZ	0.0046	0.0046	0.0000
STO-VZ	0.1244	0.0065	0.1238

The standard deviation of E* is indeed larger under VRS models, in many cases by a factor of ten. The variation of SI is zero by construction in CRS models, causing the low variability in E*. Interestingly we also see significant differences in standard deviations between the two estimators. Whereas StoNED has more variation in SI, the variation in HA is larger in DEA. This is consistent with our earlier observations about the differences between the estimators.

Next we examine whether CRS produces more beneficial mergers than VRS in terms of HA in Figure 6. Results concerning the overall learning adjusted gains (E*) are presented in Appendix A. Now it only makes sense to compare the same estimator with the same z-variable specification. As expected, in all cases, VRS models produce more mergers to be beneficial due to the curvature of the frontier, a finding confirmed by our earlier results.

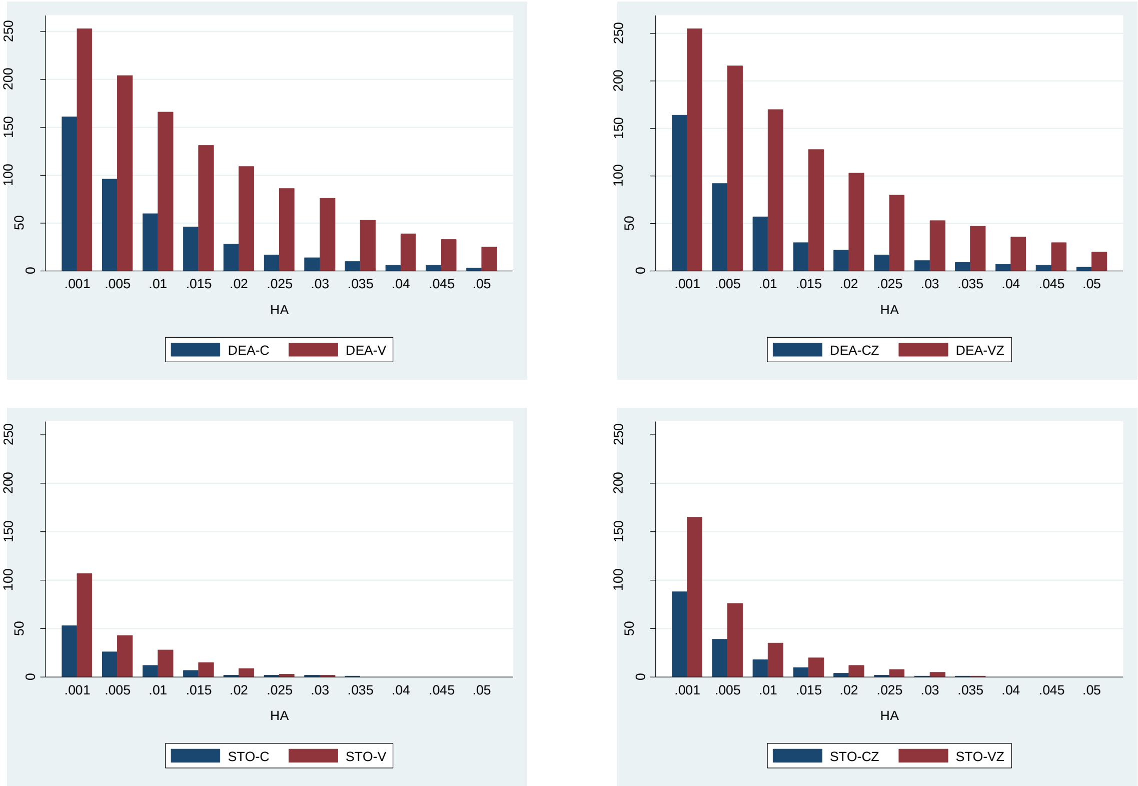

Figure 6: The effect of RTS assumption on merger gains

6.3 Effects of the operating environment

Lastly, we examine the effect of accounting for the operating environment. Now we compare only results with the same estimator and the same RTS assumption. Before examining the effects, we check how the z-variables are correlated with the cost and the outputs in Table 6.4. This reveals how environmental variables are likely to affect to the operations of the firms.

