Future Efficient Costs of Royal Mail's Regulated Mail Activities

Internal Benchmarking Final Conclusions

19 January 2006

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Glossary

We use the following abbreviations in this report:

CRS	Constant returns to scale. When the production of one additional unit of output yields a proportional increase in average costs
CWU	Communication Workers Union
DEA	Data Envelope Analysis. A quantitative non-parametric technique that optimises the number of inputs required for a particular output and vice versa
DFA	Deterministic Frontier Analysis
DO	Delivery office
MC	Mail centre
ODR	Oxera report entitled: A Review of LECG's Delivery Office and Mail Centre Data Envelopment Analysis Modelling, dated 9 September 2005
OER	Oxera report entitled: A Review of LECG's Delivery Office and Mail Centre Deterministic Frontier Analysis and Stochastic Frontier Analysis Modelling, dated 9 September 2005
OLS	Ordinary Least Squares. A statistical method of estimating a line of best fit through a particular set of data
Panel data	A dataset that contains observations on a number of units (e.g. mail centres) over a number of periods
Postcomm	Postal Services Commission
Postcomm initial proposals	2006 Royal Mail Price and Service Quality Review, Initial Proposals, Postcomm, June 2005
RML	Royal Mail's letters business
SFA	Stochastic Frontier Analysis

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1 Executive Summary

Background

1.1 Postcomm is in the process of determining the regulatory arrangements that should apply to Royal Mail's regulated mail activities after the expiry of the current price and service quality control at the end of March 2006. A key input into this review is an assessment of the future efficient costs for Royal Mail's regulated mail activities. Postcomm has engaged LECG to provide this assessment.

1.2 Our initial conclusions on the level of future efficient costs for Royal Mail's regulated mail activities is set out in our report "Future Efficient Costs of Royal Mail's Regulated Mail Activities" dated 2 August 2005[1]. We refer to this report hereinafter as our "August Report".

1.3 Royal Mail has provided a response to this report, which is set out in its report "Response to LECG's report on Future Efficient Costs of Royal Mail's Regulated Mail Activities", dated September 2005. We refer to this report hereinafter as "Royal Mail Response".

1.4 One component of our analysis involved internal efficiency benchmarking across Royal Mail's delivery and mail centres. Using data supplied by Royal Mail, we applied statistical techniques to isolate underlying efficiency measures. The techniques we used were deterministic and stochastic frontier analysis ("DFA" and "SFA") and data envelopment analysis ("DEA").

1.5 Royal Mail engaged Oxera to provide a technical response to this component of our work. Oxera's response is contained in two documents, "A Review of LECG's Delivery Office and Mail Centre Deterministic Frontier Analysis and Stochastic Frontier Analysis Modelling" (henceforth referred to as the OER report) and "A Review of LECG's Delivery Office and Mail Centre Data Envelopment Analysis Modelling" (henceforth referred to as the ODR report). Both documents are dated 9 September 2005.

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[1] An excised version of this report is available at http://www.postcomm.gov.uk/policy-and-consultations/consultations/price-control/LECG_efficiency_review_report_excised.pdf

1.6 This report provides LECG's response to Royal Mail's review of our internal benchmarking conclusions.

1.7 Our response is set out as follows. First, we discuss Oxera's review of our econometric (DFA and SFA) modelling. Second, we discuss Oxera's review of our data envelopment analysis (DEA). Finally, we set out our conclusions on the implied cost savings. In setting out our conclusions, we also comment on two specific points raised by the Communication Workers Union (CWU).

1.8 This response has been written under the direct supervision of Professor John Cubbin, Professor Meloria Meschi and Professor Robin Sickles.

1.9 Professor Cubbin is a renowned and published expert in Non-Parametric Analysis[2]. He is an affiliate of LECG, and a Professor of Economics and Head of the Department of Economics at City University, London. Before his appointment at City University, he worked for NERA and held a series of University posts. He has taught on a wide variety of courses for economics and MBA students. He was a founding editor of the Business Strategy Review, and is on the editorial board of Applied Economics. Together with J Ganley he has co-authored *Public Sector Efficiency Measurement: Applications of Data Envelopment Analysis*, North-Holland (Elsevier) 1992. Professor Cubbin has written a series of articles on comparative performance analysis, such as "The use of real cost as an efficiency measure: An application to merging firms", *Journal of Industrial Economics*, September 1979, 73-95 (with G. Hall); and, "Regression versus Data Envelopment Analysis for Efficiency Measurement: An application to the England and Wales Water Industry" Utilities Policy, vol 7, 1998, 75-85 (With G. Tzanidakis.) Professor Cubbin has applied quantitative techniques of cost and performance analysis to over 15 organisations.

1.10 Professor Meschi, an LECG consultant, teaches Applied Microeconomics and Industrial Organization at John Cabot University in Rome, and is a Professor at the Masters in Antitrust and Regulation at Tor Vergata University, Rome where she teaches "The Estimation of Cost Functions and Efficiency." She has a double PhD in Applied Econometrics (University of Warwick) and Economic

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[2] Non-parametric methods are mathematical procedures to estimate relationships among variables without either knowledge of the form or of the parameters of the statistical distribution from which observations are drawn

Policy (University of Genova, Italy). Her international publications in the fields of statistics and applied econometrics include work on the estimation of random coefficients frontier models, and she is a co-author of the *Office of Fair Trading Research Paper N. 17*, on "Quantitative Techniques in Competition Analysis." She has designed and supervised the empirical analysis in more than 30 antitrust, regulatory and damages cases in a variety of industries including telecommunications, media, retail, advertising, pharmaceuticals, consumer goods, software solutions, and the tobacco industry.

1.11 Professor Robin Sickles, an LECG Director, is an expert in both Parametric[3] and Non Parametric Analysis and has worked extensively in the Postal Sector. Professor Sickles is a renowned and published expert in Parametric Analysis. He is the Professor of Economics and the Professor of Statistics at Rice University. He is also the Director of the Graduate Program in Economics and is an Adjunct Professor of Medicine at Baylor College of Medicine. The principal focus of his research and teaching at Rice is in the area of applied econometrics and micro econometrics with extensive work in non-parametric and panel data methods, productivity and stochastic frontier analysis. He has authored or co-authored more than 90 articles and papers and two books. He has held or holds senior editorial positions with the Journal of Applied Econometrics, Communications in Statistics: Theory and Methods, Southern Economic Journal, Journal of Business and Economics Statistics, Journal of Econometrics, and Empirical Economics. He is the current Editor-in-Chief of the Journal of Productivity Analysis. He has a long-standing research program measuring productivity and efficiency in regulated industries.

1.12 Before responding to Oxera's papers, we restate our initial conclusions and briefly discuss Oxera's estimated cost savings. At the end of the report, we restate our conclusions in light of the work that we have performed.

Initial conclusions

1.13 Internal benchmarking compares the cost performance (or efficiency) of similar units within the same company against each other. Our initial results indicated there was potential for Royal Mail to lower costs by achieving its own best

[3] Parametric methods are mathematical procedures to estimate relationships among variables, which assume that the distributions of the variables being assessed have certain characteristics

performance consistently across mail centres and delivery offices. Our findings indicated that:

- savings in the range £250m to £300m were achievable simply by applying existing best practices within the delivery office network; and
- savings of at least £100m were achievable simply by applying existing best practices within the mail centre network.

1.14 The exercise we carried out to estimate the scale of potential efficiency savings was based on Royal Mail data, using cost drivers that Royal Mail agreed to be relevant and which collectively explained over 90% of cost variation. There was a high correlation not just between the overall results of the three different techniques that we applied, but also between the rankings of efficiency scores that each produced. The models were tested for sensitivity to key assumptions and proved robust.

1.15 We believed our figures to be conservative. We excluded those delivery offices and mail centres that Royal Mail indicated as having poor data quality from the analysis; adopted a conservative benchmark (the first decile point[4] of delivery offices and mail centres for DFA); and applied a 20% downward adjustment factor to the DFA and DEA results for delivery offices and a 15% downward adjustment factor to the DFA and DEA results for mail centres.[5]

1.16 There was some precedent to use a more challenging benchmark. The table below summarises our initial estimate of delivery office savings, based on DFA and using a range of different benchmarks and discounts.

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[4] The first decile point is the point in the distribution where 90% of the observations lie above, and 10% below that point. It is therefore approximately the worst of the top 10%

[5] Both DEA and DFA take as the default assumption that all cost deviations left unexplained by the variables used represent efficiency variations. It is well known that this is an implausible assumption and needs some adjustment in order to set realistic cost targets. The potential sources of error are as follows: omitted variables; poor proxy; sampling error; measurement error; and mathematical form

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Table 1: Initial delivery office savings

DFA	Against best office	Against average of top 10%	Against worst of top 10%
No Discount Factor	£814m	£429m	£338m
10% Discount Factor	£732m	£386m	£305m
20% Discount Factor	£651m	£343m	£271m

Source: LECG analysis. The first decile point is defined as the point in the distribution where 10% of observations lie above, and 90% below that point. It is therefore approximately the worst of the top 10%.

1.17 Adopting the best office as the benchmark suggested savings of between about £650m and about £815m. A less challenging benchmark, of the average of the top 10%, suggested savings of between about £340m and £430m. We adopted the worst of the top 10% (i.e. the first decile point) as benchmark. Even under this benchmark, we believed that savings in the range £270m to £300m could be supported. The upper end of this range was consistent with the level of savings derived under the DEA technique after applying a 20% discount.

1.18 The table below summarises our initial estimate of mail centre savings, based on DFA and using a range of different benchmarks and discounts.

Table 2: Initial mail centre savings

DFA	Against best office	Against average of top 10%	Against worst of top 10%
No Discount Factor	£178m	£140m	£125m
10% Discount Factor	£160m	£126m	£112m
15% Discount Factor	£152m	£119m	£106m

Source: LECG analysis.

1.19 We adopted the first decile point as benchmark, making allowance for the diseconomies of scale evident in the larger mail centres. In the longer term, we expected that the diseconomies of scale of mail centres could be redressed. This would increase the scope for further efficiencies by up to £50m.

1.20 Royal Mail indicated to us that only labour costs could be allocated to mail centres and delivery centres with any degree of accuracy. Consequently, our analysis was limited to labour costs. The impact of this was that any scope for efficiency would be underestimated (i.e. it will exclude the scope to reduce vehicle, property and overhead costs).

1.21 Delivery office labour costs were £2,056m[6] in 2003/04. A cost saving of between £250m and £300m is equivalent to a 12.2% and 14.6% reduction in total delivery labour costs. Mail centre labour costs were £1,341m in 2003/04. A cost saving of £150m (i.e. including diseconomies of scale) is equivalent to an 11.2% reduction in mail centre labour costs.

1.22 Our initial findings were converted into an efficiency cost trend, the level of which depended on the period over which the assumed efficiencies could be achieved. The table below presents implied cost trends for different time periods:

Table 3: Internal benchmarking RUOE trends: initial conclusions

Time period	Annual rate of improvement
3 years	3.6% to 4.6%
4 years	2.7% to 3.5%
5 years	2.2% to 2.8%

Source: LECG analysis. The cost trend relates only to mail centre and delivery office labour costs and reflects savings in constant volume and constant mix terms.

1.23 We concluded that Royal Mail should be able to achieve the savings over a four to five-year period. Both of these periods roughly coincided with the proposed length of the forthcoming price control period, depending on the date on which such savings are assumed to begin to be made. We concluded that it was unlikely that Royal Mail would achieve these savings over a three-year period. Royal Mail assumed that savings could be achieved over a five-year period[7].

1.24 We also noted that our internal benchmarking assessed the potential for Royal Mail to lower costs by applying its *own current best practices* consistently across mail centres and delivery offices. It did not capture savings associated with moving Royal Mail's efficiency frontier by, for example, adopting international best practice, increasing the level of automation, switching to a part-time delivery model, etc. The benchmarking assumed that Royal Mail's current level of automation remained constant (i.e. cost savings come from increased labour productivity, not through capital substitution). We also noted that high levels of sick leave, overtime rates, and attrition were not correlated with efficiency.

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6 Labour costs are those provided by RM for the purpose of LECG's internal benchmarking analysis

7 Royal Mail response, paragraph 10.9, page 62

Consequently, the internal benchmarking savings will not double count any potential savings associated with lowering overtime, sickness absence or attrition rates.

1.25 Our initial conclusions were that over a four-year period, savings of between 2.7% to 3.5% per year could be available. Expressed over a slightly less challenging period of five years, savings of between 2.1% and 2.8% per year could be available. These rates were stated in constant volume and constant mix terms.

Oxera's estimated cost savings

1.26 In reviewing LECG's cost models and cost saving estimates, Oxera used alternative models. These models implied lower cost saving estimates. We comment on Oxera's estimates in the following two sections. In this section, we summarise Oxera's conclusions.

1.27 For mail centres, Oxera concluded that it is possible to develop models that could distinguish between noise and inefficiency (in contrast to LECG's initial findings) and that the resulting SFA model suggested savings of around £100m. Removing estimated inefficiency at the frontier and setting this as the benchmark for all other mail centres reduced this estimate to £83m. Accounting for noise in the modelling process reduced this still further to £65m, based on a top-decile benchmark, as recently used in the comparative efficiency analysis of BT[8]. Overall, Oxera suggested savings for mail centres in the range £67m to £100m[9]. Oxera suggested that this conclusion was supported by its DEA analysis, which provided a range of £50m to £70m[10]. This contrasts with our efficiency conclusions, before diseconomies of scale, of at least £100m.

1.28 For delivery offices, Oxera's econometric analysis suggested cost savings in the range of £80m to £150m, based on its preferred (translog) SFA model[11]. Based on its preferred DEA model Oxera estimated savings in the range of £130m to

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8 OER, Oxera, page 37

9 OER, Oxera, page 38

10 ODR, Oxera, page 26

11 OER, Oxera, page 38

£170m[12]. This contrasts with our estimate of savings that were in the range of £250m to £300m.

1.29 Royal Mail concluded from this that the SFA approach suggested potential savings as low as £150m, with a range of £150m to £250m. Royal Mail noted that on a cost base of £2.7bn, this would be equivalent to a cost reduction of between 1.1% and 1.9% per year over a five-year period[13].

1.30 Royal Mail concluded that the DEA approach suggested savings as low as £190m, with a range of £190m to £250m. Royal Mail noted that on a cost base of £2.7bn, this would be equivalent to a cost reduction of between 1.4% and 1.9% per year over a five-year period[14]. Royal Mail concluded that the results of each of the methods were consistent.

CWU issues

1.31 The CWU believed that the internal benchmarking analysis was flawed because it failed to recognise the need for investment to achieve the efficiency savings and because it failed to take account of some factors that would influence the performance of different offices (e.g. staff working beyond their contractual requirements and different technology and facilities in offices).

