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Total Cost Benchmarking at RIIO-ED1: Econometrics methodology review.

A Final Report for Western Power Distribution

29 May 2013

This report has been prepared on the basis of the limitations set out in the service agreement and the matters noted in the Important Notice From Deloitte on page 1.

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1 Overview

1.1 Introduction

Ofgem commissioned Frontier Economics in 2012, as part of the RIIO-ED1 price control review, to undertake an econometric benchmarking study of totex for the 14 electricity distribution companies ("DNOs") regulated by Ofgem. This analysis was updated in a report published by Ofgem in May 2013 setting out the final results from Frontier Economics' analysis. Frontier Economics utilised data from all 14 DNOs over a period of 6 years (2006/07 to 2011/12), and estimated their relative totex efficiency by means of pooled and panel regression analysis. In short, the results of the study showed statistically and economically significant differences in the efficiency levels of the DNOs. Additionally, Frontier Economics built and published an Excel modelling tool, which can be used by Ofgem and DNOs to update the Frontier models when new data become available, and/or to estimate alternative model specifications.

This brief report reviews Frontier Economics' econometric analysis in order to assess the degree to which the results are statistically sound, and hence provide a reliable basis for the RIIO-ED1 price control review.

1.2 Approach

We obtained the data used by Frontier Economics, replicated their two main econometric models and carried out additional analysis to diagnose the models' statistical adequacy. In particular, we applied a mis-specification check to test for omitted factors in Frontier Economics models. Additionally, we used an alternative methodology, namely Stochastic Frontier Analysis ("SFA"), to estimate the inefficiency parameters. The advantage of this approach is that, among other things, it allows the inefficiency parameters to vary over time, and hence is more flexible than the pooled OLS or panel approaches used by Frontier Economics.

1.3 Key results

- **Mis-specification**. Statistical analysis testing for heteroskedasticity suggests that Frontier's preferred model is mis-specified. While the variables in the Frontier model are statistically significant, the test for heteroscedasticity indicates that the model is likely to suffer from omitted variable bias. This could indicate that the models are missing key explanatory factors such as quality of service components, and/or do not adequately control for differences in cost reporting that may arise through the application of different accounting practices by the DNOs, such as the application of capitalisation policies. In other words, the results of the Frontier Economics model may be imprecise and misleading.

- **Additional evidence of mis-specification.** The evidence of model mis-specification is further reinforced by examining the results from re-estimating Frontier's models using Stochastic Frontier Analysis. The estimates of relative inefficiency are shown to vary substantially over time. This variation through time does not follow a trend, and is higher

than would be expected from year to year variations in DNO relative inefficiency. This indicates that the model results reflect factors other than technical inefficiency alone.

- **Uncertainty surrounding the inefficiency estimates.** Putting the above aside and assuming that the Frontier Economics models are well-specified, we estimated 95% confidence interval of the inefficiency point estimates. We found that the confidence intervals are such that it is difficult to draw firm conclusions about the relative efficiency of the ownership groups on the basis of the Frontier Economics models. In other words, the results are not able to distinguish the relative efficiency of the ownership groups at a 95% level of confidence.

Our analysis provides evidence of potential misspecification of the Frontier Economics models, suggesting that the parameter estimates and inefficiency measures derived from the models can be misleading.

1.4 Structure of report

The remainder of this report is structured as follows:

- Section 2 describes the Frontier Economics main model specification.
- Section 3 provides additional econometric analysis and tests carried out by Deloitte.
- Section 4 provides a brief discussion of various issues with regards to Frontier Economics models.
- Section 5 provides the conclusions.