Table 6.4: The correlations between the original variables

	totex	customers	hv_lines	stations	dist	under	forest	geo1	geo2
totex	**1.000**	0.983	0.946	0.966	-0.112	0.286	0.107	-0.165	-0.074
customers	0.983	**1.000**	0.882	0.922	-0.124	0.326	0.115	-0.165	-0.073
HV lines	0.946	0.882	**1.000**	0.985	-0.075	0.144	0.064	-0.182	-0.084
stations	0.966	0.922	0.985	**1.000**	-0.130	0.218	0.119	-0.197	-0.095
distance	-0.112	-0.124	-0.075	-0.130	**1.000**	-0.359	-0.483	0.016	0.267
under	0.286	0.326	0.144	0.218	-0.359	**1.000**	0.183	-0.058	-0.085
forest	0.107	0.115	0.064	0.119	-0.483	0.183	**1.000**	0.008	-0.147
geo1	-0.165	-0.165	-0.182	-0.197	0.016	-0.058	0.008	**1.000**	-0.127
geo2	-0.074	-0.073	-0.084	-0.095	0.267	-0.085	-0.147	-0.127	**1.000**

Underground cabling and *forest* are positively correlated with costs, since both generally imply higher costs. As underground cables are often located in larger cities with a large customer base, this positive correlation is rather expected as larger companies naturally have larger costs. The positive correlation of *forest* with cost and outputs can also be interpreted in terms of the company size. Smaller companies often operate on mountainous regions of Norway, where the density of the forests is smaller due to the harsh growing conditions for trees.[13] The correlation between *forest* and costs seems natural since the presence of dense forest generally implies higher maintenance costs due to trees falling on top of cables. Distance to road is negatively correlated with the costs. Again this is an implication of firm size as for the small companies with smaller costs, the access to road is generally more challenging since they operate in harsh environment. Similar considerations apply to the composite variables *geo1* and *geo2*. Both include components that are more prevalent for smaller companies. Thus in summary, the environmental variables here can be considered as indirect indicators of company size.

Now we move on to examine how the inclusion of z-variables affects the level of merger gains. First, we look back to Table 6.1. We see that in all CRS models, the inclusion of environmental variables does not have too much effect on the magnitude of gains (in terms of E*) in the best mergers. On the contrary, in VRS models the magnitude of the gains in the best mergers is generally smaller when we also account for the operating environment. We discuss the reason for this soon. However if we look at Table 6.2, it can be seen that the change in the median gains is very small even in VRS after inclusion of operating environment variables. Thus the operating environment mainly seems to affect the most beneficial mergers only. To see how gains are distributed when introducing z-variables, in Figure 7 we compare the number of beneficial mergers in terms of E* with and without the z-variables.

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[13] The forest density is lower in the more mountainous regions (see e.g. Norwegian Environment Agency, 2010).