LECG final conclusions

1.32 We have considered all the points raised by Oxera and the CWU. In some areas, we have accepted particular points made and this has led us to some recalculations of our models and estimates. In other areas, we do not accept the arguments made, and therefore we reject the estimates of efficiency savings that would result.

1.33 In response to Oxera's concerns, we have amended a number of our models to take account of Oxera's points. In relation to mail centres, our econometric, but not DEA, models produce slightly lower estimates than Oxera's, but in relation to delivery offices, our estimates are significantly higher. Taking account of Oxera's final conclusions, our final conclusions are as follows:

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12 ODR, Oxera, page 26

13 Royal Mail Response, page 62

14 Royal Mail Response, page 62

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- savings in the range £220m to £300m are achievable simply by applying existing best practices within the delivery office network; and
- savings of at least £100m are achievable simply by applying existing best practices within the mail centre network. This assumes that mail centres are currently optimally configured. If this assumption is not true, then there is up to £50 million extra savings available either from re-optimising the network, or from operating the larger centres in a way that is consistent with the operation of the smaller centres.

1.34 Again, we have converted these findings into an efficiency cost trend, the level of which depends on the period over which the efficiencies are assumed to be achieved. The table below presents implied cost trends for different time periods:

Table 4: Internal benchmarking RUOE trends: final conclusions including diseconomies of scale

Time period	Annual rate of improvement
3 years	3.2% to 4.6%
4 years	2.4% to 3.5%
5 years	2.0% to 2.8%

Source: LECG analysis. The cost trend relates only to mail centre and delivery office labour costs and reflects savings in constant volume and constant mix terms.

1.35 Our final conclusions, including diseconomies of scale, are that over a four-year period, savings of between 2.4% to 3.5% per year might be achieved. Expressed over a slightly less challenging period of five years, savings of between 2.0% and 2.8% per year might be achieved. These rates are stated in constant volume and constant mix terms.

1.36 Our conclusions, excluding diseconomies of scale, are that over a four-year period, savings of between 2.4% to 3.1% per year might be achieved. Expressed over a slightly less challenging period of five years, savings of between 2.0% and 2.5% per year might be achieved. Again, these rates were stated in constant volume and constant mix terms.

1.37 With respect to the CWU, we believe that the issues raised are incorrectly stated. The internal benchmarking controls for the current level of technology and does not assume any change in the efficiency frontier, so all estimated improvements are based on the currently available technology in a mail centre or delivery office

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without the need for investment. In addition, we worked with Royal Mail to determine the principal factors that would influence the performance of different offices, and as such believe the models to be well specified.

1.38 Our full conclusions are set our in Sections 2 and 3 below, and are summarised in further detail in Section 4.

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2 Econometric analysis

Introduction

2.1 This section contains LECG's response to the technical points raised by Oxera with respect to our deterministic frontier analysis and stochastic frontier analysis. Oxera's response is contained in the OER document. We first summarise the main points that have been raised and provide a response in summary form. We then respond to each point in further detail.

Summary of Oxera's position

2.2 For mail centres, the main points put forward by Oxera can be summarised as follows[15]:

- LECG estimated diseconomies of scale at large mail centres. A large mail centre is one that has volume larger than the median value. This finding is driven by two factors: the use by LECG of a volume measure that excludes delivered volume; and the presence of an outlier in the sample, London Central;
- LECG's stochastic frontier model cannot distinguish between noise and inefficiency. Oxera developed a model that can; and
- there are theoretical arguments not to include LECG's £50m relating to diseconomies of scale (OER section 3.3 and ODR section 2.3.1).

2.3 For delivery offices, the main points put forward by Oxera can be summarised as follows[16]:

- LECG used a Cobb-Douglas function to model costs, but Oxera argued that a translog form would be more appropriate; and
- LECG's stochastic frontier model is based on a half-normal distribution for the inefficiency component, but statistical testing showed that the truncated

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15 Source: Oxera, OER, Executive Summary, pages ii to iii. In this section, we provide only a summary of Oxera's main points. In the detail of this report, we believe that we address all material and/ or valid points. Oxera's full report can be found on Postcomm's website

16 Source: Oxera, OER, Executive Summary, pages iii to iv. In this section, we provide only a summary of Oxera's main points. In the detail of this report, we believe that we address all material and/ or valid points. Oxera's full report can be found on Postcomm's website

normal distribution would be more appropriate. Oxera stated that LECG should also have considered the exponential model.

2.4 Oxera estimated models that it believed were not subject to the above criticisms. These models yielded lower cost savings, which Oxera estimated to be in the order of £106m for mail centres[17] and between £141m and £151m for delivery offices[18].

2.5 Oxera argued that the DFA model should be disregarded if an appropriate SFA model could be developed (i.e. one that could distinguish between noise and inefficiency). Oxera also argued that efficiency savings from SFA could be computed via several approaches. One approach would be to compute efficiency savings using the top decile as the benchmark, or could be computed by setting the inefficiency of the most efficient observation equal to zero. This contrasts with our use of the average inefficiency for the whole sample. Modelling against the top decile reduced the estimated cost savings to around £66m for mail centres and £83m for delivery offices.

Summary of LECG response

2.6 With respect to mail centres, LECG's response can be summarised as follows:

- the volume measure used by Oxera suffers from measurement error and distorts results;
- the use of Oxera's volume measure requires a reclassification of mail centres. Once mail centres have been reclassified, LECG's finding of diseconomies of scale at large mail centres is confirmed even when using Oxera's alternative volume measure;
- the procedure used by Oxera to identify outliers is incorrect. Once a rigorous procedure is followed, LECG's finding of diseconomies of scale at large mail centres is confirmed;
- we estimate an alternative and equally valid cost model and find, once again, that there are diseconomies of scale at large mail centres only;

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17 Oxera, OER, table 2, row v, page ii

18 Oxera, OER, table 3, row iii, page iii

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- we have estimated an alternative model that estimates the cost impact of the volume delivered from mail centres. Adopting the results of this model, to refine our efficiency analysis, would reduce the estimated potential savings by only 2%, in total terms, over the whole period;
- the fact that LECG's stochastic frontier model cannot distinguish between noise and inefficiency is due to the presence of an extreme observation, relating to the Inverness mail centre. When Inverness is removed from the sample, both LECG's original model and its alternative cost model are able to distinguish between noise and inefficiency; and
- we find that diseconomies of scale still exist. In the longer term, we expect that the diseconomies of scale of mail centres could be redressed. This would increase the scope for further efficiencies by up to £50m.

2.7 With respect to delivery offices, LECG's response can be summarised as follows:

- the functional form proposed by Oxera is neither compatible with economic theory, nor with the stylised facts about the operation of the industry, and is therefore unacceptable;
- the stochastic frontier model with truncated normal disturbances does not converge properly and it yields very different results with alternative software programs. The truncated normal model would appear to be unreliable and incorrect, and it should not be used to estimate efficiency; and
- the only other workable stochastic frontier model[19], the exponential model, does not have known large sample properties. It is not widely used in practice. For sensitivity purposes, however, we have considered the efficiency estimates implied by an exponential model.

2.8 With respect to Oxera's argument on the use of the top decile as the appropriate benchmark for SFA, we disagree on theoretical grounds. Whilst we will discuss this at length below, we note here that it is well known that individual efficiency

[19] Of the four available SFA models, the one based on the gamma distribution consistently failed to converge for both mail centres and delivery offices. The SFA based on a truncated normal distribution also failed to converge for delivery offices. This leaves the SFA models based on the half-normal and the exponential distributions. Our initial conclusions were based on the half normal model

estimates obtained with cross-sectional data are not accurate[20], and one should not use a benchmark that relies on individual estimates, such as the top decile.

2.9 Our conclusions are explained in further detail below. We review our conclusions on mail centres first, then those on delivery offices. Finally, we discuss the methodology and benchmark issues.

Review of mail centres

2.10 In this section, we review the issues raised by Oxera with respect to our Ordinary Least Squares ("OLS") and Stochastic Frontier Analysis ("SFA")[21]. Oxera's conclusions on the econometric modelling for mail centres can be summarised as follows[22]:

- LECG used the wrong volume measure in its analysis (i.e. LECG used weighted volumes excluding delivered volume). Oxera argued that LECG should have added weighted delivered volume to the volume measure. When delivered volume is added to the volume measure, there is no evidence that diseconomies of scale affect only large mail centres. Oxera found that there are diseconomies of scale across all mail centres;
- London Central is an outlier, and LECG should have excluded it from the analysis;
- there are theoretical arguments not to include LECG's £50m relating to diseconomies of scale (OER section 3.3 and ODR section 2.3.1); and
- the SFA model estimated by LECG cannot distinguish between noise and inefficiency. Consequently, LECG should have used only positive residuals from the OLS model to calculate efficiency scores.

2.11 Our response can be summarised as follows:

- Oxera's volume measure is wrong because it suffers from measurement error. In addition, Oxera's finding that diseconomies of scale affect all mail

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20 A cross-section is a dataset in which each unit (e.g. mail centre or delivery office) is observed at a single point in time. Such are the datasets that we received from Royal Mail

21 All the results presented in this section were obtained with Stata v. 8.2.

22 In this section, we provide only a summary of Oxera's main points. In the detail of this report, we believe that we address all material and/ or valid points. Oxera's full report can be found on Postcomm's website

centres, not just large ones, is based on a classification error. Once mail centres are properly classified according to the volume measure used by Oxera, LECG's original results are confirmed. This result is confirmed further by running an alternative, but equally valid, cost model. Consequently, whichever volume measure is used, we find that there is strong evidence that large mail centres have diseconomies of scale. Small mail centres do not appear to have diseconomies of scale. With a correctly specified model, using mail centre delivered volumes changes our results by only £2m;

- Oxera used the wrong procedure to determine whether London Central is an outlier. Once the correct procedure is followed, we find that London Central is not an outlier and that our original finding on diseconomies of scale is confirmed. We have found, however, one outlier in the sample, which is Inverness. Excluding Inverness does not change our conclusion that large mail centres have diseconomies of scale. Our revised model, excluding Inverness, does not have a material impact on our estimated cost savings, which stay in the order of £100m;
- the fact that our SFA model does not distinguish between noise and inefficiency is due to the presence of an extreme observation (i.e. Inverness) in the sample. Once Inverness is taken out, the SFA model is able to separate out the two components. Our refined model does not change our efficiency estimates.

2.12 We discuss each conclusion in detail below.

Volume measures

2.13 The weighted volume measure used by LECG in its analysis, which we will call net volume, excludes weighted delivered volume. Total weighted volumes (henceforth referred to as total volumes) include weighted delivered volume[23]. There are six mail centres for which weighted delivered volume figures are available. For all other mail centres, net and total volume figures are identical. The six mail centres are Bristol, Gatwick, Glasgow, Inverness, Southend and Swansea.

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[23] Delivered volume represents mail that is delivered direct to customers from a mail centre. This activity only takes place at six mail centres. Weighted volume is weighted such that differing amounts of time required to process different mail is accounted for.

2.14 Oxera stated, *"Excluding delivered traffic is erroneous, as costs related to this delivered traffic are included in the cost definition… Weighted volume is weighted such that the different amount of time required to process different mail is accounted for."*[24] This statement is incorrect.

2.15 First, the cost definition supplied by Royal Mail made it clear that cost figures only relate to sorting activities, not to delivery. Royal Mail indicated (bold emphasis added):

"…Postcomm were provided with total operational staff costs (including NIPOC and pension contributions) recorded against the cost centres for each MC. The figure should not include pay for non-processing functions such as collection and ***delivery*** *that might operate from the same building."*[25]

2.16 Second, the definition of weighted delivered volume supplied by Royal Mail makes it clear that the weights applied to this figure are delivery office delivery weights and not mail centre processing weights. Third, Royal Mail is uncertain about the accuracy of the data. Royal Mail indicated in a previous submissions (bold emphasis added):

"Mail centre delivered volume is intended to represent mail that is delivered direct from the mail centre, i.e. it bypasses the delivery office operation. This mail is usually for very large receivers of mail that warrant direct selections at the inward mail centre. Most mail centres do not have delivery points that fall into this category and therefore do not record delivered volumes against IMC operations.

Royal Mail is uncertain about the accuracy of the delivered volume measure and it was therefore omitted from the dataset (although it was included as a component of the total weighted volume). In particular, there does not appear to be a common understanding between mail centre managers as to the definition of "delivered volume".

The weighting applied to this mail stream is ***inappropriate*** *because it is based on a per item workload for processing mail at a delivery office. This is likely to* ***overstate the workload*** *for this mail because mail centre "delivered volume"*

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[24] Oxera, OER, paragraph 3.3.1, page 22

[25] Royal Mail, File PCR3 6070 MC Data for Internal Benchmarking.PB.191004.doc, para. 2.1

*requires **considerably less effort** per item (there is no walksort activity at mail centres, no walk sequencing, and delivery is in bulk by van). Therefore the total weighted volume for the 6 mail centres is likely to **overestimate** the workload relative to other mail centres."*[26]

2.17 LECG understands that these six mail centres have a number of very large customers[27], whose mail they receive, process and deliver. Royal Mail stated previously that the sorting of this mail requires considerably less effort than the sorting, sequencing and delivery that takes place at delivery offices. Weighting volumes based on delivery costs could significantly bias the results. Clearly, it would be wrong to use this measure, and given the context above, we are surprised that Oxera has done so. Hence, Oxera's analysis is inconsistent and suffers, perhaps significantly, from measurement error.

2.18 We do appreciate that delivered mail is sorted at the mail centre, and as such, our net volume figure is subject to measurement error. Ideally, sorting costs for each of the six mail centres would be adjusted to reflect the impact of delivered mail on sorting costs. We have asked Royal Mail to provide cost data so this adjustment can be made, but Royal Mail confirmed, "*that the systems do not separately record the cost related to the measured delivered volumes at the six Mail Centres*"[28]. We believe the scale of the measurement error in labour-related costs would be smaller than the error contained in Oxera's volume measure. It is important to note that we accounted for this potential error by discounting the results of our DFA and DEA analysis by 15%. We have also estimated that total cost savings for mail centres will be reduced by 2% at most when delivered mail is properly accounted for.

2.19 Oxera claims that, when total volumes are used, rather than the net volumes, there is no evidence of diseconomies of scale across large mail centres. Oxera then estimates a model in which it finds no differential scale effects for large and small mail centres. Oxera finds that the scale elasticity for the whole sample is

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26 Royal Mail, file PCR3 6110 RM response to LECG memo 171104.PB.291104.doc, page 3

27 For example, Swansea mail centre delivers all mail address to the DVLA; and Southend all mail addressed to VISA

28 Royal Mail, Comment On Delivered Volume At Mail Centres, 8 November 2005

1.13, which is significantly different from one.[29] In other words, Oxera finds diseconomies of scale across all mail centres.[30]

2.20 The implied mail centre cost savings from Oxera's model, at the LECG benchmark[31], would be £110.5m. This compares to LECG's estimate of £106.1m before adding £50m for diseconomies of scale relating to large mail centres.