2 Frontier Economics model specification

Frontier Economics primary specification to estimate the level of efficiency for the DNOs is:[1,2]

$$\ln\left(\frac{totex_{it}}{capital\ prices_{it}}\right) = \beta_1 \ln(customers_{it}) + \beta_2 \ln(peak_{it}) + \beta_3 \ln(density_{it}) + \beta_4 \ln\left(\frac{wages_{it}}{capital\ prices_{it}}\right) + \varepsilon_{it}$$

$$\varepsilon_{it} = u_i + v_{it} \quad (1)$$

where
i: DNO id
t: year
ln: natural logarithm
$\frac{totex}{capital\ prices}$: total expenditure divided by capital prices
$customers$: number of customers
$peak$: peak demand served
$density$: average connection density
$\frac{wages}{capital\ prices}$: labour price (wage) divided by capital price
ε: composite error term
u: DNO inefficiency
v: error/residual term

The primary parameter of interest is the inefficiency term u_i, which can be estimated by a number of different estimators: corrected pooled OLS, random effects, fixed effects, and stochastic frontier. Frontier Economics use the first two estimators but place more weight on Random Effects (RE).[3]

[1] For more details regarding variable definition and construction, see the Frontier Economics reports: (1) Total cost benchmarking at RIIO-ED1 - Volume 1; (2) Total cost benchmarking at RIIO-ED1 - Volume 2.

[2] Frontier Economics estimated a number of alternative specifications. We understand that their preferred specification is equation (1).

[3] Pooled OLS assumes that each observation is independent whereas the panel approach recognises that there is time-dependency in observations within each DNOs, and hence is more appropriate.

3 Testing the Frontier Economics models

We have obtained the data required to estimate equation (1) from "Benchmarking model - Model version 1.1 - Phase2", the modelling tool provided to the industry by Frontier Economics, and are able to replicate Frontier Economics' RE results using their two main controls of employee wages, national SIC35 and regional SIC35. Furthermore, we investigate:

- the degree to which equation (1) is well specified; and
- the robustness of the results using an alternative estimator, namely stochastic frontier.

3.1 Panel RE: mis-specification test

A model is well-specified if it captures all important factors that affect the dependent variable. That a model is well specified, is one of the main assumptions underlying the accuracy of the estimates. In other words, if a model omits one or more important explanatory variables, the estimator is biased and inconsistent and the model parameter estimates and standard errors can be imprecise and misleading.[4] Model adequacy can be tested once the model has been estimated. Intuitively, the tests are based on the estimated model residuals and aim to assess the degree of residual randomness. If there are no omitted factors, the residuals should be random noise. If there are omitted factors, these essentially "sit" in the error term, and induce non-randomness. Two standard diagnostic tests that are commonly used are for serial correlation and heteroskedasticity. Given the short span of the time dimension of the sample, we focus on the latter.[5]

Table 1 reports the results of the heteroskedasticity test applied on equation (1) when estimated by RE. In essence, the test assesses the equality of the variance of the residuals across the 14 DNOs. The null hypothesis is that the residual variance is the same across DNOs (indicating homoscedasticity), and the alternative that the residual variance differs across DNOs (indicating heteroskedasticity). Three versions of the test are reported for both the regional and national wage specifications.[6] The null hypothesis of homoscedasticity is rejected in 4 cases at 95% level. In one case, the null is rejected at 90% level, and in another one the null cannot be rejected at the 90% level. The W50 test is conservative when the number of groups (DNOs) is small (see Conover, Johnson, and Johnson, 1981): it tends to under-reject the null of constant variance even where the alternative of heteroskedasticity applies. We interpret these results as evidence of residual heteroskedasticity, and hence omitted factors from equation (1). These omitted factors may be related to differences in the investment cycle and quality of service across DNOs, or may reflect that the cost function has the wrong functional form. For instance, if a DNO invests heavily in capex

[4] This has long been established in the econometrics literature and is widely recognised by practitioners and academics alike.

[5] Serial correlation tests assess the dependency of residuals over time and require a relative long sample period in order to provide accurate results.

[6] W0 is Levene's (1960) robust test statistic for the equality of variances between groups; W50 and W10 are two alternative versions of W0 proposed by Brown and Forsythe (1974).

in one year and very little in another year, its estimated error term variance will be large whereas if another DNO invest equally across years, its estimated error variance will be small.

