Measuring the efficiency levels of companies operating in the European postal sector: a nonparametric approach

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Preface

This thesis was written in the second year of the Master Management, Economics and Consumer Studies at Wageningen University, The Netherlands. The research was done under supervision of dr. ir. Frederic Ang, who is part of the Business Economics Group (BEC). This process started in September 2019 and finished in February 2020.

The aim of this thesis was to analyze the efficiency levels of companies operating in the European postal sector, to indicate where improvements could be made. A comparison between the efficiency levels of private- and state-owned companies was of particular interest. The data was also plotted against time to investigate trends in the development of the efficiency levels.

I would like to thank Frederic Ang for his supervision, as I appreciate the valuable input I got from our meetings. I would also like to thank my peers for their support during this process.

Barneveld, February 2020

Robin Kamphorst

Abstract

The aim of this study was to analyze the efficiency levels of companies operating in the European postal sector, to indicate where improvements could be made. The rationale of this study was to investigate whether the postal sector could live up to the European Commission's expectations. A comparison between the efficiency levels of private- and state-owned companies was of particular interest. The data was also plotted against time to investigate trends in the development of the efficiency levels.

Data of 25 companies was collected, of which 10 were private- and 15 were state-owned. Firstly, the most current efficiency levels were measured by using Data Envelopment Analysis (DEA) with the data of 2018 (retrieved from balance sheets and P&L statements). Secondly, independent sample T-tests were used to investigate whether a difference existed between the efficiency levels of private- and state-owned companies. Thirdly, several trend analyses were done, using simple- and multiple regression, to investigate the development of the efficiency levels over time.

The average efficiency score for the entire sample was 0.555 or 55.5%. No difference was found between the efficiency scores of private- and state-owned companies for 2018, and neither for the 5-year period between 2014 and 2018. The hypothesis that "private companies are more efficient than state-owned companies" was therefore rejected. No trend was found for the private- or state-owned companies for the 5-year period between 2014 and 2018. However, for the same 5-year period, an average increase in efficiency of 1.4% per year was found for the European postal sector overall.

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1. Introduction

1.1 Background

In 1993, a green paper was published by the Commission of the European Communities (1993) indicating their objectives for the European postal sector. The focus of this paper was particularly on the development of the single market for postal services. During a 15-year period following the publication of this green paper, three postal directives were adopted by the EU to realize the objectives.

The stated purpose of the postal directives was to "complete the internal market for postal services and to ensure, through an appropriate regulatory framework, that efficient, reliable and good-quality postal services are available throughout the European Union to all its citizens at affordable prices" (Eurostat, 2009).

These directives described and resulted in the provision of universal postal services by all EU members and the gradual opening of the European postal market to competition (European Commission, n.d.; ITA Consulting & WIK-Consult, 2009). The 31st December 2010 was the deadline for the full opening of the market (except for 11 EU members that received two extra years of time), as described in the third directive (ITA Consulting & WIK-Consult, 2009).

Some member states even went a step further and privatized their national postal service. The Netherlands privatized PTT Post (currently PostNL) in 1989, Portugal privatized CTT Correios in 1991, Germany privatized Deutsche Post in 2000 and the UK fully privatized Royal Mail in 2015.

Postal services play an important role in the EU market. The postal sector provides about 1.8 million jobs (European Commission, 2019a) and other sectors, such as e-commerce, insurance and banking, are highly dependent on the postal sector. The EU commission finds it very important to protect effective competition in this sector and "it is also important in reaching the Europe 2020 goals for sustainable growth in a resource-efficient and more competitive economy" (European Commission, 2012).

The total size of the postal market has grown from 84 billion euros in 2013 to 90 billion euros in 2016. Letter post accounted for 47% of total revenue in 2013, which decreased to 43% in 2016. This means that the share of parcels increased from 53% in 2013 to 58% in 2016 (Copenhagen Economics, 2018).

Ecommerce Europe (2018) estimated that the European B2C e-commerce market reached a turnover of 534 billion euros in 2017, as opposed to 307 billion euros in 2013 (AAGR of nearly 15%). This growth in domestic and cross-border e-commerce is driving the growth of the European parcel market (ITA Consulting & WIK-Consult, 2009).

At the same time, the growth in digital communications is partly the reason for the decreasing amount of letter traffic in many EU countries (European Commission, 2019b). Letter post volume decreased from 73.4 billion items in 2013 to 64.6 billion items in 2016 (AAGR of -4.2%). The increasing amount of parcel deliveries and the decreasing amount of letter traffic are two of the main trends in the European postal sector at this moment (Copenhagen Economics, 2018).