2.21 We have found, however, that Oxera's results are based on a classification error, which stems from a fundamental problem with its approach. When Oxera changes volumes from net to total, mail centre rankings, in terms of volume size, change. In particular, Swansea goes from being a rather small mail centre to being a rather large one.[32] Consequently, the dummy variable for small centres, which identifies small mail centres according to net volume, needs to be revised. Oxera does not appear to have made this revision.

2.22 The results presented by Oxera therefore suffer from a double source of error. First, measurement error, due to the wrong volume measure, and second, the misclassification of Swansea mail centre as a small mail centre in terms of volume of mail sorted.

2.23 We have re-classified Swansea as a large mail centre, and re-estimated Oxera's version of the Cobb-Douglas cost model, using total volumes. The results are shown in the table below. Model 1 shows the original results obtained by LECG; Model 2 shows the results presented by Oxera (OER table 3.9, page 23); and Model 3 shows the results obtained by re-classifying Swansea mail centre as a large rather than as a small mail centre.

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29 LECG have replicated all of the results presented by Oxera in OER exactly, using both Stata 8.2 and Limdep 8

30 Oxera, OER, paragraph 3.3.1, page 24

31 Worst MC of the top decile; obtained by setting the inefficiency of the 7th most efficient mail centre equal to zero and benchmarking every other MC against this efficient unit. To this, LECG have added a 15% discount

32 Swansea's weighted volume increases by about 40% when weighted delivered volume is included. This implies that it's ranking, in terms of volume size, goes from 21, which is below the median value, to 45, which is above the median value

LECG

Table 5: Mail centre DFA cost equations

Variable	Model 1 LECG Table 221	Model 2 Oxera Table 3.9	Model 3 Total volume Swansea reclassified
Constant	-8.71 -5.39**	-6.98 -4.43**	-7.57 -4.56**
Dummy for small MCs	5.02 2.58**	4.08 2.08**	3.99 1.94*
Ln(Volume)	1.25 13.98**	1.14 13.17**	1.18 12.86**
Ln(Volume * Dummy for small MCs)	-0.29 -2.63**	-0.24 -2.17**	-0.23 -2.00*
Percent of intra-MC inward mail	0.81 1.61	1.51 2.95**	1.51 2.78**
Percent of MC area that is urban	0.39 3.86**	0.50 4.98**	0.50 4.66**
Percent of mail that is walk sorted at MC	0.89 3.05**	0.99 3.28**	0.96 3.05**
R^2	0.959	0.957	0.952
a) Test of Volume coefficient = 1 F(1,62)	7.78 (p=0.01)	2.76 (p=0.102)	3.72 (p=0.06)
b) Test of (Volume + Volume*dummy)=1 F(2,62)	0.30 (p=0.59)	1.83 (p=0.18)	0.51 (p=0.48)
c) Test of (Vol – (Vol + Vol*dummy)=0 F(2,62)	6.93 (p=0.01)	4.72 (p=0.03)	4.00 (p=0.05)

Source: LECG analysis. Dependent variable is log staff costs divided by basic wage rate. T-ratios are in second rows. ** significant at 1%, *significant at 5%. The coefficient on the dummy for small mail centres in column 3 is significant at 5.6%.

2.24 The last three rows show the results of a range of statistical tests for economies of scale. Row a) presents a test of the null hypothesis that the coefficient on volume is equal to 1 for large mail centres. The null hypothesis is rejected in Models 1 (at the 1% level) and 3 (at just above the 5% level). Only in Model 2, the null hypothesis cannot be rejected. Row b) presents a test of the null hypothesis that the coefficient on volume is equal to 1 for small mail centres. The null cannot be rejected in any of the three models. Row c) presents a test of the hypothesis that the scale coefficients for large and small mail centres are the same. This hypothesis is rejected in all the three models.

2.25 These results confirm that when mail centres are properly classified and using Oxera's total volume measure, only large mail centres have diseconomies of scale. Small mail centres do not. Given Oxera's misallocation error, we do not think that it is appropriate to consider Model 2 further.

2.26 In order to test whether the result on economies of scale holds true with a different model specification we have estimated a cost model with a quadratic volume term. The use of a quadratic output term in the cost function is commonly used to allow varying returns to scale. It is parsimonious (in that only one additional parameter needs be estimated) and it allows each mail centre to have different scale estimates, depending on its size, in terms of volume. We have estimated the quadratic model using both volume measures. The regression results are summarised in the table below:

Table 6: Mail centre DFA cost equations – Quadratic Models

Variable	Model 4 Net volume	Model 5 Total volume
Constant	47.04 3.22**	38.34 2.48**
Ln(Volume)	-4.97 -2.99**	-3.98 -2.27**
$(Ln(Volume))^2$	0.17 3.68**	0.14 2.91**
Percent of intra-MC inward mail	0.58 1.23	1.23 2.39**
Percent of MC area that is urban	0.31 3.25**	0.42 4.09**
Percent of mail that is walk sorted at MC	0.89 3.18**	0.98 3.17**
R^2	0.961	0.953
a) Implied scale elasticity, whole sample	1.17	1.15
b) Implied scale elasticity, large mail centres	1.32	1.27
c) Implied scale elasticity, small mail centres	1.03	1.03

Source: LECG analysis. Dependent variable is log staff costs divided by basic wage rate. T-ratios are in second rows. ** significant at 1%, *significant at 5%. Large mail centers are those with volume above the median value.

2.27 There is little difference in the performance of the quadratic models with respect to the models presented in Table 5 above. The residuals are homoscedastic, the models pass a form of the RESET test for misspecification, and the R^2 are very similar. The implied scale elasticity for the whole sample is 1.17 in Model 4[33] and 1.15 in Model 5[34], again indicating that diseconomies of scale are present in mail centres.

[33] The f-test for the scale elasticity being equal to 1 is F(2, 63) = 25.96, with a p-value of 0.00

[34] The f-test for the scale elasticity being equal to 1 is F(2, 63) = 15.56, with a p-value of 0.00

2.28 One advantage of the quadratic model is that it allows an estimation of the scale elasticity for each individual mail centre. Given that the coefficient of the quadratic term is positive (and statistically significant), the scale elasticity is increasing in volume. We have separated mail centres into the two groups of small and large mail centres[35], and have tested the hypothesis that the scale coefficient is equal to one in each group. The table below reports the results of this analysis.

Table 7: Test for economies of scale – quadratic models

Variable	Model 4 Net volume	Model 5 Total volume
Large Mail centres: t – value	**16.97**	**16.61**
P-Value. Ha: scale elasticity < 1	1.00	1.00
P-Value. H_0: scale elasticity = 1	0.00	0.00
P-Value. Ha: scale elasticity > 1	0.00	0.00
Small Mail centres: t – value	**1.53**	**1.94**
P-Value. Ha: scale elasticity < 1	0.93	0.97
P-Value. H_0: scale elasticity = 1	0.14	0.06
P-Value. Ha: scale elasticity > 1	0.07	0.03

Source: LECG analysis.

2.29 The results show that there are diseconomies of scale in large mail centres, but not in small ones. The conclusion is the same for both volume measures.

2.30 We have computed efficiency savings at the LECG benchmark for Models 1, 3, 4 and 5. The results are presented in the table below, which shows cost savings ranging approximately from £106m to £96m, before accounting for diseconomies of scale.

[35] Where again large mail centres are those with volume above the median value

Table 8: Estimated potential savings: Mail Centres

	Model 1 £'m	Model 3 £'m	Model 4 £'m	Model 5 £'m
Type of benchmark	First decile	First decile	First decile	First decile
Costs of included centres	703.1	703.1	703.1	703.1
Savings at benchmark	124.8	118.5	117.9	112.4
Less 15% adjustment	18.7	17.8	17.7	16.9
Aggregate potential cost saving	106.1	100.8	100.2	95.5
Additional savings from diseconomies of scale	50.0	64.0	na	Na

Source: LECG analysis

2.31 We find that whilst the total volume measure has little impact on cost savings at the LECG benchmark, it has a large impact on savings from diseconomies of scale. The additional potential savings due to diseconomies of scale, which were £50m in the original LECG model (Model 1), rise to £64m when total volume is used (Model 3)[36]. Whilst we would argue that the total volume measure should not be used, we find that if it is used, it does not reduce the estimated potential savings when incorporated into the model properly. Although we have not explored the reason for this, one intuitive explanation is that a model with a poorly specified dependent variable will, other things being equal, have a worse fit than a model with a better-specified dependent variable.[37] That is, in a model with a poor fit, more will tend to be attributed to inefficiency.

2.32 Postcomm's postal experts believe that LECG's model provides a better classification than the Oxera alternative. When total volume is used in the cost equation, the efficiency rankings of mail centres change. For example, the Southend mail centre changes from being ranked as relatively inefficient in Models 1 and 4 to being ranked the second most efficient one in Models 3 and 5. Postcomm's postal experts do not believe that Southend is the second most efficient mail centre in the country. This result may be due to the use of weighted delivered volumes. The problem is particularly severe for Southend because its total volume increases by 44% when delivered volume is added in. Given that

[36] They cannot really be computed for models 4 and 5

[37] The dependent variable, sorting costs is poorly specified when total volume rather than net is used. This is because the cost variable only includes sorting activities, while total volume also includes (over weighted) delivery activities at the 6 mail centres

this volume is overstated, it will lead to lower unit costs – and hence greater implied efficiency. Clearly, this would bias the estimates.

2.33 When total volume is used instead of net volume, model performance also worsens – even though the adjustment only concerns six mail centres out of a sample of 69, and for two of these six the adjustment is minor[38]. The root mean squared error of the forecast goes from 0.138 to 0.149 when we switch from Model 1 to Model 3, and from 0.134 to 0.147 when we switch from Model 4 to Model 5. In other words, the models based on total volumes do not forecast as well as the models based on net volumes.

2.34 In conclusion, our results with respect to economies of scale are robust to changes in the volume variable and changes in the functional specification of the cost equation. We reject the contention that delivered volume, as currently measured, should be added to net volume because the variable measured contains considerable upward bias. The rankings produced using Oxera's models are counterintuitive and the performance of the models declines. As such, we have not changed our initial conclusions in response to the points raised by Oxera above.

An alternative approach to measure the effect of delivered volume on costs

2.35 At the heart of Oxera's point on delivered volumes there is a legitimate concern, namely that some mail centre activities generate extra costs and these need to be accounted for if we are to make accurate estimates of the potential savings. But it is not necessary to incorporate delivered volume into total mail centre volume to achieve this, since it can be treated as an additional output.

2.36 It is possible to obtain an estimate of the extra costs imposed on the six mail centres which undertake deliveries by including their outputs in the cost equation in the form $\mathbf{logC = X\beta + \alpha D_d log(DV) + u}$, where $\mathbf{X\beta}$ is as in our basic equation and $\mathbf{D_d log(DV)}$ is an additional dummy variable term such that $D_d = 0$ where delivered volumes are 0 (and 1 elsewhere) and DV is the delivered volumes from mail centres for which $D_d = 1$ (i.e. for the 6 mail centres that have positive delivered volume figures). The estimate of the parameter α gives an indication of the extra

[38] The proportion of total weighted volume that is delivered volume in the 6 mail centres is as follows: Bristol 12.3%; Gatwick 6.75%; Glasgow 16.44%; Inverness 1.17%; Swansea 39.74%; Southend 43.91%. The changes for Inverness and Gatwick are minor, but those for Swansea and Southend are substantial

costs associated with the delivered volumes, and the residual from this equation can be used in the normal way to calculate potential efficiency savings for the whole sample.

2.37 Our results are as follows:

Table 9: Mail centre model taking account of delivered mail

	Revised Model 1		Original Model 1
Variable	**Coefficient**	**t-ratio**	**Coefficient**
Constant	-8.07	-5.06	-8.71
Dummy for small MCs	4.13	2.14	5.02
Ln(Volume)	1.21	13.69	1.25
Ln(Volume * Dummy for small MCs)	-0.24	-2.2	-0.29
Percent of intra-MC inward mail	1.07	2.13	0.81
Percent of MC area that is urban	0.42	4.29	0.39
Percent of mail that is walk sorted at MC	0.91	3.21	0.89
$D_d$log(DV)	0.40	2.21	N/a

Source: LECG analysis

2.38 As shown in the table above, the basic coefficients of the revised model are very similar to those of our original equation. The estimated coefficient of $D_d$log(DV), (i.e. delivered mail) is positive and significant. Inclusion of this variable reduces the available savings by £2.2 million to £103.9 million. From this we conclude that our conclusion on the extent of constant and decreasing returns to scale are robust and the impact of delivered mail on sorting costs is immaterial.

London Central and other possible outliers

2.39 Oxera claimed that London Central is an outlier. It stated that our findings on diseconomies of scale are due to two facts: a) we have used net volumes, and b) we have kept London Central in the regression. We have shown in the last section that our findings on diseconomies of scale are robust to changes in the volume variable. In this section, we show that London Central is not an outlier.

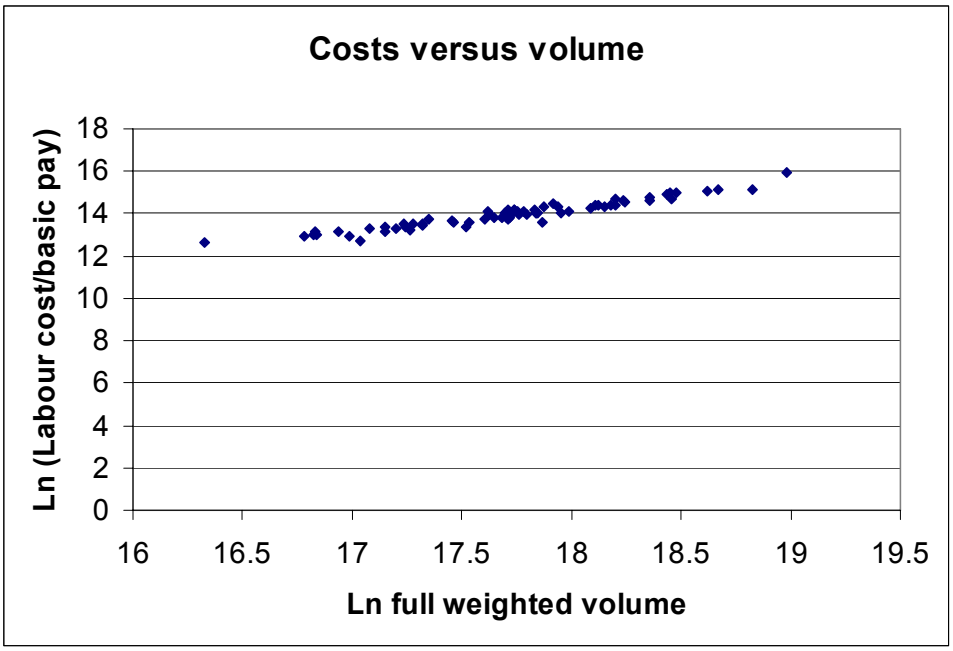
2.40 Figures 3.1 and 3.2 in Oxera's OER report suggest that London Central is an outlier[39]. The figures plot levels of weighted volume versus normalised labour

[39] Oxera, OER, figure 3.1 and 3.2, page 25

costs[40], and the percentage of walk sorted mail versus levels of normalised labour costs. We contend that this presentation of the data exaggerates the difference between London Central and the other offices in the estimated models. It is important to recognise that since our volume and cost variables are used in the form of natural logs of volume and costs, not of levels of these variables, it is the transformed (logarithmic) values that should be compared.