Table 1: Heteroskedasticity test

Test	Regional SIC35 Specification	National SIC35 Specification
W0	1.93**	2.28**
W50	1.5	1.82*
W10	1.93**	2.28**

*Source: Deloitte. **, * indicate rejection of the null hypothesis of homoscedasticity at 95% and 90% confidence level, respectively*

3.2 Stochastic frontier approach

Stochastic frontier analysis ("SFA") is the standard family of techniques for assessing technical inefficiencies in the literature (Greene, 2000), and was applied to equation (1) with the aim of investigating the robustness of the RE estimator. Most importantly, SFA is capable of allowing the inefficiency term to vary over time and hence is more flexible than the panel RE estimator, which, by design, assumes that inefficiency remains constant over time. Specifically, we use the Battese and Coelli (1995) panel SFA approach, which allows the inefficiency to vary over time and across DNOs – the time variation in the inefficiency is not restricted to be homogenous across DNOs.

Table 2 and Table 3 compare the results from the two alternative methodologies, RE and SFA, in terms of coefficient estimates and inefficiency rankings across both the national and regional wage specifications. First, the RE estimates and rankings are identical to the ones reported by Frontier Economics, and hence verify their results. The results from the two approaches are also largely indistinguishable. This implies that it is valid to use the SFA results to further explore the properties of the inefficiency estimates obtained from the RE estimation.

Figure 1 and Figure 2 depict the SFA estimates of the inefficiency across DNOs and over time. A clear picture that emerges from these figures is that the inefficiency estimates vary substantially across the years for the majority of DNOs. The scale of variation appears to be more than can be plausible accounted for by year-on-year changes in cost or output performance. This implies that the inefficiency measure is likely to be capturing factors other than the DNOs technical inefficiency alone, which have not been adequately controlled for in the estimation. This is consistent with the results from the mis-specification test reported in the previous section, which suggests omitted factors. These omitted factors are likely to contaminate the inefficiency estimates and may explain the substantial time-variation that they exhibit.

Table 2: RE vs. SFA model estimates

Variable	Regional SIC35		National SIC35	
	RE	*SFA*	*RE*	*SFA*
customers	0.47***	0.42***	0.58***	0.44***
peak	0.35***	0.40***	0.24*	0.39**
density	-0.08***	-0.08***	-0.06*	-0.06***
wages	0.33***	0.30***	0.54***	0.45*
constant	-8.21***	-8.12***	-8.63***	-8.07***

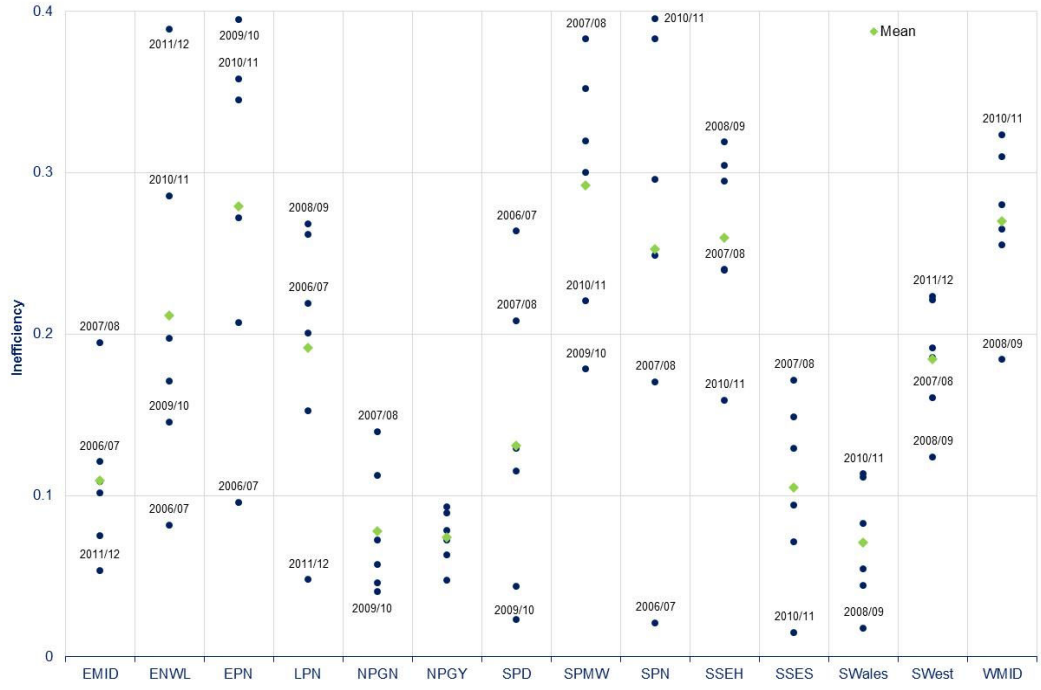
*Source: Deloitte. ***, **, * indicate rejection of the null hypothesis that the coefficient estimate is zero at 99%, 95% and 90% confidence level, respectively.*