1.2 Problem statement

Efficiency is an important aspect within the European postal market for several reasons. The growth of the postal market is largely driven by the increasing number of parcels being sent, which is in turn driven by the increasing size of e-commerce. Increasing efficiency is therefore paramount for companies in this market to deal with the increasing workload and to be able to remain competitive. Also, efficient postal services are part of the goals set by the postal directives (Eurostat, 2009). Moreover, efficiency is once again highlighted as an important aspect in the Europe 2020 goals for sustainable growth "in a resource-efficient and more competitive economy" (European Commission, 2012).

The postal directives have also led to the liberalization of the entire European postal market, which allowed competition to enter the market. Some countries have even privatized their formerly state-owned companies. As efficiency gains are often mentioned alongside privatization (Pack, 1987; Pack, 1989; Carter, 2013; Cato Institute, 2016), a comparison between the efficiency levels of private- and state-owned companies in the postal sector could be insightful for governments and other policy makers.

Tochkov (2015) already measured efficiency in the European postal sector, but focused on Eastern Europe and used data from 1994 to 2009. Iturralde and Quirós (2008) analyzed the productive change in the European postal sector using the Malmquist index, but this only resulted in an average measure of efficiency between 1999 and 2003 and did not highlight the changes per year. Also, Quirós (2011) examined "the relationship between the introduction of competition in the European Union postal markets from the end of the 1990s and the productive change that has occurred in the sector".

This shows that research in the area of efficiency (in parts of the European postal market) exists, but the results are outdated (even before the full opening of the postal market) and none of the studies investigated possible differences between private- and state-owned companies.

As not much is known about the current level(s) of efficiency, this research paper will fill the knowledge gap by performing an efficiency analysis for companies operating in the European postal market. Besides the general analysis of the market, a comparison between private- and state-owned companies will also be made to see if differences exist. The results of this research are not only useful for policy makers, but also for managers and shareholders of these companies, as this

research will indicate where these companies might be able to improve their level of efficiency and indirectly generate a higher profit.

1.3 Objectives

The main objective of this study is to analyze the efficiency levels of companies operating in the European postal sector, which will indicate where improvements can be made. The efficiency levels will be measured by applying Data Envelopment Analysis (DEA). A comparison between the efficiency levels of state-owned and private companies will be of particular interest. The data will also be plotted against time to reveal whether any trend exists in the development of the efficiency levels.

This study will answer the following questions:

- How efficient are the companies operating in the European postal sector?
- Is there a difference between the efficiency levels of private- and state-owned companies?
- What is the trend in the development of the efficiency levels?

1.4 Report outline

Chapter 2 discusses the methods that were used and the choices that were made specifically for this study. Chapter 2.1 explains Data Envelopment Analysis (DEA), which was the foundation of this study, and describes how it was applied. Chapter 2.2 describes how independent sample T-tests were done to compare the efficiency scores of private- and state-owned companies. Chapter 2.3 describes how the trend analysis was done to investigate the development of these efficiency scores. Chapter 3 describes how the data for this study was collected. Chapter 4 describes the results of this study: Chapter 4.1 describes the DEA results of all postal companies for 2018, Chapter 4.2 compares the private- and state-owned companies and Chapter 4.3 describes the trend analysis. Chapter 5 provides a discussion of the methods and the results. Lastly, Chapter 6 presents the conclusions of this study.

2. Research methods

2.1 Data Envelopment Analysis

2.1.1 General description of DEA

To calculate the efficiency scores for the companies in the European postal sector, data envelopment analysis (DEA) was used. DEA relates all inputs to all outputs for a company (Cooper, Seiford & Tone, 2006), which means that it gives a complete view of the efficiency level of a company, as opposed to partial measures (such as energy use per square meter or kg of feed per cow).

The first step is to define the input and output for the companies in the sample. For simplicity, only one input and one output are used in Figure 1, although it is possible to combine multiple inputs and outputs in DEA. The second step is to choose for constant returns to scale (CRS) or variable returns to scale (VRS), whichever is most applicable to the companies in the sample. CRS assumes that a change in input results in a proportional change in output, whereas VRS assumes that the production technology may exhibit increasing, constant and decreasing returns to scale for different companies at the same time (Huguenin, 2012; FAO, n.d.). The last step is to choose for an input- or output-oriented approach. An input-oriented approach seeks to minimize the input for a given level of output, whereas an output-oriented approach seeks to maximize the output for a given level of input. This choice depends on the objectives of the companies in the sample.