2.41 The graph below shows a plot of the log of normalised labour costs versus the log of the full weighted volume, which includes delivery costs. In this plot, London Central (the rightmost point) does not appear to be an outlier.

Figure 1: Variables used in MC cost models: costs and volume

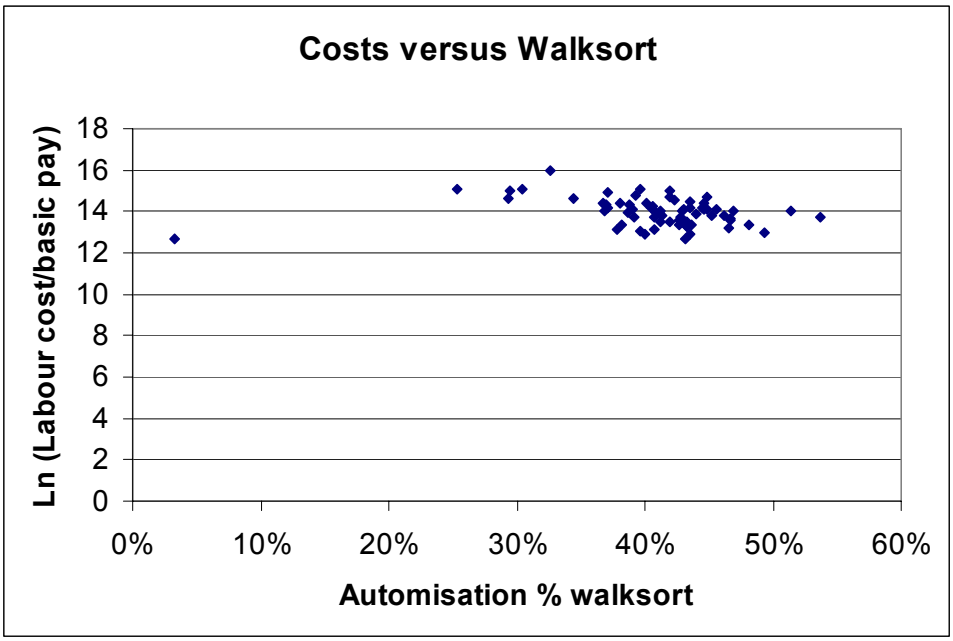


Source: LECG analysis

2.42 The graph below shows the plot of the log of normalised labour costs versus the percentage of mail that is walk sorted at the inward mail centre. There is one obvious outlier in this graph, and that is the leftmost point (Inverness).

[40] Normalised labour costs are total labour costs divided by basic pay rate

Figure 2: Variables used in mail centre cost models: costs and automation



Source: LECG analysis

2.43 Whether an observation is an outlier in a regression model is usually ascertained by analysing the residuals of the model. It is common practice in applied work to look at the standardised residuals from a regression model. Outliers are generally accepted to be those observations that have standardised residuals in excess of 2 in absolute value. The table below lists the largest standardised residuals values in the cost models presented in the last section.

Table 10: Standardised residuals (SRES)

Model	SRES London Central	Mail centres with absolute SRES larger than London Central, or larger than 2
Model 1	1.571	Bristol, Chelmsford, Greenford, Inverness, Swindon; Truro*
Model 3	1.479	Chelmsford, Southend, Swansea, Swindon, Truro; Greenford*, Inverness*, Northampton*
Model 4	0.737	Bristol, Chelmsford, Swindon; 37 mail centres have SRES larger than London Central
Model 5	0.805	Chelmsford, Southend, Swansea, Swindon; 29 mail centres have SRES larger than London Central

Source: LECG analysis. * SRES larger than London, but not larger than 2.

2.44 The evidence above suggests that London Central is not an outlier. However, this is not conclusive and more formal and objective methods are available. Outliers should be considered in terms of whether their inclusion distorts the

estimated equation. To assess this, we tested whether the coefficient estimates were significantly different when London Central is omitted. If this turned out to be the case, then Oxera's procedure of re-running the model omitting London Central might be reasonable. If, however, there was no evidence that the coefficients, as a whole, changed as London Central was dropped, then London Central should be kept in the regression.

2.45 We have re-estimated Models 1, 3, 4 and 5 without London Central. We have run a predictive test for the hypothesis that the coefficients of the cost model change significantly when London Central is omitted from the sample. We found that the hypothesis that the coefficients are the same can never be rejected, as shown in the table below. Consequently, it would be incorrect to drop London Central from the sample.

Table 11: Stability tests for the model coefficient with respect to the inclusion of London Central mail centre in the sample

Model	F-value	Null Hypothesis: the coefficients are the same with and without London Central
Model 1	2.529*	Cannot reject the null
Model 3	2.232*	Cannot reject the null
Model 4	0.531**	Cannot reject the null
Model 5	0.633**	Cannot reject the null

Source: LECG. *F(1,61); **F(1,62)

2.46 As a second step, we added a dummy for London Central interacted with the weighted volume variables and tested for the significance of this additional variable. If this additional variable were found to be significant, then the claim by Oxera that the inclusion of London Central skews the regression line and yields the wrong estimate for scale effects might be correct. This would mean that London had a different volume coefficient from the rest of the sample. As shown in the table below, the volume coefficient for London Central is not statistically different from zero in Models 1 and 3. We did not perform the test for the squared models because interacting the London dummy with both volume and volume squared would result in perfect collinearity.

Table 12: Test for a differential effect on weighted volume for London Central

Model	t-ratio	Null Hypothesis: the coefficient on (dummy for London Central * volume) = 0
Model 1	1.59	Cannot reject the null (p-value 0.12)
Model 3	1.49	Cannot reject the null (p-value 0.14)

Source: LECG analysis.

2.47 Based on the evidence presented above we conclude that London Central is not an outlier, and that its presence does not have a significant impact on the relationship between volume and costs, whatever measure of volume is included. We believe that Oxera's procedure to test for economies of scale, in a regression model that excludes London Central, is inappropriate.[41]

2.48 There are, however, two obvious outliers in the graphs above. One is Truro, which is a very small mail centre in terms of volume (both total and net). The other is Inverness, which has a percentage of walk sort mail equal to 3.3%, whilst the second ranked mail centre, Glasgow, has a percentage of 25.4% and the third ranked, Newcastle, has 29.4%.

2.49 We have tested for the sensitivity of Models 1, 3, 4 and 5 for the exclusion of Truro, and found no evidence that excluding the mail centre would have a significant impact on our findings. The situation for Inverness is rather different. As Oxera states *"Inverness … is an outlier in many other respects"*[42]. Inverness has no automation and covers a huge area with more than 100 delivery offices. Moreover, it has the lowest urban area percentage in the sample.

2.50 For sensitivity purposes, we have tested Models 1, 3, 4 and 5 excluding Inverness. Our findings are as follows:

- for Model 1, the original LECG model, we found that Inverness is an outlier. The coefficients of the estimated cost models are significantly different when Inverness is excluded.[43] The finding on economies of scale

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41 Simply put, Oxera excluded London Central from the sample and looked at the resulting volume coefficient, but excluding London Central was not justified because there is no evidence that the coefficients of the cost equation as a whole change when London Central is excluded; so, London Central should not be excluded

42 Oxera, OER, paragraph 3.3.1, page 23

43 The value of the test is F(1,61) = 4.26, significant at the 5% level

is confirmed, and the average inefficiency is 14.5%.[44] The coefficient on walk sort mail, however, changes from 0.889 to 0.116– which is a large change;

- when total volumes are used (i.e. Model 3), the exclusion of Inverness does not have a significant impact on the model coefficients. It is not possible to test whether the coefficient of the walk sort variable changes or not, due to the value of that variable being too small (0.033). We found that the estimated coefficient on walk sort for Inverness[45] is very poorly determined (i.e. it has a large standard error); and
- in the quadratic models (i.e. Models 4 and 5) the coefficient on walk-sorted mail becomes insignificant when Inverness is excluded from the regression, but the other coefficient estimates do not vary significantly.[46]

2.51 Therefore, we have found evidence to suggest that Inverness, and not London Central, is an outlier. Removing Inverness has no impact on estimated scale economies, but does impact the estimated coefficient on walk-sorted mail. This does not have a material impact on the estimated efficiency savings (see below) but it does have implications both for the discriminating power of the SFA model and for the variables to be used in the data envelopment analysis. This issue is also discussed further below.

Stochastic Frontier Analysis

2.52 Oxera argues that the SFA model estimated by LECG cannot distinguish between noise and inefficiency. Further analysis suggests that this point is valid. We had relied upon the test of significance for the lambda parameter, but we appreciate that the size of this test is poor compared with the Likelihood Ratio test presented by Oxera[47].

2.53 The fact that the SFA model cannot distinguish between noise and inefficiency, however, does not mean that LECG's model is incorrectly specified. It might

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44 This implies cost savings at the benchmark in the order of £100m

45 This is obtained by multiplying a dummy for Inverness times the pct_wks variable

46 The values of the tests are F(1,62) = 3.73 in Model 4 and 2.01 in Model 5, not significant at the 5% level

47 This is partly an accident of the software employed. The software we used (Limdep) has some advantages over Stata (used by Oxera) but unlike Stata does not present the likelihood ratio test, only the test of lamda

simply mean that there are some extreme observations in the sample that make it difficult to identify the frontier. Consequently, we have used the information gathered when estimating the OLS models to confirm whether the SFA is unable to identify the frontier is due to the presence of outliers.

2.54 With the full samples (i.e. with all the mail centres in the model), the frontier cannot be identified with *any* of the models described above (i.e. models 1, 3, 4 and 5). This result is robust to the inclusion or exclusion of either London Central or Truro.

2.55 When we exclude Inverness from the sample and estimate Models 1 and 4, both models can distinguish between noise and inefficiency. The significance levels for the likelihood ratio tests for the variance of the inefficiency component to be zero in the half-normal models are 8% and 5%, for Models 1 and 4 respectively. This confirms that the models can distinguish between noise and inefficiency. We find that the models that use the total volume measure (i.e. Models 3 and 5) can never distinguish between noise and inefficiency. We believe that this further confirms that there is a problem with Oxera's inclusion of delivered mail in the volume measure.

2.56 The results from the SFA for Models 1 and 4 are presented in the table below[48].

[48] The LR for the exponential models were never significant. The truncated model has a non-concave likelihood function and fails to maximise

Table 13: Mail centre SFA cost equations excluding Inverness

Variable	Model 1	Model 4
Constant	-7.53 -4.35**	47.38 3.11
Dummy for small MCs	4.09 2.11*	
Ln(Volume)	1.20 13.09**	-4.96 -2.85*
Ln(Volume * Dummy for small MCs)	-0.23 -2.16*	
$(Ln(Volume))^2$		0.17 3.49**
Percent of intra-MC inward mail	0.54 1.18	0.38 0.91
Percent of MC area that is urban	0.30 3.11**	0.25 2.77**
Percent of mail that is walk sorted at MC	0.02 0.05	0.15 0.36
Log-Likelihood	44.61	46.36
LR – $\sigma_u = 0$ (p-value)	1.89 (0.08)	2.83 (0.05)

Source: LECG analysis. Dependent variable is log staff costs divided by basic wage rate. T-ratios are in second rows. ** significant at 1%, *significant at 5%.

2.57 The implied average efficiency is 14.3% for Model 1 and 15.6% for Model 4, with implied cost savings for the overall sample (including Inverness) of £100.5m and £109.7m respectively. These figures exclude any adjustments for diseconomies of scale, and are consistent with the 14.9% average inefficiency that Oxera found in its alternative model[49] (which had an implied average cost savings of £106.5m).

2.58 In conclusion, we have thoroughly examined the issue of outliers. It would appear that London Central is not an outlier but Inverness is. Once we omit Inverness the overall quality of the model improves (specifically, in its ability to distinguish the "random" and "inefficiency" components of the error term). We have also revisited the issue of delivered volume, and consistent with our view that this variable is misstated/ mismeasured, we find that its inclusion, predictably, reduces the ability of the model to distinguish noise from inefficiency.

[49] Oxera, OER, table 3.7, page 21. Estimates of the alternative model are presented in table 3.6, page 20

Review of delivery offices

2.59 In this section, we review the issues raised by Oxera with respect to our Ordinary Least Squares ("OLS") and Stochastic Frontier Analysis ("SFA") in respect of delivery offices[50]. Oxera's review of LECG's econometric modelling for delivery offices focused on the following issues[51]:

- LECG did not use the most suitable functional form for the cost function; and
- for its SFA estimates, LECG considered the half-normal model only, whilst the exponential and the truncated model should have been considered as well.