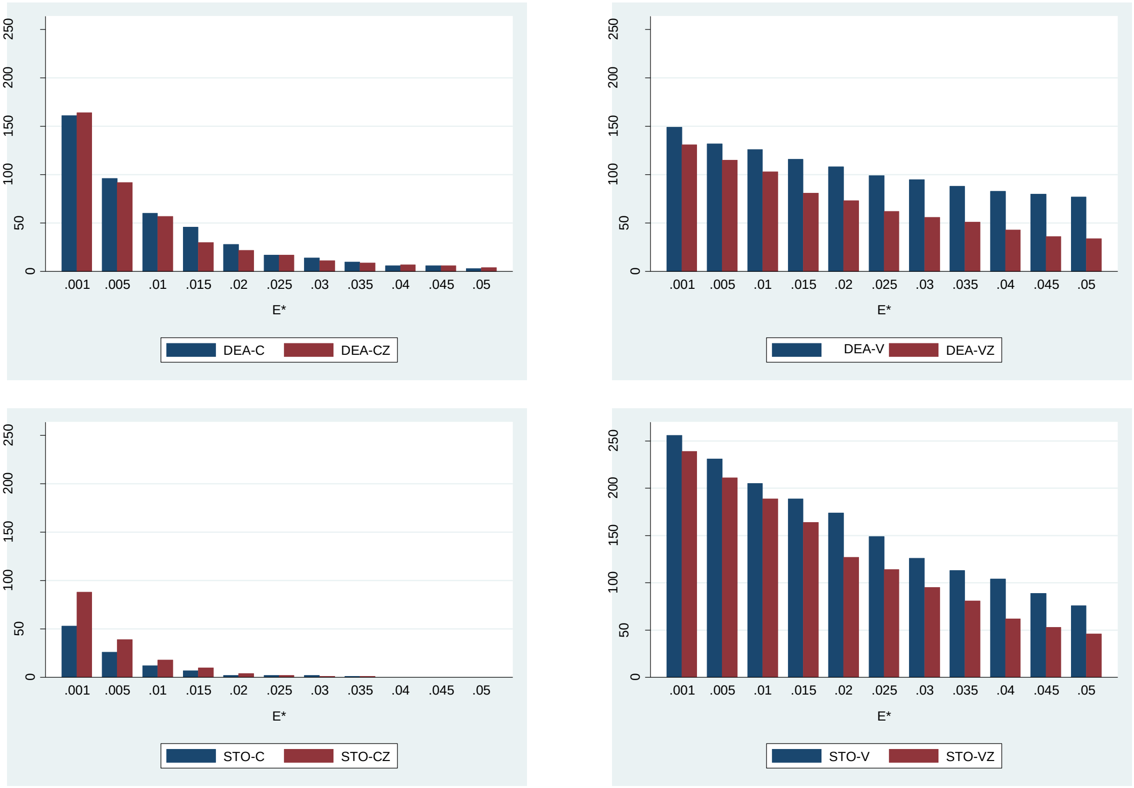

Figure 7: The effect of z-variables on harmony gains

In the DEA CRS model, the effect of including z-variables is rather small to number of beneficial mergers. Under CRS E* is fully comprised from HA, for which we saw in left panel of Figure 4 that the effect of accounting for environment is small in DEA model. Recall that z-variables are a reflection of company size and thus we would expect that the effect of z-variables manifests itself more in the size effect. Note that the DEA CRS frontier is probably quite linear and thus the same few companies form the frontier before and after the adjustment. In other word, the relative position of the companies does not change even after the adjustment. Thus we do not see much of a difference between the two DEA CRS models.

In the DEA VRS case we see a different pattern due to the size effects. In Figure 5 we saw that the inclusion of z-variables reduces the amount of beneficial mergers in terms of the size effect. Since the size effect generally dominates the harmony effect, the effect on E* follows the patterns of the size effect. The number of beneficial mergers goes down after the environment adjustment. The effect of z-variables to the gains is rather expected considering the correlations of z-variables with costs. As the costs due to the operating environment have been explicitly accounted for, there should be less improvement potential in the merger coming out of size effects. Consequently these costs cannot be accounted anymore as possible cost savings. This however does not yet tell which companies would be affected the most from the adjustment. Thus, in Figure 8 we have plotted the original costs against the share of the environment adjustment from the original costs.[14] Although the variation is high, for some of the smallest companies the magnitude of the adjustment relative to the original cost is higher than the adjustment of the largest companies. Thus it seems that in terms SI, it is the smaller companies which lose the most potential gains if environment adjustment is applied. Given that it is the smaller companies that generally are seen to benefit from increases in scale (see introduction), this result is quite logical.

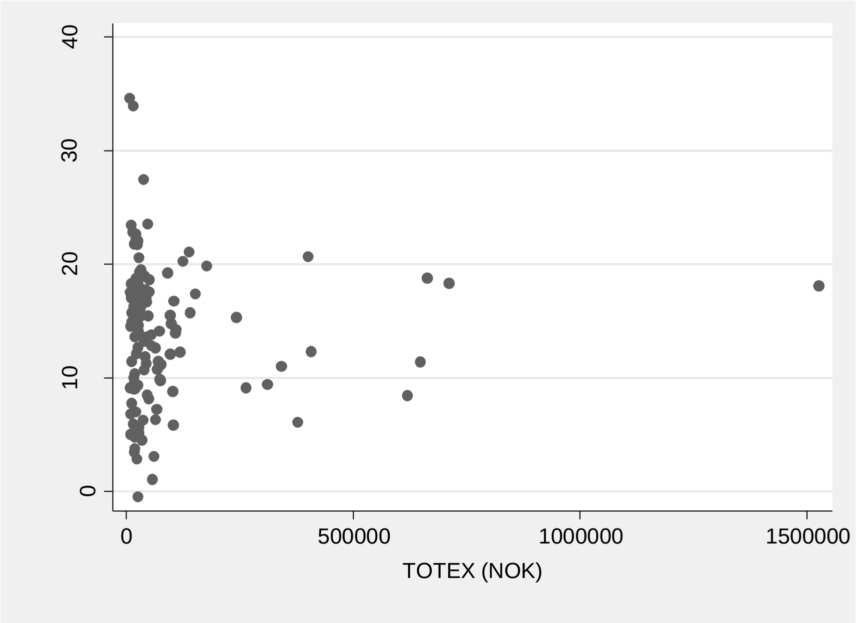

Figure 8: The share of environment adjustment and company size

Going back to Figure 7, when we examine the StoNED models, we see that the results concerning VRS model are mostly similar than in DEA case. Again, adjusting the VRS model with environmental variables reduces the number of beneficial mergers. However, the STO CRS model shows a completely different behaviour than the corresponding CRS DEA model. The inclusion of environmental factors in fact increases the number of beneficial mergers. Recall that the adjusted costs are smaller than the original costs for almost all companies (see footnote 12). As firms are now perceived more efficient, more firms are closer to the frontier. This alters the shape of the frontier such that the possibilities for some harmony gains are now larger, i.e. there are more of those kink points present. Of course the same result applies to the