Figure 1 will be used as a reference point to further explain the concept behind DEA. As depicted, companies A, B and C are on the efficient frontier. These companies are deemed 100% efficient (under VRS). Companies D, E and F are inefficient, because they are using relatively more of the input than any of the other companies to produce a given level of output.

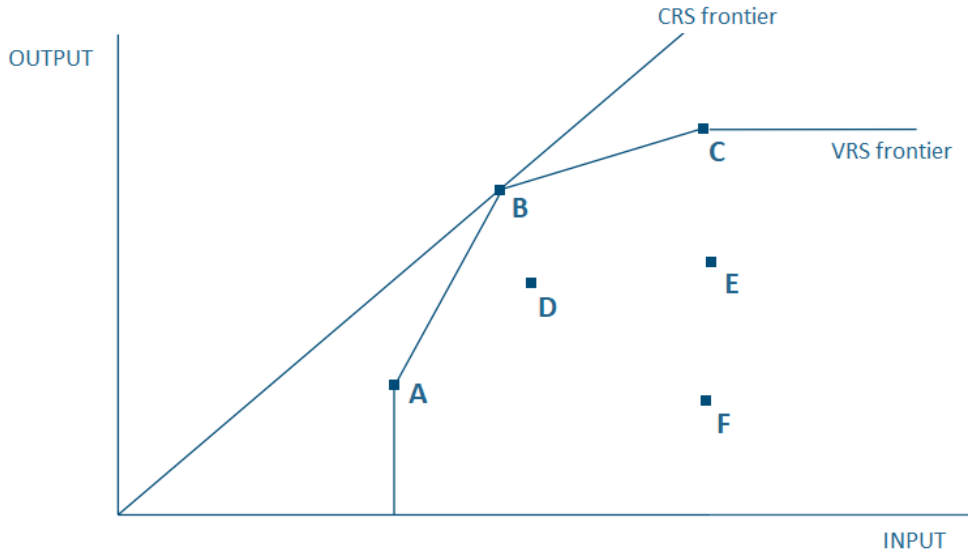

Figure 1. An example of a data envelopment analysis efficient frontier with input on the x-axis and output on the y-axis. The frontier for both the constant- and variable returns to scale (CRS and VRS respectively) has been drawn. Letters A-F represent the position of companies w.r.t. the frontier, thus showing their efficiency level.

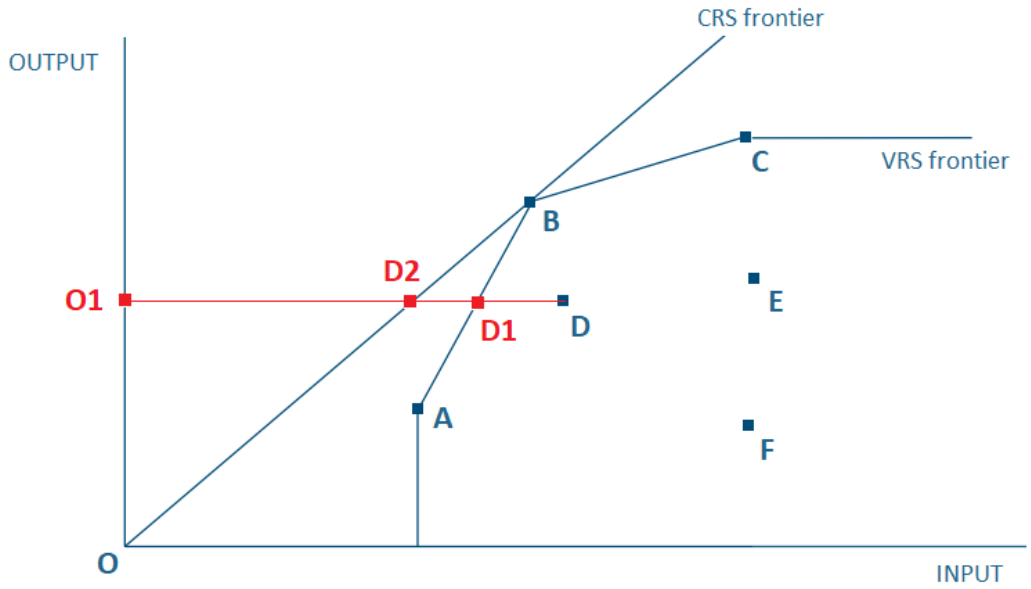

Figure 2. An example of a data envelopment analysis efficient frontier (extension of Figure 1). An input-oriented approach is used.