Table 3: RE vs. SFA Inefficiency Ranking

DNO	Regional SIC35		National SIC35	
	RE	*SFA*	*RE*	*SFA*
EMID	5	5	4	5
ENWL	8	8	8	9
EPN	12	12	13	13
LPN	9	9	9	8
NPGN	7	6	2	3
NPGY	1	1	3	2
SPD	6	7	6	6
SPMW	14	14	14	14
SPN	10	11	10	10
SSEH	11	10	11	11
SSES	3	3	5	4
SWales	2	2	1	1
SWest	4	4	7	7
WMID	13	13	12	12

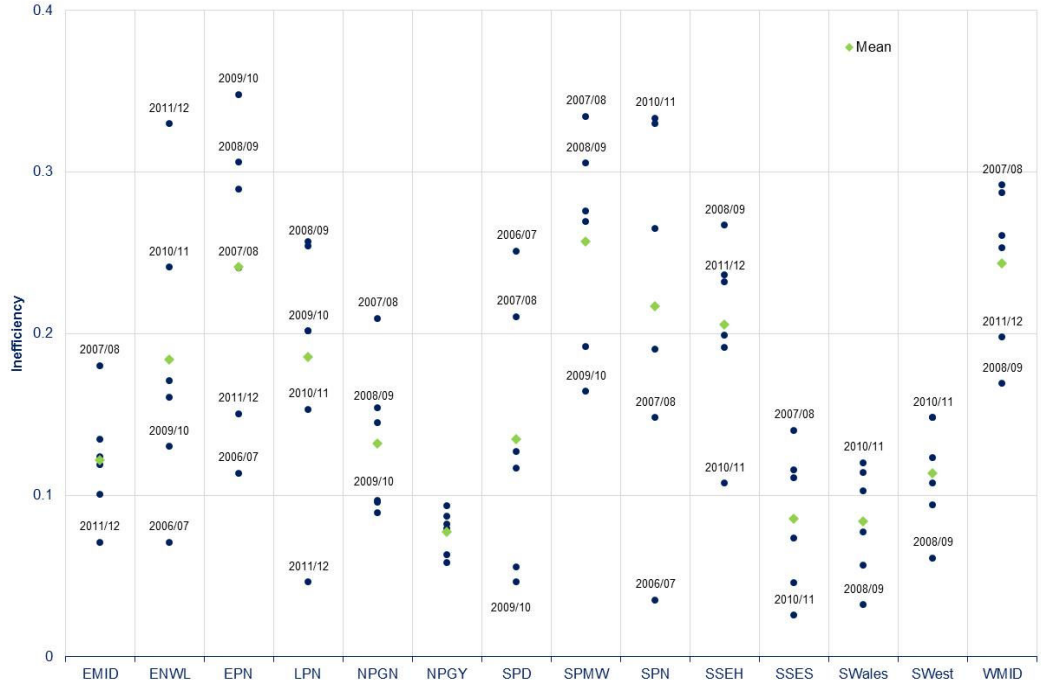
Source: Deloitte

Figure 1: SFA inefficiency, Regional SIC35 model



Source: Deloitte analysis

Figure 2: SFA inefficiency, National SIC35 model



Source: Deloitte analysis

In an updated report (April, 2013), Frontier Economics derive the efficiency scores using only data for 2011/2 (pp. 87). The ranking implied by these scores for the regional wage specification are shown in Table 4 together with the ranking implied by the RE and Pooled OLS (POLS) models using the whole sample period. The last column in Table 4 shows the difference in ranking between the POLS using the whole sample period and POLS using only the last year of the sample.[7] In line with Frontier Economics' conclusion (see pp. 88), the change in the efficiency ranking is significant. This is consistent with the time variation in the efficiency scores reported earlier in this report, which is likely to reflect omitted factors.