2.60 Our response to these two points can be summarised as follows:

- the model proposed by Oxera does not have the economic or industrial engineering properties we would expect of a plausible model and is therefore unacceptable as an estimate of a cost function; and
- the truncated model presented by Oxera "converges" after more than 300 iterations with very large derivatives. This means that the software has been unable to find the maximum of the likelihood function and the resultant equation should be discarded.[52]

2.61 We discuss each conclusion further below.

Functional form

2.62 The functional form of a model allows for variations in curvature of the relationship between the explanatory and the dependent variables, and for interactions between the explanatory variables. All functional forms are likely to be approximate, but by introducing additional variables it may be possible to get closer to the underlying data generating process. However, the advantages of

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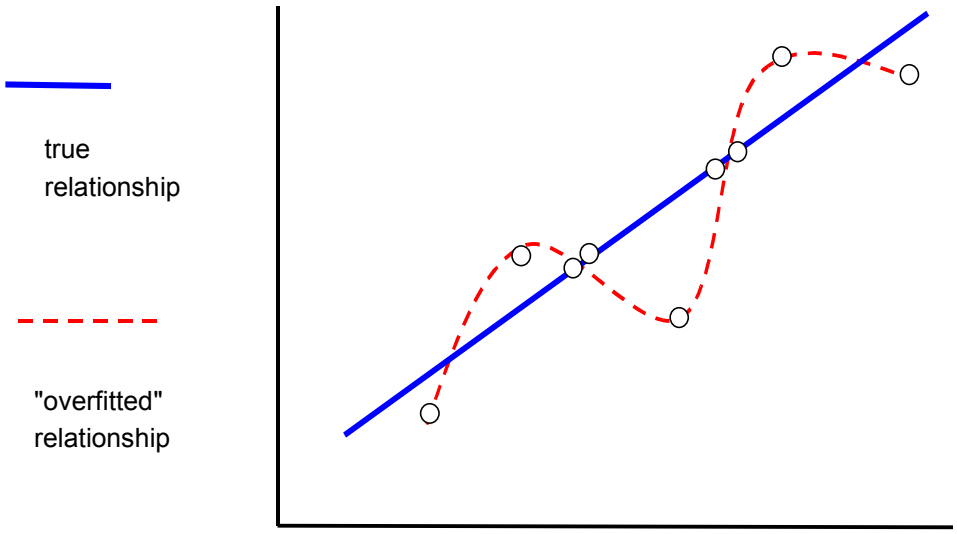
50 All the results presented in this section were obtained with Stata v. 8.2

51 In this section, we provide only a summary of Oxera's main points. In the detail of this report, we believe that we address all material and/ or valid points. Oxera's full report can be found on Postcomm's website

52 The first order condition for the maximisation of any function is that the first derivatives with respect to the arguments of the function should be zero. If the first derivatives are not zero, then the function cannot be at its maximum

an apparently better fit need to be set off against the danger of over fitting. One of the symptoms of over fitting is that the model makes no economic sense.

Figure 3: Example of over fitting



2.63 Modellers can be helped in their choice of functional form by the use of statistical tests, of which the most widely used is the RESET test. This tests to see whether the residual is related to a polynomial (e.g. quadratic, cubic) function of the fitted values of the dependent variable. However, this test – like other "t" or "F" tests – is biased in the presence of heteroscedasticity.

2.64 There are more than one thousand delivery offices in the UK, and in the sample on which we based our cost-modelling exercise. Given the heterogeneity of delivery activities, we expected and found the residuals of our cost model to be heteroscedastic.[53] In line with standard practice, we therefore adjusted the covariance matrix using the White correction. The White correction adjusts the covariance matrix only; the residuals are still heteroscedastic after the White correction has been applied. The consequence of this is that significance tests based on “t” or “F” distributions will, inappropriately, result in the rejection of the null hypothesis that is being tested. Thus, the test used by Oxera is biased in

[53] Heteroscedasticity is found when the variance of the disturbances varies across the sample units

favour of rejecting our model in favour of a more complex one, especially given its strong power in the presence of so many observations.

2.65 It is unclear why Oxera used a RESET test, which is an F-test, in the presence of heteroscedasticity. Oxera does not appear to take account of the heteroscedastic errors. Based on our reading of Oxera's report, it would appear that it has dismissed our model based on an incorrectly applied test.

2.66 Oxera claims that a translog cost function[54] should be used instead, and that *"… as would be expected with the larger dataset, a translog functional form actually seems to be reasonably appropriate for DOs (in contrast to LECG's stated position)."*[55] This is not true.

2.67 According to economic theory, a cost function must be homogeneous of degree one in factor prices and non-decreasing in output. Translated into elasticity estimates for the labour cost function for delivery offices, this means that the wage elasticity must be one, and the volume elasticity must be positive. The table below shows the wage and output elasticities implied by LECG's and Oxera's models:[56]

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54 The transcendental cost function (translog) is a flexible functional form that includes square terms and cross products, as well as level terms. It is expressed in logarithms

55 Oxera, OER, paragraph 4.2.3, page 33

56 The results for Oxera refer to the translog specification for the SFA half-normal. The other two models estimated by Oxera have similar results. The elasticities for Oxera's model are evaluated at the sample means

LECG

Table 14: Implied cost elasticities

Variable	LECG Cobb-Douglas	Oxera Translog
Average wage rate	1.03	34.65
Wage competitiveness index	0.10	0.04
Volume per delivery point	0.66	-2.26
Number of delivery points	1.01	0.68
Length of road per delivery point	0.08	0.002
Major city centre dummy variable	-0.10	0.66
Urban dummy variable	-0.13	0.64
Suburban dummy variable	-0.10	4.47
Rural dummy variable	-0.11	0.63
Percentage of business delivery points	0.10	0.08
Mail redirection	0.04	0.19
Number of RM2000 frames	-0.001	0.004

Note: Both sets of results were calculated using the parameter estimates from the stochastic frontier, half normal models, as reported in OER, Table 4.1, column 3 (LECG model) and in OER, Table A3.2.

2.68 The value of the wage elasticity estimated by Oxera is 34.65. LECG's model estimates unit wage elasticity. The implied cost elasticity with respect to volume per delivery point is *negative* in Oxera's model, meaning that an increase in volume reduces costs, and it is 0.66 in LECG's model.

2.69 These results are incompatible with industry knowledge and with economic theory. Whatever Oxera's translog model is estimating, it is not a cost function, and it would be difficult to justify efficiency ratings derived from it. Such an over fitted model, with 68 more variables than the Cobb-Douglas – mostly insignificant – inherently overstates the degree of fit and will underestimate the potential for inefficiency reduction.

SFA Modelling[57]

2.70 We discuss Oxera's comments on our SFA model below. We first explain why we discarded the truncated normal model, and then discuss the use of the exponential distribution.

2.71 The software used by LECG to produce the estimates shown in Oxera's report[58] is Professor Greene's Limdep version 8. The convergence criteria in this software package are set to have a maximum number of iterations equal to 100. If the likelihood function does not converge after 100 iterations, this should be taken as an indication that there is something wrong with the model. SFA models usually converge after a small number of iterations given that they use OLS coefficient estimates as their starting values, which are BLUE[59].

2.72 The truncated regression model estimated by Limdep did not converge after 100 iterations. We reset the maximum number of iterations to 400, and then to 1000. The software forced "convergence" (i.e. the iterations were stopped) in all cases. Independent of the number of iterations allowed we note:

- the value of the log-likelihood does not change (i.e. 683.97);
- the estimated coefficients of the cost function do not change;
- the estimated parameters for the error component do not change;
- the gradient of the function, that is the vector of first derivatives, is non-zero; and
- the estimated average inefficiency is 23%, which is above the 8% found by Oxera for the very same model.

2.73 The fact that the likelihood function has a non-zero gradient indicates that it is not clear what this forced "convergence" means. The normal meaning is that the model has not converged at all and the likelihood function is not at a maximum. Given this, we discarded the truncated normal model. We did not present the

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57 The results discussed in this section were obtained with two software programs. First, we replicated all of LECG's original results using Stata v. 8.2. Second we used Stata v 8.2 and Limdep v.8 to make sure that the results matched

58 Oxera, OER table 4.2, page 31

59 Best Linear Unbiased Estimators

results in our report. It is worth noting, however, that the estimated inefficiency from this model was much higher than that from the half-normal model.

2.74 To check whether this result depends on the particular software package used, we have used Stata version 8.2 as a cross check. From this, we have attempted to replicate Oxera's results. Our results differ slightly from those obtained by Oxera, who appear to have used either Stata version 8 or 8.1. With respect to our Stata estimates, we found that:

- the estimated log-likelihood is higher than in Limdep and differs slightly from that obtained by Oxera in their OER report[60];
- the estimated coefficients of the cost function are identical to those estimated by Limdep but the standard errors are different;
- the estimated variance of the symmetric error component (σ^2_v) is identical between Limdep and Stata, but the variance of the inefficiency component (σ^2_u) is much higher in Stata. The proportion of error that is inefficiency is high in both cases, 0.998 for Stata and 0.996 for Limdep; and
- the gradient is again non-zero**,** and most of its components are larger than those of the gradient returned by Limdep.

2.75 It would appear, therefore, that the lack of true convergence (i.e. the nonzero gradients) is a feature of the model, not of the software used. The table shows the parameter estimates for the truncated normal model obtained with Limdep and Stata.

[60] Oxera used Stata versions 8.0 and 8.1 to estimate these models. They do not specify which version of Stata was used to estimate which model

LECG

Table 15: Estimated cost function, SFA truncated normal

Variable	Limdep 8	Stata 8.2
Average wage rate	0.996 (10.33)	0.995 (10.09)
Wage competitiveness index	0.070 (0.95)	0.070 (0.98)
Volume per delivery point	0.639 (30.84)	0.639 (24.30)
Number of delivery points	0.984 (79.41)	0.984 (68.31)
Length of road per delivery point	0.078 (5.91)	0.078 (5.78)
Major city centre dummy variable	-0.088 (-1.55)	-0.088 (-1.59)
Urban dummy variable	-0.122 (-2.26)	-0.122 (-2.43)
Suburban dummy variable	-0.091 (-1.86)	-0.091 (-2.00)
Rural dummy variable	-0.104 (-2.37)	-0.104 (-2.53)
Percentage of business delivery points	0.100 (7.31)	0.100 (7.05)
Mail redirection	0.064 (5.94)	0.065 (4.85)
Number of RM2000 frames	-0.001 (-1.44)	-0.001 (-1.23)
Constant	-2.265 (-8.03)	-2.260 (-6.94)
Log-L	683.969	684.006
Average inefficiency	23.06%	8.97%

Source: LECG analysis. t-ratios in brackets.

2.76 The following table shows the gradients.

Table 16: Gradient of the likelihood function, Cobb-Douglas SFA truncated normal

Variable	Limdep	Stata	Variable	Limdep	Stata
Constant	4.40	13.74	Suburban	2.39	6.67
Average wage rate	8.56	26.33	Rural	0.68	3.07
Wage competitiveness Index	9.53	29.40	Percent business d.p.	-10.56	-30.60
Volume per delivery point	29.90	93.43	Mail redirections	29.18	86.14
Number of delivery points	43.38	133.80	RM 2000 frames	9.13	35.38
Road per delivery point	10.06	34.21	Error component1	-0.87	0.01
Major city centre	-0.15	0.47	Error component 2	-0.19	0.07
Urban	1.44	3.41	Error component 3	-4.54	43.13

Source: LECG analysis. Columns 2 and 5 show the first derivatives for the cost function estimated by Limdep 8; columns 3 and 6 show the derivatives for Stata 8.2. Not one of these derivatives is zero.

2.77 It is clear from the table that the elements in the gradient of the likelihood function are all non-zero. The first order condition to maximise (or minimise) ANY function, is that at the maximum (or minimum) the first derivatives have to be zero. Our analysis shows that neither software package can find this maximum. Limdep and Stata also report wholly different results (another sign of non-convergence). We believe therefore that the results from the truncated regression model are unreliable and should not be taken into consideration.

2.78 This leaves two stochastic frontier models, the half-normal and the exponential. In 1988, Battese and Coelli[61] suggested that the half-normal distribution is the most useful formulation. The asymptotic properties of the efficiency estimators have been analysed and subjected to thorough scrutiny for the half-normal

[61] Battese G.E. and Coelli T.J., 1988, "Prediction of Firm- Level Technical Efficiencies with a Generalised Frontier Production Function and Panel Data", Journal of Econometrics, 38 387-399

distribution only[62]. Perhaps for this reason the half-normal distribution is by far the most used distributional form in SFA. We do, however, accept Oxera's point that both the half normal and the exponential model should be estimated. The table below reports the results obtained for the SFA models for delivery offices using Stata 8.2.

Table 17: Estimated cost function, SFA Half-normal and Exponential

Variable	Half-normal		Exponential	
	Coeff.	*z-value*	*Coeff.*	*z-value*
Average wage rate	1.03	10.55	1.00	10.09
Wage competitiveness index	0.10	1.41	0.07	0.98
Volume per delivery point	0.66	27.51	0.64	24.26
Number of delivery points	1.01	89.56	0.98	68.12
Length of road per delivery point	0.08	5.78	0.08	5.78
Major city centre dummy variable	-0.10	-1.77	-0.09	-1.58
Urban dummy variable	-0.13	-2.48	-0.12	-2.43
Suburban dummy variable	-0.10	-2.08	-0.09	-2.00
Rural dummy variable	-0.11	-2.59	-0.10	-2.53
Percentage of business delivery points	0.10	7.31	0.10	7.04
Mail redirection	0.04	4.51	0.06	4.86
Number of RM2000 frames	-0.001	-1.11	0.00	1.23
Constant	-2.62	-8.97	-2.26	-6.92
Log-L	677.30		684.05	
Average inefficiency	12.8%		9.0%	

Note: The results shown in this table have been obtained with Stata 8.2. Significance is not indicated due to the heteroscedasticiry of the residuals.

2.79 We have not been able to replicate Oxera's results exactly, but we have obtained identical parameter estimates with Stata 8.2 and Limdep 8, but with slightly different standard errors. The implied efficiency savings are 8.97% for the

[62] See for example Kumbhakar, S. C. and Löthgren M., 1998, A Montecarlo Analysis of Technical Inefficiency Predictors, *Working Paper Series in Economics and Finance*, No 229, Stockholm School of Economics.

exponential model and 12.8% for the half-normal[63], which was LECG's original model[64].

2.80 It is clear from the table above that the only difference between the half-normal and exponential lies in the proportion of the error variance that is attributable to inefficiency. Since they are non-nested, there is no widely accepted statistical procedure to select between these two models. The half normal is much more widely used than the exponential, in part because the asymptotic properties of the efficiency estimates obtained from this model are well established. There is no corresponding wealth of knowledge for the exponential model. Under our base case, therefore, we have adopted the half normal results, which is consistent with our initial conclusions.

2.81 For a lower case estimate, we have taken the average between the half-normal and the exponential inefficiency estimates, which gives an average inefficiency of 10.9%. This would imply efficiency savings of £220 million for the delivery offices network, compared to our original estimate of £263 million. Overall, we believe that an estimate at this lower level is extremely conservative.

Methodological issues and choice of benchmark

2.82 Oxera argued that, where a SFA model is able to distinguish between noise and inefficiency, the DFA model should be completely disregarded. We disagree, because no one technique gives a complete picture of the likely degree of inefficiency.

2.83 The SFA approach has its advantages but it can be sensitive to the form of the distribution assumed. For example, if the random and inefficiency component were distributed in a very similar way (such as a truncated normal with the truncation point a long way in the negative tail), SFA might well be unable to distinguish them[65]. This would not mean that all the residuals (or even all the negative residuals) were random fluctuations. It does mean, however, that we would need to take a view – based on our knowledge of the industry and the

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63 This is a common feature where both exponential and half-normal models are estimated

64 We note that the estimated efficiency is slightly different from that shown in our original report (13%). This is due to the fact that the figures in our original report were obtained with Limdep v.8, while those in this report have been obtained with Stata 8.2

65 This could be one explanation of the failure of an SFA model to converge, for example

actual equations estimated – about the likely size of the random component in the residuals. This is what Ofwat does and it is what we have done.