One of the inefficient companies, company D, is used as an example in Figure 2. Company D is inefficient because it could reduce its input while remaining at the same level of output. The horizontal red line in Figure 2 is used to depict an input-oriented approach, as it seeks to minimize the input of a company for a given level of output. Company D could move itself towards position D1, which is located on the efficient frontier under VRS.

The technical efficiency for company D under variable returns to scale (VRS):
θ TEvrs = O1D1 / O1D **[1]**

If constant returns to scale (CRS) were assumed, company D would still be inefficient at position D1. Company D would have to move further to position D2 to end up on the CRS frontier.

The technical efficiency for company D under constant returns to scale (CRS):
θ TEcrs = O1D2 / O1D **[2]**

The difference between the technical efficiency under VRS and CRS is called 'scale efficiency'.
At position D1, company D will not have reached its optimal size yet. To improve their scale efficiency, company D should increase their output. This would work because they currently operate under increasing returns to scale, meaning that an increase in output by one percent would result in a less than one percent increase in input (and therefore a decrease in average input(s) used) (Huguenin, 2012).

The scale efficiency for company D:
SE = O1D2 / O1D1 = θ TEcrs / θ TEvrs **[3]**

The θ is the ratio (a score) that represents the efficiency level of a company and is always between 0 and 1. The companies on the efficient frontier, which are deemed 100% efficient, therefore have an efficiency score of 1 (θ = 1). A company is technically efficient when it can produce the same level of output with fewer inputs than its competitors (Hamzah & See, 2019). For example, a company with a score of θ = 0.60 should reduce its inputs by 40%. The target amount of input for an inefficient company is determined by the relevant peer companies (the companies on the efficient frontier). If company D were to move to position D1, located on line segment AB, its peer companies would be company A and B. These peer companies receive weights, denoted as λ, which indicate how much input of company A and B should be used by company D (to reach θ = 1).

The representation of the LP problem depends on the specification of the DEA model. For this research, the input-oriented BCC model was chosen (motivation in Chapter 2.1.2). The efficiency score (θ) was calculated by solving the following problem (Cooper, Seiford & Tone, 2006):

$$(BCC_o) \qquad \min_{\theta,\boldsymbol{\lambda}} \ \theta \qquad \textbf{[4.1]}$$

$$\text{subject to} \qquad \theta \boldsymbol{x}_o - X\boldsymbol{\lambda} \geq \mathbf{0} \qquad \textbf{[4.2]}$$

$$Y\boldsymbol{\lambda} \geq \boldsymbol{y}_o \qquad \textbf{[4.3]}$$

$$\boldsymbol{e\lambda} = 1 \qquad \textbf{[4.4]}$$

$$\boldsymbol{\lambda} \geq \mathbf{0} \qquad \textbf{[4.5]}$$

where X and Y are matrices of inputs and outputs for all companies, respectively. x_o and y_o represent the inputs and outputs of the company for which the efficiency score (θ) is being measured. Finally, the λ is a vector of parameters that represents the (input and output) weights. The sum of these weights must be exactly one for each company (eλ =1). This is called the convexity constraint.

2.1.2 Specification of the DEA model

This section will elaborate on the choices that were made particularly for this research.

To allow for the analysis of postal companies throughout Europe within a six-month time frame, readily available data was used to construct the DEA model. Inputs and outputs were therefore retrieved from balance sheets and P&L statements.

The main objectives of postal companies are to deliver mail and parcels. However, data pertaining to the amount of delivered mail and parcels was not found for most of the companies (in the sample). Turnover was therefore chosen as an output instead, as it equals the amount of sales (mail, parcels, etc.) multiplied by a price. In order to fairly compare the turnover of companies from different countries, Price Level Indices (PLIs) were retrieved from Eurostat (2019) and applied to the data. The price levels for the category 'communication' were used, as this category includes postal services. The Netherlands was arbitrarily used as the base country (=100) to convert the turnover of all companies from different countries to an equal standard (Appendix Table A).