Table 4: Efficiency score ranking using the full sample vs. using 2011/12

	Ranking			
DNO	RE	POLS	POLS	POLS
	(2006/07-2011/12)	(2006/07-2011/12)	(2011/12)	Change in ranking
WMID	13	13	11	2
EMID	5	5	3	2
ENWL	8	9	14	-5
NPgN	7	7	5	2
NPgY	1	2	4	-2
SWales	2	3	7	-4
SWest	4	4	9	-5
LPN	9	8	2	6
SPN	10	10	10	0
EPN	12	12	8	4
SPD	6	6	6	0
SPMW	14	14	13	1
SSEH	11	11	12	-1
SSES	2	1	1	0

[7] The RE estimator cannot be used with only one year's worth of data.

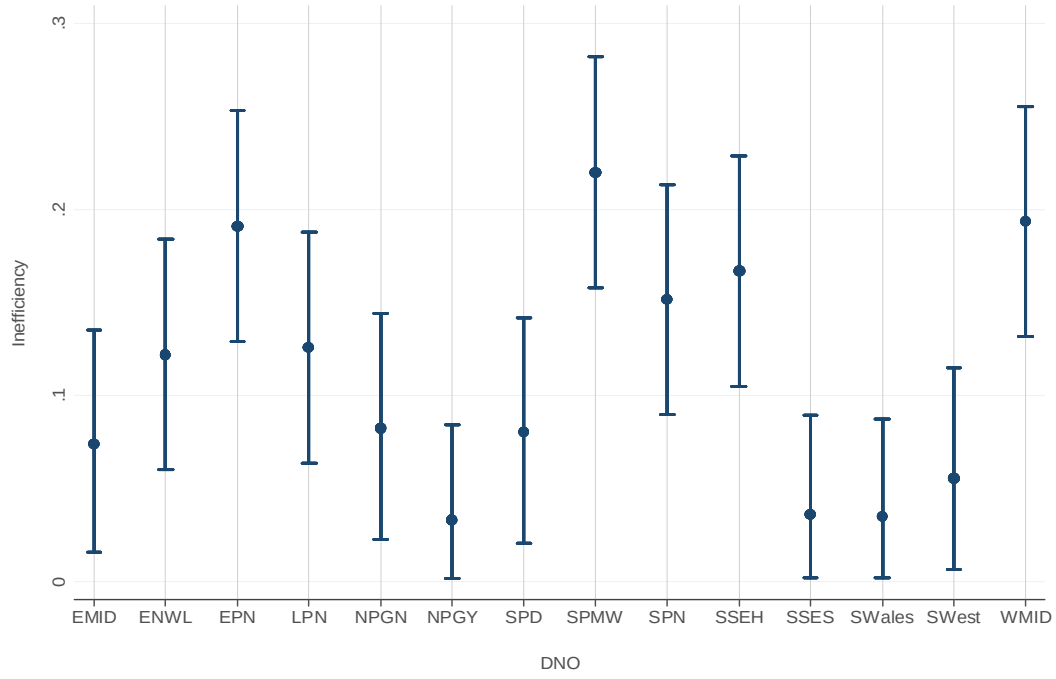
4 Other Comments

Confidence intervals

We have estimated equation (1) by SFA and calculated confidence intervals for the inefficiency estimates. The confidence intervals reflect the statistical uncertainty surrounding the point estimates, and provide information about the degree to which differences in inefficiency across DNOs are statistically significant. Confidence intervals cannot be calculated directly from the RE model, which is the reason why we used SFA.