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[14] The variable on y-axis in Figure 7 is defined as: (totex-adjtotex)/totex. We see that for all but one company, the adjusted cost is lower than the original *totex* as the share variable is positive. The negative share for one company implies that environment adjustment increases the costs.

VRS STO frontier also (see Figure 4, right panel). But here the large negative size effects often cancel out the potential small improvements in harmony gains, thus the net effect on E* is similar than what we observed in VRS DEA.

5.4 Summary of the results

When interpreting the results it is important to distinguish between the level of gains and the number of beneficial mergers. It was argued that these effects do not need to go in the same direction. The former effect can be seen to matter more when evaluating the individual mergers but the latter may have more relevance when assessing the prospects of industry restructuring. The results are also highly interlinked. As estimator choice, RTS-assumption and z-variables individually may affect in different directions, it is challenging to identify sources of overall gains/losses unless the analysis is broken down onto the level of individual mergers. The estimator choice influences the gains through the differences in smoothness/curvature of the frontier. The RTS assumption also affects to the shape of the frontier, altering both the presence of harmony and size related gains. The move from a CRS model to a VRS model introduces significant scale related gains or losses which generally offset the smaller scope related effects. This would suggest that rather than giving a premium from size for small or large companies, it would be better to incentivize firms towards the optimal scale size by using CRS (see Kuosmanen, 2012). From the Norwegian experience, we know that adopting VRS will lead to so called weak regulation among the largest companies since by construction some of the large companies are efficient with any given cost level in VRS model (Bjørndal, et al., 2010). The effect of including operating environment varied between the estimators. Since in our application, environmental variables were heavily related to the size of the companies, the effect of operation environment adjustment depended whether size related gains were allowed to be present. In both methods, the adjustment reduced the amount of beneficial mergers when VRS was assumed due to the negative size effects. In CRS models, the effect varied between the two estimators. As environment adjustment generally made the companies more efficient in our application, it was the way how different estimators allow observations to affect to the frontier that determined the direction of the effect.

7. Conclusions

In the electricity distribution industry, companies usually are local natural monopolies and they generally have a legal obligation to provide distribution services within their service areas. Under such circumstances the market structure is not shaped by the normal entry and exit but rather through the merger activity between the companies. This activity may be affected by the regulatory environment these companies face. For example, the incentive structure of the regulatory model may favour certain sized units. In this paper we illustrate how the incentives to merge may be shaped by the way how the regulatory model deals with mergers. Using Norwegian data we show, that the potential gains from the mergers vary significantly depending from the assumptions made about the production technology.

The general policy suggestion from your results is that the assumptions concerning the estimation of the cost norm should be stated clearly by the regulator. It is important to explicitly define what types of gains are acknowledged when assessing the potential gains from the mergers. Few examples are in place. First the costs due to harsh operating environment may be misattributed as potential cost savings without any explicit assumptions about the environment. Second, constant returns to scale technology is often assumed in the regulatory models since it treats all firms equally regardless of the size. It also gives stronger incentives to move towards the optimal scale size, which is of course desirable in terms of restructuring the industry. However, for the merger analysis, CRS assumption also implies that it is in fact synergies in the form of harmony gains that the can be considered as true merger gains. Given that scale economies are not necessarily sufficient to guarantee any true savings from mergers in a multiproduct industry this seems to be a valid choice from the part of the regulator.

Some limitations of this study and directions for the future research can be pointed out. First, a more detailed examination at the level of individual mergers would be needed in order to understand the exact sources of gains or losses in each case. Here we took the industry perspective to characterize some overall patterns of gains. Second, an analysis to identify under which operational conditions mergers are beneficial could be done. We did not examine how individual environment variables affect the presence of merger gains. Only the overall effect of environment was accounted for in our analysis. Third, analysing mergers of different size beyond pairwise mergers would shed light on the optimal size of the mergers. Last, different methods could be compared in a controlled Monte Carlo setting. Since in an empirical setting, the true data generating process is unknown, we cannot place any general preference of one model over another within this study. Of course this was not the purpose of our examination either. But for the regulator deciding over methodologies, knowing the comparative advances and weaknesses of a given method under certain circumstances would be beneficial.