The chosen inputs were based on the traditional factors of production, namely land, labor and capital. Land itself is not appropriate for postal companies, but a suitable substitute would be the buildings and vehicles that they deploy. Therefore, fixed assets were chosen in its place. Unfortunately, no suitable price indices were found to convert the monetary values of the fixed assets to a standardized amount. The number of employees was naturally chosen to represent labor and capital was represented by material costs.

However, the latter was eventually excluded from the DEA model. The main reason for this decision was a lack of data for most of the companies in the sample, as only 15 companies could have been used if material costs were included. As such a decrease in the sample size would harm the credibility of the analysis, this did not seem like a good choice. Still, two DEA models were run with these 15 companies to see whether the exclusion of material costs would significantly affect the results. Judging by the efficiency scores (Appendix Table B), this was not the case. For 10 out of 15 companies, the efficiency scores remained the same. There were some differences for the other companies, but it should be noted that the costs of the materials were not standardized, as no Price Level Index (PLI) was applied yet. If material costs were included with such a conversion, the differences would have likely been even smaller.

Therefore, the production function was as follows:
y(turnover) = x(fixed assets, #employees) **[5]**

It was assumed that, in general, postal companies in Europe were not performing at their optimal scale. This is largely because of imperfect competition in Europe, as most countries deal with oligopolies in the postal market. Moreover, most companies have to deal with strict government regulations. These aspects make the VRS specification very suitable (Huguenin, 2012).

It was also assumed that postal companies seek to minimize their inputs for a given level of output, which is why an input-oriented approach was used. This means that postal companies seek to satisfy demand (in terms of mail, parcels, etc.) by deploying as few inputs as possible. For example, they would look for ways to deliver the parcels that are supplied by customers by carefully choosing the most efficient route (and thereby deploying as few vehicles and employees as possible).

To get an overview of the most current efficiency levels in the European postal market, the DEA model in Chapter 4.1 used data from 2018 for the inputs and outputs (Table 1).

Table 1. Inputs and output for the Data Envelopment Analysis (DEA) model of 2018.

Company name	Turnover[1]	Fixed assets	No. of employees
Bpost	3811443829	2187409000	34074
Bring Parcels	218083271	817000	129
Bulgarian Posts	174726391	58224447	10562
Ceska posta	1016128431	423929000	29961
Chronopost Portugal	54514541	3575883	840
CTT Correios	639150751	462388391	10843
CTT Expresso	94193292	17091359	521
Deutsche Post	86978506059	39850600000	547459
DHL Parcel UK	674614454	167985519	2914
Econt Express	188618671	14264723	550
GLS Romania	98504819	7257040	151
InPost	361882167	34407798	749
La Poste	19949758206	15054468000	214070
Latvijas Pasts	172978263	24598366	3948
Lietuvos Pastas	203740466	64755071	5177
Magyar Posta	1191232690	521919000	31156
Mondial Relay	302513459	19453006	656
Omniva	6070650	39663	128
Osterreichische Post	3397794405	1119925000	20545
Posti	2298281185	135048000	11688
PostNL	4064752000	913710000	37785
PostNord	2365460068	269056000	17663
Royal Mail	11261872127	7816124000	138873
Seur-Geopost	460099251	258004707	1969
Slovenska Posta	525997209	299498946	15000

[1] Turnover for 2018, adjusted for the Price Level Indices (PLIs) of the countries (Appendix Table A).

2.1.3 DEA models for T-tests and trend analyses

Additional DEA models were used to calculate the efficiency scores over the 5-year period between 2014 and 2018 for the analyses in Chapter 4.2 (T-tests) and 4.3 (trend analyses).The data for these models was adjusted for inflation based on figures from Eurostat (2018), after which the data was also adjusted for the Price Level Indices of the countries (as also done for the data in Chapter 4.1).

The DEA model of which the results were used for the first T-test (Figure 6) was the same as the DEA model that was used to measure the efficiency scores for 2018 in Chapter 4.1.

Additional DEA models were used for the second T-test (Figure 7), which tested the robustness of the results by increasing the range of the data from one year (2018) to five years (2014-2018). This was done by running DEA models for each year between 2014 and 2018, shifting the reference frontier each time. This means that “the firms determining the technology”, as explained by Bogetoft and Otto (2019), consisted of input- and output data of all 25 companies for that particular year. Five different DEA models were therefore run with the ‘Benchmarking’ package in R.