2.84 It seems to us that the principle danger in this approach is that the equation based on ordinary least squares goes through the average of the observations, rather than a notional frontier, and this might have coefficients which are substantially different, leading to different conclusions about efficiency. In the present case, the coefficients in the DFA and SFA equations were very similar, so the danger appears small.

2.85 Our August Report sets out in some detail why we believe that it is appropriate to consider the results of both the SFA and DFA analysis. In Appendix 18, we set out the regulatory precedent that supports our approach. In Appendix 20, we contrasted the different techniques and fully explained why we believed it sensible to consider both approaches. Oxera has not provided sufficient evidence to show that our approach is either flawed or contrary to regulatory good practice. As such, we continue to consider both approaches.

2.86 We now discuss Oxera's contention that when using SFA we should have applied the top decile benchmark, after having set the inefficiency of the most efficient unit equal to zero. When using SFA, we have calculated average efficiency savings for mail centres and delivery offices, rather than taking any individual unit as the benchmark. This is because we are working with cross-sectional samples of mail centres and delivery offices. That is, we have a single observation for each sample unit. It is a well known result that when dealing with cross-sections one should not focus on individual efficiency estimates, but only on average estimates. These estimates are "clean" of the effect of random noise. The whole point about SFA is that it allows one to separate noise from inefficiency.

2.87 Oxera suggests that we should use the top decile as the benchmark for the SFA estimates. This would reduce cost savings to £66.5m for mail centres, and to between £83m and £89m for delivery offices[66].

2.88 Oxera's argument is based on a recent paper by NERA which says that "*if there are any data or estimation problems (for example, unobserved heterogeneity) the*

[66] Oxera, OER, table 2, row vii, page ii and table 3, row iv, page iii

techniques could produce a frontier that is biased outward and would make observations appear spuriously efficient… therefore by comparing observations relative to the decile we can be certain that we are comparing against an achievable level of efficiency."[67]

2.89 There are three comments that need to be made regarding NERA's argument. The first argument concerns the context in which that argument was made. The other two comments are more substantive and they relate to technical properties of the efficiency estimates obtained when SFA is applied to a cross-section of data, as it is the case for both mail centres and delivery offices.

2.90 NERA's argument is set in a different context, and it pertains to an analysis conducted using panel data and in the face of differences in data definitions between BT and the set of companies with which BT is being compared. In particular, NERA is trying to calculate an efficiency measure for a single observation (i.e. BT), a UK company being compared with a set of US companies. Furthermore, this is being done in a context in which there are panel data, in which it is more appropriate to draw inferences on individual efficiency estimates. However, in the current application of SFA we are trying to estimate the *average* level of inefficiency within Royal Mail, across the whole sample of delivery offices or mail centres. In addition, we are doing this using data from a single cross-section, without repeated observations for each delivery office or mail centre at different points on time.

2.91 It is well known that with cross-sectional data the stochastic frontier cannot identify the marginal expectation of observation-specific, or *individual*, efficiencies. With panel data such identification is possible, as shown by Schmidt and Sickles in 1984[68]. However, Jondrow et al. (1982)[69] were able to construct an estimator for individual efficiencies that was not unconditional, but conditional on the stochastic component of the composed error.

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67 The efficiency of BT in 2003: A Report for Ofcom, NERA, 11 March 2005

68 Schmidt, P. and Sickles, R.J., 1984, "Production Frontiers and Panel Data," *Journal of Business and Economics Statistics*, 2, 367-74

69 Jondrow, J., Lovell, C.A.K., Materov, S.I. and Schmidt, P., 1982, "On the Estimation of Technical Inefficiency in the Stochastic Frontier Production Function Model," *Journal of Econometrics*, 19, 233-38

2.92 This estimator of the conditional mean for each firm is what most software programs report, as well as reporting unconditional mean efficiency of the entire sample of firms based on an assumed parametric distribution of the composed error – the efficiency component and the standard disturbance term. Although the firm-specific conditional expectation of the one-sided efficiency term is informative, it does need to be interpreted with caution. Because it is conditional on stochastic noise, it is likely that the firm-specific conditional mean efficiency estimates will change when the conditioning information changes. Moreover, since the non-systematic idiosyncratic error is the conditioning random variable the individual efficiency estimates using cross-sectional data must be interpreted as estimates based on unknown random events.

2.93 Finally, since there is only one observation on which to base individual efficiency estimates, one is able to construct an unbiased estimate for each sample unit, but this estimate has a problematic large sample asymptotic behaviour, as shown by Schmidt and Sickles[70]. What this implies is that one should not rely on individual inefficiencies, or use any one of those as benchmarks. While SFA does provide an estimate of the inefficiency for each observation, there are problems interpreting these as *individual* inefficiencies. Faced with the need to provide an estimate for a single company, it is understandable that some account be taken of what is akin to a sampling error, as NERA did with BT. NERA, however, used an individual estimate which was based on a panel, not on a cross-section, which would in any case have mitigated the problems discussed above.

2.94 However, what we are trying to do, and can achieve here is quite different. It is to estimate the *average* inefficiency across the whole sample, not for any one delivery office or mail centre. The widespread use of SFA is predicated on its large sample properties of consistency i.e. the estimates of the *aggregate (average) inefficiency* converge to the true value as the number of observations increases – at least for the half-normal distribution.[71]

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[70] Schmidt, P. and Sickles, R.J., 1984, *op.cit*

[71] Refer to Khumbakar et.al. (1998) for a Monte Carlo study using the half-normal distribution

LECG

Conclusions

2.95 We have reviewed the points raised by Oxera. With respect to the benchmark, we do not agree with Oxera's claim that we should use the top decile as a benchmark for the stochastic frontier as well as for the DFA. Average inefficiency estimates produced by SFA are the correct figures to use, as there are problems with individual efficiency estimates. Our specific conclusions for mail centres and delivery offices are discussed below.

Mail centre conclusions

2.96 We have shown that our initial analysis is robust. Oxera's criticisms are based either on classification errors or on procedural errors. We have produced an alternative cost model, a quadratic model, which confirms our original results. Specifically, diseconomies of scale are present in large mail centres. Small mail centres operate at constant returns to scale.

2.97 We have shown that the failure of our original SFA model to distinguish between noise and inefficiency was due to the presence of an outlier in the sample, Inverness. Once this outlier is accounted for, the model is properly specified, and can distinguish between noise and inefficiency.

2.98 We acknowledge that in our original model labour costs in six mail centres included sorting costs for delivered mail, and this was inconsistent with the corresponding volume figure. The impact of this measurement issue is thought to be small. However, Royal Mail has been unable to provide better data. What we can say with confidence is that the volume figures containing delivered volumes cannot be used, as they are based on the wrong weights.

2.99 To estimate the scale of this point, we developed an additional model to estimate the cost impact of this issue. We estimate that adjusting for delivered mail sorting costs would lower our efficiency estimates by around £2.2 million. The scale of this adjustment is plausible, given that delivered volumes only impact six mail centres.

2.100 Estimated potential savings for mail centres are as shown in the table below. These exclude any savings relating to diseconomies of scale.

Table 18: Estimated potential savings: mail centres £m

	DFA Model 1 (LECG Original)	DFA Model 4 (LECG Quadratic)	SFA Model 1 (LECG Original)	SFA Model 4 (LECG Quadratic)
Type of benchmark	First decile	First decile		
Costs of included centres	703.1	703.1	703.1	703.1
Savings at benchmark	124.8	117.9	100.5	109.7
Less 15% adjustment	18.7	17.7		
Less delivered volume adjustment	2.2	2.2	2.2	2.2
Aggregate potential cost saving	103.9	98.0	98.3	107.5

Source: LECG analysis.

2.101 For mail centres, Oxera calculates the *average* cost savings to be £106.5 million[72]. This is consistent with our analysis above. Our initial conclusions were that savings of at least £100m per year were achievable simply by applying existing best practices within the mail centre network. Based on the analysis above, we believe that this initial conclusion is still robust. Oxera's model, after correcting for outliers, actually suggests a higher level of efficiency savings.

2.102 In the longer term, we expected that the diseconomies of scale of mail centres could also be redressed. This would increase the scope for further efficiencies by up to £50m.

Delivery offices

2.103 We have shown that Oxera's proposed cost model does not satisfy the requirements of economic theory. As such, Oxera's estimates must be disregarded. We have also shown that the truncated regression model proposed by Oxera does not converge and cannot be taken into consideration.

2.104 We acknowledge that the exponential model, although not as widely used as the half-normal, is a possible candidate for SFA. However, the asymptotic properties of the efficiency estimates are not known for this model. There is no statistical test that allows for an informed choice between the half-normal and the exponential, and as such, the choice has to be based on judgement.

[72] Oxera, OER, Table 3.8, page 22

2.105 We believe that the half-normal is used more in practice and as such would place greater weight on this estimate. However, as a conservative estimate we considered the average of the two models. This reduces the cost savings factor to 10.9%, from the 12.8% factor implied by the half-normal model.

Table 19: Estimated potential savings for delivery offices

		DFA £m	SFA half normal £m	SFA exponential £m	SFA combined £m
1.	Type of benchmark	First decile			
2.	Costs of included offices	1,843.9	1,843.9	1,843.9	1,843.9
3.	Savings at benchmark	310.0	236.0	165.4	201.0
4.	Less 20% adjustment	62.0			
5.	Net potential saving	248.0	236.0	165.4	201.0
6.	% factor implied (Row 5 / Row 2)	13.4	12.8	8.97	10.9
7.	Costs of omitted offices	169.7	169.7	169.7	169.7
8.	Potential cost saving using same factor	22.7	21.7	15.2	18.5
9.	Aggregate potential cost saving	270.7	257.7	180.6	219.5

Source: LECG analysis. Note: The 'potential cost savings using same factors' is derived by multiplying 'cost of omitted offices' by % factor implied'.

2.106 Our initial findings were that savings in the range £263m to £270m per year were achievable simply by applying existing best practices within the delivery office network. For our initial conclusions, the DFA and SFA estimates were within 5% of each other. For our final conclusions, under our central case, we find that the DFA and SFA results remain close. However, we have derived a lower case estimate of £220m, based on the average of the half-normal and the exponential distributions.

3 Data envelopment analysis

Introduction

3.1 This section contains LECG's response to the technical points raised by Oxera with respect to our data envelopment analysis. Oxera's response is contained in the ODR document. We first summarise the points that have been raised and provide a response in summary form. We then respond to each point in further detail.

Summary of Oxera's points

3.2 For mail centres, the main points put forward by Oxera can be summarised as follows[73]:

- that the finding of significant diseconomies of scale is due to the influence of one large observation;
- it is more appropriate to use a variable returns to scale assumption than constant returns to scale. Scale cannot readily be changed to fully exploit economies of scale;
- LECG excluded delivered traffic from its volume measure. If this is included the estimated savings are reduced; and
- LECG made insufficient allowance for outliers. These can be identified by calculating "super-efficiency" scores and omitting those with the highest super-efficiencies from the analysis.

3.3 For delivery offices, the main points put forward by Oxera can be summarised as follows[74]:

- a model based on assumption of variable returns to scale is more appropriate than LECG's "hybrid" model;
- disaggregation by zones is less appropriate than disaggregation by volume per delivery point;

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73 Oxera, ODR, page ii to iii

74 Oxera, ODR, page iii to iv

- LECG made insufficient allowance for outliers, so the benchmark is inappropriate. Outliers can be identified by calculating "super-efficiency" scores and omitting those delivery offices with the highest super-efficiencies from the analysis.

3.4 Oxera estimated alternative models, which produced lower estimates of the available efficiency savings. Oxera estimated savings to be in the order of £50m to £70m for mail centres[75] and £140m to £180m for delivery offices[76].

Summary of LECG's response

3.5 Some of Oxera's points (e.g. the issues relating to diseconomies of scale and weighted delivered volume) have been discussed extensively in Section 2 above.

3.6 It is not the case that the finding of diseconomies of scale is due to a single observation. We excluded volume delivered from the mail centre analysis on the advice of Royal Mail, which indicated that such volume measures would create a distortion in our models owing to the inappropriate weighting given to delivered volumes. Presumably, this still applies. We have estimated the additional costs associated with delivered volumes and make a separate adjustment for this.

3.7 Another category of comment relates to the treatment of scale economies more generally, which we can split into issues relating to economies of scale and of density. This pertains both to delivery offices and to mail centres.

3.8 We assumed constant returns to scale in both models. In the case of delivery offices this is largely straightforward given that the econometric tests indicated that scale (as indicated by the number of delivery points) was an important variable and that there are essentially constant returns to scale.

3.9 In the case of mail centres, the case is rather different. Our use of constant returns to scale is predicated on the assumption that the same outputs can be produced either by one large mail centre or two smaller centres. If there are cost savings elsewhere in the network which would be lost if the larger centres were divided into smaller units then there might be a stronger case for using a variable returns methodology. However, Royal Mail has not made this case. Instead, we

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75 Oxera, ODR, page iv

76 Oxera, ODR, page iv. Estimate based on unmodelled Dos as opposed to Oxera's preferred DEA model, which gives a range of £130m to £170m

understand that there is some recognition that building of very large mail centres may have been a mistake and that future plans do not envisage the construction of any more mail centres in the largest size category. However, we know of no immediate plans to split the large mail centres into smaller centres.

3.10 On the issue of the economies of density for delivery offices we believe that Oxera made a valid point – namely that theory, Royal Mail's own internal models, and our econometrics all indicate that volume per delivery point is an important source of economies of density with a cost elasticity in the region 0.65-0.67. This affects two other variables, roads (which should be included as roads divided by number of delivery points) and business delivery points (which should be business delivery points as a fraction of total delivery points). Accordingly we have calculated a revised model that incorporates these points.

3.11 In the remainder of this section, we discuss our response to each of Oxera's points in detail. First, we discuss Oxera's points that are common to both mail centres and delivery offices. These are the matter of constant versus variable returns to scale, and that of the treatment of outliers. Second, we look at the issues that pertain to mail centres. Finally, we discuss delivery office issues.

Issues common to both mail centres and delivery offices

3.12 Oxera suggested the following criteria as the basis for using constant or variable returns to scale:

- Can Royal Mail control scale size?
- What is the timescale in which scale size can be changed to a more productive one?
- What is the most productive scale size for each delivery office?

3.13 These factors are only relevant where there are no constant returns to scale. As the above section on the econometric analysis shows, for delivery offices there is a strong evidence of constant returns in the dimension of delivery points, which is the dimension in which our revised model has the property of constant returns. Even if we were to accept the alternative proposition – that there are slight diseconomies of scale in the operation of delivery offices, Royal Mail has not explained how these diseconomies arise or why it chooses to operate delivery offices at apparently uneconomically large scales.