Figure 3 shows the 95% confidence bounds of the inefficiency parameters from the Regional SIC35 model. For instance, the inefficiency point estimates suggest that Western Power Distribution East Midlands (EMID) is more efficient than Electricity North West (ENWL) but given that the confidence intervals overlap, statistically the two operators have the same level of efficiency for this level of confidence.

Figure 3: 95% Confidence intervals of estimated inefficiency, Regional SIC35 model

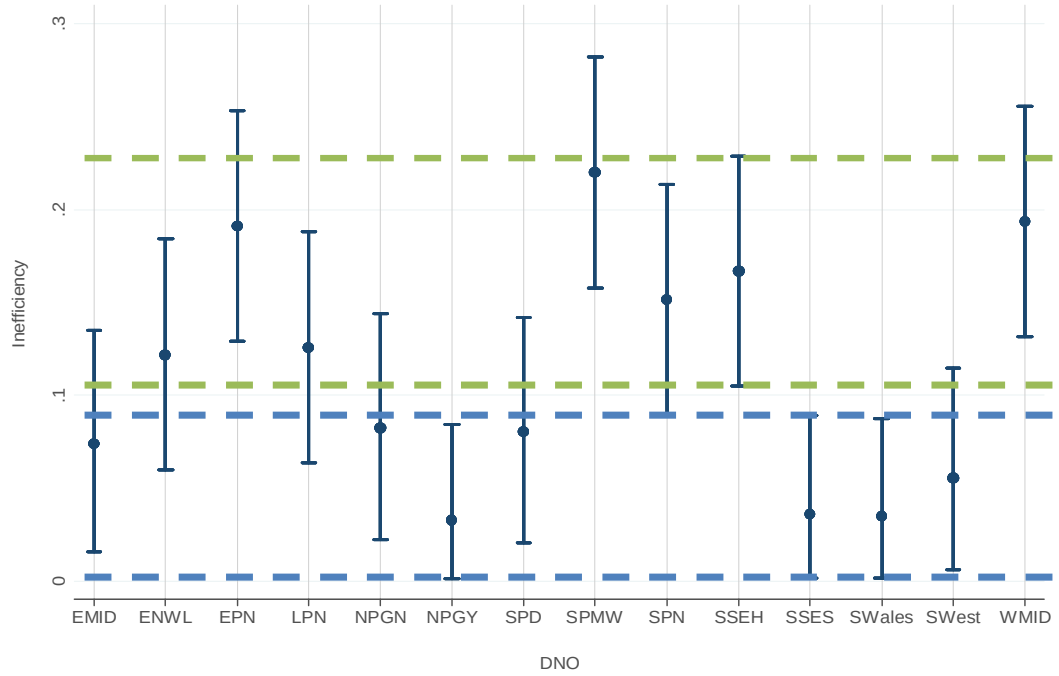


Source: Deloitte analysis

The confidence intervals are also such that it is difficult to draw firm conclusions about the relative efficiency of the ownership groups on the basis of the models. For example, SSE Hydro (SSEH) appears at first less efficient than most DNOs. However, the 95% confidence interval for its inefficiency estimate overlaps with 10 other DNOs as highlighted by the horizontal green dashed lines in Figure 4. At the same time, SSE Southern (SSES) in the same ownership group appears to be one of the most efficient DNOs. However, the 95% confidence interval for its inefficiency

estimate also overlaps with 9 other DNOs as indicated by the horizontal blue dashed lines. In other words, the results are not able to distinguish the relative efficiency of the ownership groups at 95% confidence.