The same five DEA models for the 5-year period between 2014 and 2018 were used for the trend analyses in Chapter 4.3.1. Because the reference frontier shifted for each year, these trends only indicate a relative change in the efficiency scores (relative to other companies in the sample). It was therefore not possible to identify whether a change in the efficiency score of a company was a result of a change in the input/output ratio of the company itself or a change in the input/output ratio of other companies in the sample.

To overcome this limitation and get more insight, five different DEA models were used for Chapter 4.3.2. Before, the reference frontier shifted for each model, meaning that the reference frontier was determined by the performance of the companies for that particular year. Now, the reference frontier was the same for each model (representing one of the five years). The reference frontier, or "firms determining the technology", now consisted of all observations (125 in total, 5x25 companies). This procedure enabled the measurement of the absolute changes in the efficiency scores of a company, because the reference point was the same each time. A company was therefore compared with the same observation (same efficient peer with the same input/output ratio) for each year between 2014 and 2018. These results (Table 7) therefore show how much of the change in the efficiency score of a company was attributed to their own actions.

2.2 Independent sample T-tests

The second research question was posed to investigate whether there was a difference between the efficiency scores of private- and state-owned postal companies in Europe. To determine whether there was a significant difference, independent sample T-tests were conducted in R. The built-in t.test function was used for this purpose.

Before conducting the T-tests, the assumption of homogeneity of variance had to be tested. The built-in var.test function was used for this purpose, as this function conducts the necessary F-test to compare the variances of two groups (private- and state-owned companies). The most important output of this function was an F-statistic along with a p-value. Equality of variances was assumed if the null hypothesis was not rejected at the critical 5% level ($p > 0.05$) (Laerd statistics, 2018). A T-test gives slightly different results when the variances of two groups are not equal, which is why the F-test (var.test) was necessary. The parameters of the t.test function were therefore adapted to fit the results of the var.test function. The observations were also tested for normality using a Q-Q plot.

Similar to an F-test, the most important output of a T-test was a T-value along with a p-value. The T-value is most useful in case of large sample sizes (high degrees of freedom), which is why its predictive power was not as strong for this research (as the groups contained only 10 and 15 companies each). Therefore, the p-value was used to determine whether differences existed between the two groups (at the critical 5% level). The null hypothesis for the T-tests was that there was no difference between the two groups (private- and state-owned postal companies). If the p-value was smaller than 0.05, the null hypothesis was rejected. If the p-value was larger than 0.05, the null hypothesis was not rejected.

The T-tests for the average efficiency scores of 2018 had 10 and 15 observations for the private- and state-owned companies respectively. The T-tests for the average efficiency scores over the 5-year period (2014-2018) had 50 and 75 observations.

As described by Carter (2013), it is assumed that privatization is a step towards a free market with more competition and should therefore lead to an increase in efficiency. Therefore, the T-tests will also be used to test the following hypothesis:

HYPOTHESIS: “Private companies are more efficient than state-owned companies”.

2.3 Trend analysis

The purpose of the third research question was to investigate the development of the efficiency levels over time. The chosen time frame was 2014 to 2018 (5 years). Regression analysis was used for this purpose, as it enables investigating the relationship between an independent variable and a dependent variable (or multiple variables). This analysis was also done in R.

Simple regression was used for all but one of the trend analyses (standard formula in equation 6).

$$Y_i = ß_0 + ß_1 X_i + \varepsilon_i \qquad \textbf{[6]}$$

For this study, the independent variable 'year' represented the time between 2014 and 2018. This variable therefore consisted of numbers from 1 to 5, representing the years 2014 to 2018. The dependent variable was the efficiency score of a company in a particular year (equation 6.1).

$$\text{eff\_score}_i = ß_0 + ß_1 \, \text{year}_i + \varepsilon_i \quad \textbf{[6.1]}$$

For one of the analyses, multiple regression was used instead of simple regression (Figure 10). A dummy variable 'dummy_private' was introduced to measure the difference between the efficiency scores of private- and state-owned companies. Observations therefore belonged to either state-owned companies (dummy = 0, the reference group) or private companies (dummy = 1). The variable 'year' in this model represented the efficiency change between year 'x' and year 'x+1' (equation 6.2).

$$\text{eff\_score}_i = ß_0 + ß_1 \, \text{year}_i + ß_2 \, \text{dummy\_private}_i + \varepsilon_i \quad \textbf{[6.2]}$$

The data was tested for linearity, normality and homoscedasticity, as these are requirements for a (simple) regression analysis. A Q-Q plot of the residuals was used to find out whether the errors were normally distributed (normality) and a scatterplot, with predicted values on the X-axis and standardized residuals on the Y-axis, was used to check the homoscedasticity assumption. Linearity could be assumed once the criteria for normality and homoscedasticity were met.