3.14 Therefore, the above considerations apply only to the mail centres, on which there seems to be agreement that over at least part of the size range the data exhibit decreasing returns to scale.

Issues specific to mail centres

3.15 Two issues are specific to mail centres. These are the issue of constant versus variable returns to scale and that of the treatment of outliers. We discuss each in turn.

Returns to scale

3.16 Oxera states that LECG's model is not consistent with the assumption of constant returns to scale, and it is true that there is evidence that larger mail centres are more costly. As Oxera notes, a constant returns to scale model would be appropriate if Postcomm wished to incentivise Royal Mail to operate at the most productive scale size[77].

3.17 The key question is whether apparent diseconomies of scale for the larger offices reflect poorer efficiency or whether the larger offices are optimally scaled because their extra costs are offset by savings elsewhere in the system. In their response to our work, Oxera seemed keen to stress that diseconomies of scale are a real phenomenon, although it does say that "*it will not always be possible to achieve the optimal input-output mix due to the fixed nature of the population distribution and transport networks.*"[78]

3.18 In response to our request for further information Royal Mail told us:

"At the meeting on 1 November 2005 Postcomm (John Cubbin) asked Royal Mail to explain why, from an operational perspective, there could be some diseconomies of scale occurring within the Mail Centres, as exhibited in Oxera's results."

"In response, a key driver may be that the larger Mail Centres can undertake additional work to seek to fulfill the requirements of the mail services and in particular the first class services. For example, larger Mail Centres can undertake more detailed outward sortation to relieve smaller Mail Centres

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77 Oxera, ODR, page 10

78 Oxera, ODR, page 9

undertaking the same levels of work. Such factors may not be picked up in explanatory variables because there is no available variable or because it is a refinement that does not yield statistically significant coefficients on an available variable… Further, such factors may not be picked up in the weighted volumes measure and thereby may cause the weighted volumes (as a proxy for the work undertaken) of larger Mail Centres to be understated relative to smaller Mail Centres."

"In addition, smaller Mail Centres may be less capacity constrained, as raised in Oxera's report. Indeed, it is noted that the models only look at part of the cost base. Even if more smaller Mail Centres were to deliver higher staff efficiency they may also cost proportionately more in accommodation costs and, more importantly, introduce inefficiency into the transport network. More smaller Mail Centres could also require a greater depth of sorting (i.e. more work) to be carried out everywhere."[79]

3.19 It has not proved possible to test this assertion using econometric analysis or DEA since, as Royal Mail asserts, the data does not exist or the effect is too small to be picked up in the econometric analysis. We do note, however, that we did test for these effects. Our original model contained a variable relating to the percentage of mail that is walk sorted. This is no longer significant once we exclude the outlier of Inverness. Given the reasonable number of observations for the mail centres, the absence of a significant effect suggests to us that it does not have a material effect on costs.

3.20 Postcomm's industry experts expressed considerable scepticism that the factors mentioned above could be material. Royal Mail has gone to considerable lengths to measure the amount of work done by mail centres and delivery offices, (and the mail centre measurement is more automated and therefore less prone to human error), and it seems most unlikely to us that this amount of work should be uncounted – as evidenced by the fact that the proportion of mail that is walksorted is indeed counted.

3.21 Nor do we accept the arguments relating to the transport network, since reducing the size of an individual mail centre does not necessitate changing the transport

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[79] Royal Mail "Comment On Oxera's Results Indicating Some Diseconomies Of Scale At Mail Centres", 2 November 2005

network: for example two mail centres could logically be adjacent. This is an example, not a prescription. What we do accept is that such changes may need to take place over a longer period than those identified in the rest of the benchmarking work.

3.22 Oxera claims that we have added £50m to the potential cost savings from the DEA model[80]. We have not been able to identify where this has taken place. If we had done this, there would be a case for saying there was double counting.

Treatment of outliers

3.23 We believe that outliers are less likely to be a problem for mail centres than for delivery offices. The operation is much more within the mail centre itself, so there is less environmental variation; volumes are measured automatically; and mail centres' larger size means that random traffic variations will tend to even out rather more.

3.24 However, as a sensitivity test, we calculated super-efficiency scores for each mail centre. Four mail centres had a super-efficiency score of more than 1.10, which lead to removing four centres from the sample. The resulting potential efficiency gain fell to 16.6%, a fall of the order of one percentage point.

Alternative specifications for mail centres

3.25 Oxera recommends that a variable return to scale ("VRS") specification would be more appropriate than constant returns ("CRS")[81]. This is understandable given that we found decreasing returns in the econometric analysis.

3.26 However, Monte Carlo results reported by Professor Cubbin[82] suggest that, unless observations are in the hundreds rather than tens, the variable returns to scale specifications may not only lead to much wider confidence intervals than CRS, they may also give biased average efficiencies, with a tendency to overestimate efficiency.

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80 Oxera, ODR, page 11

81 Oxera, ODR, page iii

82 J Cubbin, Some more statistical properties of Data Envelopment Analysis, February 2004. http://www.staff.city.ac.uk/~sm340/Old%20public%20html/DEAStatPropsFeb2004.pdf

3.27 The same Monte Carlo simulations suggested that inclusion of irrelevant variables could also create substantial upward biases in estimated efficiency. There are two candidates for irrelevant variables. As Oxera points out the percentage of intra-Mail Centre inward mail is not statistically significant and makes little contribution to the regression estimates. Similarly, once we omit the Inverness outlier the percent of mail that is walk sorted is no longer significant.

3.28 Therefore, as a sensitivity analysis we calculated a model, as before, but with the following changes:

- variable returns to scale rather than constant;
- omitting Inverness and the percent of mail that is walk sorted; and
- omitting the percent of intra-MC inward mail.

3.29 This left volume as an output and "percentage of mail centre area that is urban" as the variables not under management control in an input minimisation framework. The implied savings were 11.34% (i.e. £80 million) as opposed to 17.4% (i.e. £122.6 million) in our original specification (before applying the 15% discount for omitted variables, etc)

3.30 However, given the simulation results referred to above we believe there is a strong possibility that this is an underestimate of the available savings. One indication of this is that the number of efficient mail centres rises from 4 to 14 under the VRS specification.

3.31 The table below demonstrates the sensitivity of the estimates to specification. This is one of the disadvantages of DEA and the reason we adopted a range of approaches.

Table 20: Estimated potential savings for mail centres

	(1) DEA original	(2) DEA only significant variables	(3) DEA only significant variables	(4) DEA original
Returns to scale	CRS	CRS	VRS	VRS
% saving	17.4%	23.1%	10.9%	8.4%
No of "efficient " centres	15/69	4/68	14/68	28/69
Implied savings	£123m	£162m	£79m	£59m

Source: LECG analysis – before taking 15% extra discount.

Mail centre conclusions

3.32 The table above shows that the DEA results are extremely sensitive to the adoption of variable returns to scale methodology. It cuts the potential saving from £162.4m to £79.6m, a difference of £82.8m, which should be compared to the £50 million estimate of the costs of diseconomies of scale from our econometric results. This tends to confirm the expectation that VRS has a tendency to severely underestimate inefficiencies, unless the sample is in the hundreds rather than tens.

3.33 If we were to accept Royal Mail's assertion that the diseconomies of scale reflect an optimised mail centre network we might be inclined to adopt a variable returns to scale methodology. However, we must be aware that there would be a significant risk that the degree of inefficiency would be underestimated as a result. It would in our view be preferable to adopt the CRS methodology and use the econometric estimate of £50m to adjust it to a VRS standard.

3.34 Having considered the arguments carefully, we are not persuaded either that there are significant amounts of uncounted activity at the larger mail centres, or that the larger mail centres are a necessary by-product of an optimised transport system. We therefore consider that the constant returns to scale estimates in our revised model are likely to be the more accurate estimate of the potential for costs savings in an internal benchmarking context.

Issues specific to delivery offices

3.35 There are three issues specific to delivery offices, and these are whether constant or variable returns to scale should be used, the treatment of outliers,

and the stratification issue. We will discuss these three issues in turn. We will then discuss the results produced by reformulating the DEA to make it consistent with our econometric model.

Returns to scale

3.36 Oxera pointed out that some of the scaleable variables used in our original analysis do not correspond to the specification used in the regression analysis (both deterministic and stochastic frontier) and therefore inferences based on the specification are potentially incorrect. In particular, the volume figure should be expressed in terms of volume per delivery point, as in the regression analysis. In addition, the measure of roads should have been expressed as length of road per delivery point.

3.37 We accept the validity of these points. We have amended our model accordingly, treating these variables as non-scaleable outputs. This moves the model in the direction of a VRS specification. There is also a case for using percentage of business delivery points as a ratio to ensure consistency with the DFA and SFA equations. We have therefore incorporated this into our revised model.

3.38 Oxera claimed[83] that its econometric model indicates that there are variable returns to scale depending on whether an area is rural or not[84]. For rural delivery offices, Oxera's model yielded constant returns to scale. As we have discussed in Section 2 above, we do not accept the validity of this alternative model because it is incompatible with economic theory and therefore does not represent the estimate of a cost function.

3.39 Since our model implies that there are constant returns in relation to the number of delivery points there can be no question that our DEA model should reflect this. Unlike the case of mail centres, there is no issue relating to the effects of re-organising the delivery office network.

Treatment of outliers

3.40 Oxera has also expressed the concern that there is inconsistency of treatment of outliers as between the DEA and the regression models. In the case of the latter,

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83 Oxera, OER, table 4.9

84 Oxera, OER, page 35

we took the office at the first decile (i.e. the worst of the top 10%) as the benchmark, because there is a clear possibility that some of the delivery offices that appeared most efficient were outliers in the sense of having especially favourable factors excluded from the analysis or measurement error. Since we had already excluded around 10% of the delivery offices on the grounds of poor data quality, this was arguably an overly conservative precaution. For example, Ofwat requires that a benchmark firm account for at least 3% of industry output – in most cases, it is actually the "top" company.

3.41 We accept that there is a possibility that the DEA results could also have been affected to some degree by the same phenomenon. However, with DEA there is a countervailing issue. Unlike DFA, there is no single observation that counts as the benchmark.

3.42 As our August Report (Table 219) indicates there were 168 delivery offices that formed the frontiers estimated for the five zones – well over 10%, which is a very different picture from the deterministic frontier and therefore warrants a different approach. However, as a sensitivity analysis we adopted Oxera's suggestion of a two-stage procedure as follows:

- calculate "super-efficiencies", by preventing each delivery office from forming a reference group consisting entirely of itself. This leads to efficiency scores above 1.00 for a number of delivery offices; and
- carry out a normal DEA omitting those delivery offices with a super-efficiency score above a certain value. Oxera recommends looking for a break in the series, and this would have eliminated only a few at the top end. Instead, we used a figure of 10%, which knocked out those that had a super-efficiency score of 1.10 or more, which amounted to 46% of the "super-efficient" delivery offices.

Stratification

3.43 Oxera suggests that stratification by location type (deep rural, rural, suburban, urban, city centre) is less appropriate than by density (i.e. by volume per delivery point). However, one of the advantages claimed for DEA as a multivariate technique is precisely that it allows us to examine the effect of several variables.

3.44 Where variables are of the regression "dummy" type (i.e. taking a value of one where a characteristic is present, but zero elsewhere) requiring that the reference

group consists only of delivery offices with the same characteristic amounts to the same thing as running separate DEAs for each category.

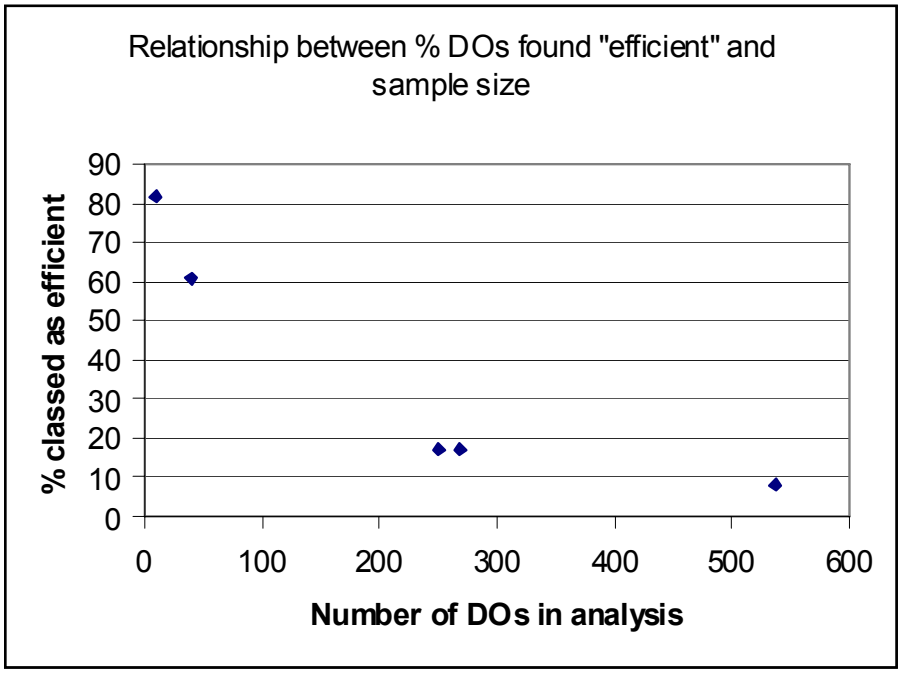
3.45 This can have the consequence that there are really too few observations to carry out a useful DEA exercise, because too many of the delivery offices will simply appear unique within the set and thus attract a spurious efficiency score of 1. That this is indeed the case is suggested by the pattern of the number of efficient delivery offices in our original report, as shown in the table and figure below.

Table 21: Proportion of delivery offices with DEA scores of 1.00 versus sample size

Delivery Zone	No. of efficient branches	Total branches in analysis	% "Efficient"	Savings identified by DEA (%)
Deep rural	9	11	82	2.3
City Centre	25	41	61	6.2
Rural	43	250	17	14.0
Urban	47	269	17	15.6
Suburban	44	537	8	24.7

Source: Analysis of Table 219 in LECG report.

Figure 4: Impact of sample size on % "efficient"



Source: Derived from data in Table 21 above.

3.46 This leads to the suspicion that many of the "efficient" branches in the first two categories, and possibly the second two categories also were on the frontier spuriously, and might partly explain why the percentage potential savings identified increase with sample size. This would imply that efficiency gains are potentially greatly underestimated for the deep rural and city centre offices.

3.47 Oxera suggests splitting the sample into a number of strata reflecting different values of volume per delivery point. The greater the number of strata, the lower the estimated costs savings. With ten strata estimated costs savings are halved. This is simply a reflection of the fact that increasing the number of strata decreases the sample size in each stratum, and therefore a larger number of observations are falsely classified as efficient.