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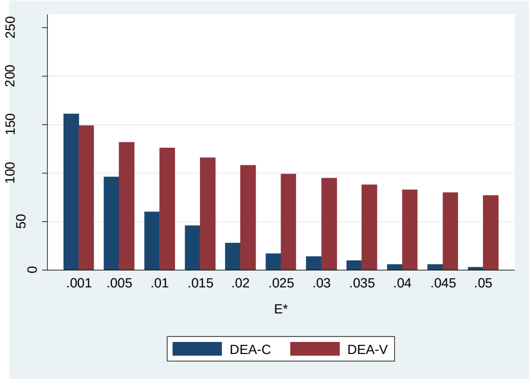
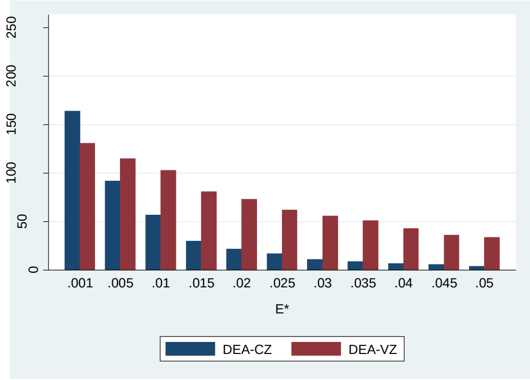
Appendix A

Below in Figure A.1 we compare the frequencies of beneficial mergers in terms of E* under both RTS assumptions for each estimator separately. When interpreting the picture, it is important to keep in mind that in the VRS models the negative size effect may offset the positive harmony effects. Thus some mergers that were beneficial in terms of HA may not be beneficial in terms of SI and consequently not in terms of E* either. Furthermore, the blue bars referring to the CRS models are exactly the same as in Figure 6 since size effects play no role.





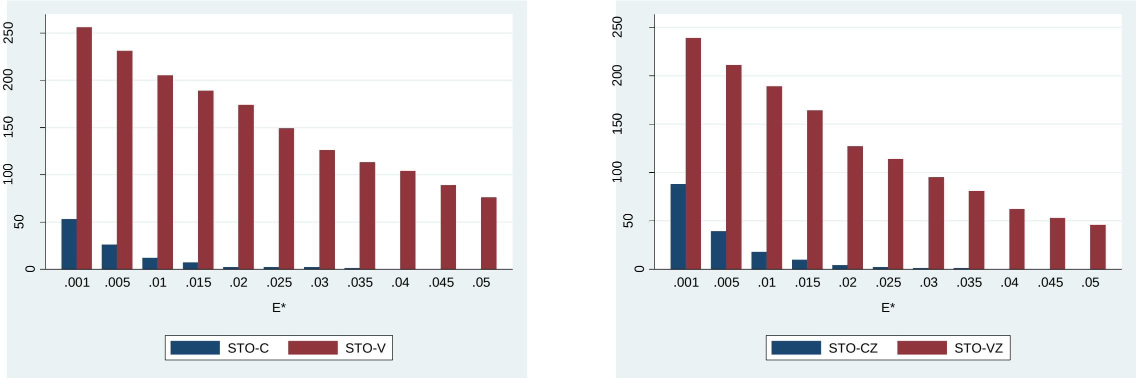


Figure A.1: The effect of RTS assumption (gains measured with E)*

The first observation from Figure A.1 is related more to the estimator choice and RTS assumption that we already dealt with in sections 6.1 and 6.2. Clearly in terms of E*, the estimators produce highly different numbers of beneficial mergers. VRS models produce more beneficial mergers than the corresponding CRS models. Only when the threshold is very small, DEA CRS model identifies more beneficial mergers than DEA VRS in terms of E*. Since we know that latter model produces more harmony gains, it must be that for some of the mergers having small harmony gains, negative size effects of VRS turns the overall measure E* below the corresponding DEA CRS value of E*. As soon the threshold is larger, we see the usual pattern that VRS produces more merger gains. In the case of STO-model we see that CRS models produce exceptionally few beneficial mergers in terms of E*. This is because size effects are not involved and StoNED cannot on average produce very large harmony gains due to its higher smoothness/smaller curvature. In STO VRS models we see a large number of mergers being beneficial. This due to the large amount of size related gains that STO-models produce.