The strength of the relationship between the independent- and dependent variable was indicated by the Pearson Correlation (R), which ranges from -1 to 1. The closer it is to 1, the stronger the relationship. If R is negative, the variables move in opposite directions (i.e. the dependent variables decreases when the independent variable increases and vice versa) and the strength is the same. The R-squared indicated how much of the variance in the dependent variable was explained by the independent variable(s), which shows the fit of the model (PennState, 2018).

The null hypothesis for the regression analysis was that there was no relationship between the dependent- and independent variable (Filho, 2013), which was tested at the critical 5% level ($\alpha = 0.05$). If the p-value was smaller than 0.05, the null hypothesis was rejected, meaning that a (significant) trend was found.

3. Data

Several reports, either commissioned by or directly from the European Commission, were used to get a view of the companies operating in the European postal market. A report from Copenhagen Economics (2018) listed all of the universal service providers (USPs) for the 31 countries from the EU, EEA and CH area. This list therefore included a wide range of companies from different countries, classified by region (Northern-, Eastern-, Southern- or Western Europe). Another useful report was one from WIK-Consult (2019a), which contained a lot of information about the postal services in the EU member states. A list of the top 3 parcel operators per country was particularly useful. Most of the other sources listed the same companies. Finally, a longlist of potential companies was developed.

To allow for a thorough analysis of postal companies throughout Europe within a six month time frame, readily available data had to be used. It was therefore decided that the database of Orbis (2019) would be used, as it contains a lot of information about millions of companies. Orbis was particularly suitable for this study because it presents financial reports in a standardized way. The data for the DEA model, the inputs and output, was retrieved from the balance sheets and P&L statements found in Orbis.

The potential companies on the longlist were all sought for in the database in order to end up with a shortlist of companies for the final sample. Unfortunately, not every company was found. As Orbis presents the data of companies from the past 10 years, the time frame for this research was 2009-2018. A lot of this data was missing for several companies, which meant that they had to be removed from the list as well. If only a few years at the beginning were missing, e.g. 2011-2018 instead of 2009-2018, this was not a big problem, as the trend analysis could still be done. The most important data was that for 2018, as this was chosen to be the base year for the DEA model (the general efficiency of the companies, which is RQ #1).

The sample consisted of 36 companies after looking for the data in Orbis. However, the data for some of the inputs and output (for the DEA model) was not always reported for all 10 years. Therefore, the companies with missing data for the inputs and output in 2018 had to be removed from the sample in order to answer the first research question. After the companies with missing data for turnover, fixed assets and employees were removed, the sample consisted of 27 companies. Two more companies were later removed because there was missing data for the trend analysis (2014-2018). The final sample therefore consisted of 25 companies. The sample was divided in two groups, namely private- and state-owned companies. In the final sample, ten companies were private and fifteen were state-owned (Table 2).

Table 2. Information pertaining to the 25 companies in the sample.

Company name	Country	EU region[1]	Ownership
Bpost	Belgium	West	State
Bring Parcels	Sweden	North	State
Bulgarian Posts	Bulgaria	East	State
Ceska posta	Czech republic	East	State
Chronopost Portugal	Portugal	South	State
CTT Correios	Portugal	South	Private
CTT Expresso	Portugal	South	Private
Deutsche Post	Germany	West	Private
DHL Parcel UK	United Kingdom	North	Private
Econt Express	Bulgaria	East	Private
GLS Romania	Romania	East	Private
InPost	Poland	East	Private
La Poste	France	West	State
Latvijas Pasts	Latvia	North	State
Lietuvos Pastas	Lithuania	North	State
Magyar Posta	Hungary	East	State
Mondial Relay	France	West	Private
Omniva	Latvia	North	State
Osterreichische Post	Austria	West	State
Posti	Finland	North	State
PostNL	The Netherlands	West	Private
PostNord	Sweden	North	State
Royal Mail	United Kingdom	North	Private
Seur-Geopost	Spain	South	State
Slovenska Posta	Slovakia	East	State

[1] Regional classification is based on the United Nations country classification (UN M49).

4. Results

4.1 DEA results for all postal companies in 2018

The results of the Data Envelopment Analysis (DEA) model are shown in Table 3.