3.48 There is no need to perform such stratification as long as we adopt a hybrid DEA model with VRS[85] in volume per delivery point and CRS in the number of delivery points.

Recalculations for delivery offices

3.49 We reformulated our model to make it consistent with our regression model. The details of the way the variables were specified are given in the table below.

Table 22: Revised specification for DEA

Variable name	Classification	Type	Exogenous or subject to managerial control?	Expected impact on costs	Constant or variable returns?
Cost	1	Input	Controllable	na	Constant
Frames	2	Noncontrollable input	Exogenous	-ve	Constant
Redirections	3	Noncontrollable output	Exogenous	+ ve	Constant
Total DP	4	Output	Exogenous	+ ve	Constant
Business DP/ Total DP	6	Noncontrollable quasi output	Exogenous	+ ve	Variable
RM wage	6	Noncontrollable quasi output	Exogenous	+ ve	Variable
Local Wage	6	Noncontrollable quasi output	Exogenous	+ ve	Variable
Road length/ Total DP	6	Noncontrollable quasi output	Exogenous	+ ve	Variable
Volume/ Total DP	6	Noncontrollable quasi output	Exogenous	+ ve	Variable

Note: The input minimisation mode was adopted.

3.50 Thus the variables which in the regression entered as levels, and which can be considered to grow in proportion to the scale of operation – which provide the target cost level for any delivery office – are treated as scaleable. That is if all the scaleable factors rise in the same proportion *K* (holding non-scaleable factors constant) efficient costs would also be expected to grow by *K*. For the non-scalable factors, the reference group should have the same, or less favourable,

[85] Strictly, Volume per delivery point is treated as a nonscaleable variable, which operates in the same way as variable returns to scale

weighted average as the delivery office being analysed. The results of the analysis zone by zone are shown below.

Table 23: Results for revised specification: potential savings

£m	(1)	(2)	(3)	(4)	(5)
Zone	Previous model	New model	Omitting super efficient > 1.10	Number omitted	No. omitted by Oxera criterion
City Centre	7.43	8.80	7.34	7	2
Urban	69.44	66.91	56.84	11	0
Suburban	239.59	264.47	236.04	14	2
Rural	36.66	41.25	38.70	13	1
Deep rural	0.13	0.24	0.73	2	0
Total	353.25	381.69	341.45	47	5
Adjustments[1]	44.6	48.2	43.23		
Total savings	308.6	333.5	298.3		

Source: LECG. [1]Adjustments include 20% discount plus estimate for excluded offices.

3.51 As the table shows, the impact of revising the specification to resemble more closely the specifications implied by the regression models is to raise the estimated potential efficiency gain from £353m to £382m. Both figures would be subject to 20% downward adjustment.

Choice of benchmark for DEA in delivery offices

3.52 Oxera expressed concern that some of the delivery offices in our reference groups might be outliers. For the same reason that we used the first decile point as our benchmark in the DFA Oxera suggested removing some of those offices which are classed as "super efficient". Oxera suggested two criteria for removal of super-efficient offices:

- first, look for a break in the series of super-efficiencies of at least 10 percentage points; and
- second, remove the delivery offices with the top 10% super-efficiency scores.

3.53 For reasons we have already explained, we do not think the latter is appropriate. On the other hand, if we adopt the first criterion only five delivery offices get removed, with a very small effect on the estimated savings. Instead, we performed a sensitivity analysis making a more extreme assumption: that every delivery office with a super-efficiency score of 1.10 or larger was potentially an outlier. This removed 47 offices in total, and the results are shown in column (4) in the table above. This assumption reduces our efficiency savings to a level that is consistent with our initial conclusions.

3.54 However, if we were to adopt this assumption there would be a strong case for reducing the discount factor from 20%. This is because we would have removed one of the reasons for applying the discount in the first place. That is, we had already taken account of the fact that there are likely to be a number of spuriously "efficient" delivery offices among all but the suburban zone sample.

Delivery office conclusions

3.55 Oxera has made some valid points with respect to the approach we adopted with DEA. We accept the specification can be improved to make it more consistent with the DFA and SFA equations that have been estimated. However, we do not accept that we should move to a totally variable returns to scale approach, as this would a) be inconsistent with the regression equations and b) would lead to an overestimation of the efficiency of the delivery office network.

3.56 We therefore carried out further analysis respecifying the model in line with the regression equations. The result was an increase in the potential savings by around £28m (gross of the 20% downward adjustment.).

3.57 On the matter of the use of the appropriate benchmark, we believe that the fact that there are many observations forming the frontier mitigates the problem of relying on a few observations, which may be outliers, especially for the smaller strata where a majority of the offices are found to be "efficient". However, for the strata containing larger numbers there is a potential problem. We therefore carried out a sensitivity analysis omitting all observations with a super efficiency score of 1.10 or more. This reduced the potential savings by £40 million.

3.58 The net effect of these adjustments is a result that is consistent with our initial conclusions.

4 Final conclusions

Summary response to Oxera

4.1 Oxera has identified a number of valid improvements to our internal benchmarking. Where the points raised have merit, we have incorporated them into our models. The main issues that we have considered further include:

- **Issue 1:** Not taking into account the sorting costs associated with delivered mail in mail centre costs.
- **Issue 2:** Inconsistency between the econometric specification and our DEA work.
- **Issue 3:** Focusing entirely on the half-normal results in the SFA.
- **Issue 4:** Retaining variables in the DEA that are not statistically significant in the DFA or SFA analysis.

4.2 However, other suggestions appear to be less well founded. These suggestions have not been included within our analysis. These issues include:

- **Issue 5:** Adding delivered volume to the main volume measure.
- **Issue 6:** Deducing decreasing returns to scale throughout the size range for mail centres.
- **Issue 7:** Adopting a translog functional form for the delivery offices.
- **Issue 8:** Adopting a top decile benchmark for stochastic frontier analysis.
- **Issue 9:** Using a truncated normal distribution for SFA.

4.3 There is a third type of comment for which, whilst Oxera's arguments may have some technical merit, its "solution" would not lead to more accurate estimates of the potential for efficiency improvement. This includes:

- **Issue 10:** Not taking sufficient account of outliers (that is super-efficient offices) in the DEA of delivery offices.
- **Issue 11:** Adopting a VRS specification for the mail centre DEA.

4.4 The impact of the first four points (i.e. the ones we have incorporated into our analysis) are summarised below:

- **Issue 1:** The effect of taking account of the sorting costs associated with delivered mail in mail centres is to reduce our estimate of the potential savings from mail centres by £2.2 million.
- **Issue 2:** The effect of revising our DEA work to remove inconsistencies between the original specification and the results of our econometric modeling is that the efficiency estimates produced by DEA for the delivery network increase by £23m. However, if we also take on board issue 10 by eliminating super-efficient offices from the analysis the net effect is to reduce estimated potential savings by £10m.
- **Issue 3:** The half-normal distribution proves to be the only viable distribution for mail centres; this is true for our analysis and for Oxera's. For delivery offices, another distributional form, the exponential, can be used. The exponential distribution is not often used in stochastic frontier analysis, perhaps in part because its properties are not well established. As a sensitivity test, we have given the results of the exponential distribution for the inefficiency of delivery offices a 50% weighting in our assessment of cost savings. If this lower case were adopted, then this would decrease our original estimate by £43.5 million to £219.5 million.
- **Point 4:** If we omit from DEA those variables, which are not significant in our preferred regression equations for mail centres, the estimated potential savings under constant returns to scale rises by £46 million (for mail centres). If we adopt the suggestion (i.e. issue 11) to use variable returns to scale, however, the potential cost savings for mail centres are reduced by £50m. However, simulations of the effects of employing the VRS formulations suggest that the resultant estimates are very imprecise and contain a strong downward bias. In consequence, we would discount these results strongly.

Summary response to CWU

4.5 The CWU believed that the internal benchmarking analysis was flawed because it failed to recognise the need for investment to achieve the efficiency savings and because it failed to take account of some factors that would influence the performance of different offices (e.g. staff working beyond their contractual requirements and different technology and facilities in offices).

4.6 The CWU is incorrect. The internal benchmarking analysis controls for the current level of technology by unit and does not assume any change in the efficiency frontier, so all estimated improvements are based on the currently available technology in a mail centre or delivery office without the need for investment. In addition, we worked with Royal Mail to determine the principal factors that would influence the performance of different offices, and as such believe the models to be well specified.

LECG final conclusions

4.7 In response to Oxera's expressed concerns, we have amended a number of our models. With respect to mail centres, our econometric, but not DEA, models produce slightly lower estimates than Oxera's but on delivery offices, our estimates are significantly higher. We have accepted Oxera's points where we think they are valid. For the others we have explained why we disagree.

4.8 Our original and final results for delivery offices, together with the cost savings computed by Oxera, are presented in the table below.

Table 24: Delivery office final conclusions, £m

	LECG original estimates	Oxera estimates	LECG Revised estimates
DFA	271	n.a.	271
DEA	309	130–170	298*
SFA	263	141–151	219–258
Decile benchmark for this alternative SFA model	Not considered	83–89	Disagree with Oxera

Source: For LECG: Own calculations. For Oxera DFA and SFA: OER, table 3 page iii. For Oxera DEA: ODR, page iv. Notes: * taking out irrelevant variables and omitting super efficient offices.

4.9 Our original and final results for mail centres, together with the cost savings computed by Oxera are presented in the table below.

Table 25: Mail centre conclusions

	LECG original estimates	Oxera estimates	LECG Revised estimates
DFA	106	64–134	98–104
DEA	104	50–70	137–144
SFA	108	107	98–107
Decile benchmark for this alternative SFA model	Not considered	67	Disagree with Oxera
Additional savings from diseconomies of scale	50	0	50*

Source: For LECG: Own calculations. For Oxera DFA and SFA: OER, table 2 page ii. For Oxera DEA: ODR, page iv. Notes: * already incorporated into DEA.

Mail centre conclusions

4.10 The exercise that we have carried out to estimate the scale of potential efficiency savings within mail centres has been based on Royal Mail data, using cost drivers that Royal Mail has agreed to be relevant and which collectively explain well over 90% of cost variation. There is a high correlation not just between the overall results of the different models, but also between the rankings of mail centres by efficiency scores that each produces. The models have been tested for sensitivity to key assumptions and have proved robust.

4.11 We have scaled back our estimates by 15% of the savings implied by the raw DEA and DFA analysis to allow for random components in the residual error terms. We have updated our results for Oxera's comments, where appropriate.

4.12 The revisited analysis still indicates that savings of the order of £100m are achievable simply by applying existing best practices within the mail centre network. In the longer term, we expect that the diseconomies of scale of mail centres could be redressed. This would increase the scope for further efficiencies by up to £50m.

Delivery office conclusions

4.13 The exercise that we have carried out to estimate the scale of potential efficiency savings within delivery offices has been based on Royal Mail data, using cost drivers that Royal Mail has agreed to be relevant and which collectively explain over 90% of cost variation. There is a high correlation not just between the overall results of the different models that we have applied, but also between the

rankings of delivery offices by efficiency scores that each produces. The models have been tested for sensitivity to key assumptions and have proved robust.

4.14 We have responded to Royal Mail's concerns over data quality by omitting delivery offices for which it believed the data was not robust; and we have dealt only with total labour costs in response to Royal Mail's concerns about data quality for disaggregated cost figures. We have scaled back by 20% the savings implied by the raw DEA and DFA analysis to allow for random components in the residual error terms. We have updated our results for Oxera's comments, where appropriate.

4.15 The analysis indicates that savings in the range £220m to £300m are achievable simply by applying existing best practices within the delivery office network. For the reasons given above, we believe this figure to be conservative. We have in fact excluded those delivery offices that Royal Mail indicated as having poor data quality from the analysis; we have adopted a conservative benchmark (the top 10% of delivery offices for DFA and DEA), and we have applied a 20% adjustment factor to DFA and DEA.

4.16 The upper end of this range is consistent with the level of savings derived under the DEA technique after applying a 20% discount. The DEA score is somewhat higher, but it should be remembered that this estimate is based on some delivery offices that are likely to be outliers, and so will set unattainable benchmarks for delivery offices having the very low cost outliers as targets. Accordingly, we believe that the DEA value should be treated as an upper limit rather than a point estimate.

4.17 The lower end of the range is based on the average between the half-normal and the exponential inefficiency estimates. As noted above, we believe that this estimate to be extremely conservative.

Implied efficiency estimates

4.18 Royal Mail indicated to us that only labour costs could be allocated to mail centres and delivery centres with any degree of accuracy. Consequently, our analysis is limited to labour costs. The impact of this is that any scope for efficiency will be underestimated (i.e. it will exclude the scope to reduce vehicle, property and overhead costs).

4.19 Delivery office labour costs were £2,056m in 2003/04. A cost saving of between £220m and £300m is equivalent to a 10.7% and 14.6% reduction in total delivery labour costs. Mail centre labour costs were £1,341m in 2003/04[86]. A cost saving of £150m (i.e. including diseconomies of scale) is equivalent to an 11.2% reduction in mail centre labour costs. Excluding longer-term diseconomies of scale would suggest costs savings of 7.5%.

4.20 Our initial findings were converted into an efficiency cost trend, the level of which depended on the period over which the assumed efficiencies could be achieved. The table below presents implied cost trends for different time periods:

Table 26: Internal benchmarking RUOE trends: final conclusions including diseconomies of scale

Time period	Annual rate of improvement
3 years	3.2% to 4.6%
4 years	2.4% to 3.5%
5 years	2.0% to 2.8%

Source: LECG analysis. The cost trend relates only to mail centre and delivery office labour costs and reflects savings in constant volume and constant mix terms. Including diseconomies of scale.

4.21 Our final conclusions, including diseconomies of scale, are that over a four-year period, savings of between 2.4% to 3.5% per year might be achieved. Expressed over a lightly less challenging period of five years, savings of between 2.0% and 2.8% per year might be achieved. These rates were stated in constant volume and constant mix terms.

4.22 If diseconomies of scale were excluded from our analysis, the implied cost trends would be as follows:

[86] Labour costs are those provided by RM for the purpose of LECG's internal benchmarking analysis

LECG

Table 27: Internal benchmarking RUOE trends: final conclusions excluding diseconomies of scale

Time period	Annual rate of improvement
3 years	3.2% to 4.1%
4 years	2.4% to 3.1%
5 years	2.0% to 2.5%

Source: LECG analysis. The cost trend relates only to mail centre and delivery office labour costs and reflects savings in constant volume and constant mix terms. Excluding diseconomies of scale.

4.23 Our final conclusions, excluding diseconomies of scale, are that over a four-year period, savings of between 2.4% to 3.1% per year might be achieved. Expressed over a lightly less challenging period of five years, savings of between 2.0% and 2.5% per year might be achieved. These rates were stated in constant volume and constant mix terms.