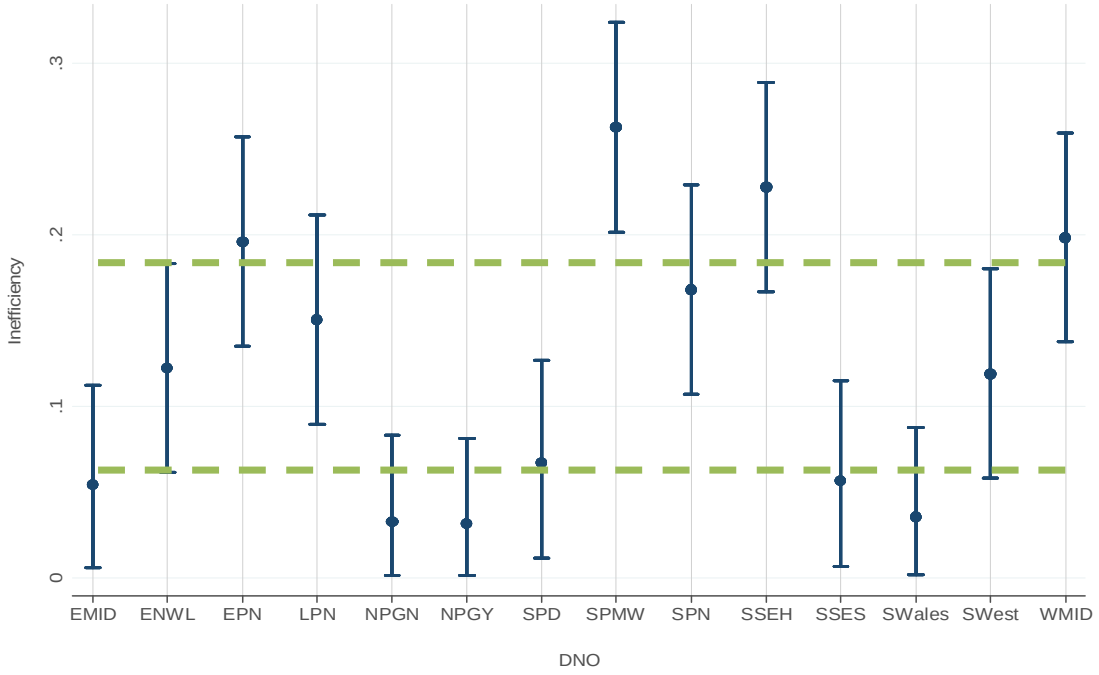
Figure 4: 95% Confidence intervals of estimated inefficiency, Regional SIC35 model



Source: Deloitte

Figure 5 below illustrates the same effects from the National SIC35 model specification, where the horizontal green dashed line indicates that at 95% level of confidence the level of estimated inefficiency for Electricity North West (ENWL) can be distinguished only from that for Scottish Power Manweb (SPMW).

Figure 5: 95% Confidence intervals of estimated inefficiency, National SIC35 model



Source: Deloitte analysis

Investment cycle

Frontier Economics attempt to infer the extent to which the investment cycles are synchronised across DNOs. The main analysis provided in their report is related to historical, time series plots of RAV additions since vesting for each DNO. Scrutinising these plots reveals significant differences in RAV additions over time and across DNOs. It does not seem to support the hypothesis that investment cycles across operators are synchronised.

Time-specific fixed effects

We have tested for time specific fixed effects in equation (1) to allow for potential industry-wide factors that may affect all DNOs in a similar fashion. The hypothesis that there are significant time fixed effects is largely rejected in both the regional and national wage specifications.

Data variability

We have analysed the variation in the independent variables to assess their suitability to be used as explanatory variables in the model specifications. There seems to be enough variation over time and across DNOs for the models to measure their effect. This is confirmed by the fact that they are statistically significant in the models.

Excel modelling tool

The Excel modelling tool promotes transparency but should be used with care only by professionals with adequate statistical skills and experience. Additionally, it does not provide diagnostics on the statistical properties and validity of the resulting estimates, and hence cannot replace specialised statistical software, a point also recognised by Frontier Economics. We expect that the Excel modelling tool enables the user to construct alternative models that can produce contradictory outcomes, while it does not provide the user with the information required to select between the models produced.

5 Conclusion

This report reviews the main model specifications put forward by Frontier Economics with the aim to diagnose their properties and assess the level of confidence in the conclusions that may be drawn from them. The main conclusion is that the Frontier Economics models seem to suffer from mis-specification or omitted variable bias, and hence their results may be imprecise and misleading.