The efficient frontier was determined by 6 of the 25 companies, which is indicated by the companies with an efficiency score of 1. These companies therefore do not have any input slack. The definition of input slack (in this model) is the sum of radial and non-radial movement, which indicates the excess of an input for a company (i.e. the distance for a company to the efficient frontier). This means that a company can reduce its inputs by the given amount of slack and remain at the same level of output.

The average efficiency score for all companies was 0.555, or 55.5%. This means that on average, postal companies had an excess of 44.5% of used inputs. However, it is important to note that there were significant differences between the efficiency scores of the companies. For example, four inefficient companies operated at a level above 0.80, whereas three other companies operated at a level below 0.10. This wide range of extremes was further investigated in Chapter 4.2.

It can be observed from Table 3 that there was more slack in the fixed assets than in the number of employees for each of the inefficient companies in the sample. This result is discussed in Chapter 5.

Lambda weights indicate how an inefficient company could improve its efficiency score, as these weights describe how much of the inputs a company should use relative to its peers. By imitating these efficient peer companies, a given company should be able to reach the same level of efficiency. The peers for each company, along with their respective weights, are shown in Table 4. Bring Parcels, Deutsche Post, InPost, Omniva, Posti and PostNL are the efficient peer companies that determine the frontier. As shown, the weights for each company sum up to 1 (per row).

Table 3. Results of the input-oriented Data Envelopment Analysis (DEA) model under VRS. Ranked by efficiency score.

Company name	Efficiency	Actual fixed assets	Target fixed assets	Actual no. of employees	Target no. of employees	Fixed assets slack[2]	No. of employees slack
Bring Parcels	1.000	817000	-[1]	129	-		-
Deutsche Post	1.000	39850600000	-	547459	-	-	-
InPost	1.000	34407798	-	749	-	-	-
Omniva	1.000	39663	-	128	-	-	-
Posti	1.000	135048000	-	11688	-	-	-
PostNL	1.000	913710000	-	37785	-	-	-
Osterreichische Post	0.908	1119925000	650726522	20545	18645	41.9%	9.2%
DHL Parcel UK	0.863	167985519	50661391	2914	2516	69.8%	13.7%
GLS Romania	0.851	7257040	378570	151	128	94.8%	15.2%
Mondial Relay	0.806	19453006	15681213	656	529	19.4%	19.4%
PostNord	0.686	269056000	166555314	17663	12113	38.1%	31.4%
Seur-Geopost	0.662	258004707	39512421	1969	1304	84.7%	33.8%
Bpost	0.624	2187409000	844730679	34074	21262	61.4%	37.6%
La Poste	0.576	15054468000	8413700404	214070	123369	44.1%	42.4%
Royal Mail	0.552	7816124000	4311624995	138873	76607	44.8%	44.8%
CTT Expresso	0.246	17091359	362762	521	128	97.9%	75.4%
Econt Express	0.234	14264723	708969	550	129	95.0%	76.5%
CTT Correios	0.214	462388391	48818240	10843	2315	89.4%	78.6%
Magyar Posta	0.174	521919000	77511519	31156	5434	85.1%	82.6%
Chronopost Portugal	0.153	3575883	217281	840	128	93.9%	84.8%
Ceska posta	0.150	423929000	63413675	29961	4482	85.0%	85.0%
Slovenska Posta	0.116	299498946	34680353	15000	1737	88.4%	88.4%
Latvijas Pasts	0.033	24598366	651624	3948	129	97.4%	96.7%
Lietuvos Pastas	0.025	64755071	764413	5177	129	98.8%	97.5%
Bulgarian Posts	0.012	58224447	658033	10562	129	98.9%	98.8%
Average	0.555	2788981997	2226239234	45496	34766	57.2%	44.5%

[1] Indicates that the target values are the same as the actual values for the given input.

[2] The slack in this table is the sum of the radial and non-radial movement, indicating the excess of an input for a company (expressed in percentages).

Table 4. Lambda weights for all of the efficient peers (represented by columns).

Company name	Bring Parcels	Deutsche Post	InPost	Omniva	Posti	PostNL
Bpost	-[1]	0.018	-	-	0.982	-
Bring Parcels	1	-	-	-	-	-
Bulgarian Posts	0.795	-	-	0.205	-	-
Ceska posta	0.191	-	0.457	-	0.352	-
Chronopost Portugal	0.228	-	-	0.772	-	-
CTT Correios	-	-	0.857	-	0.143	-
CTT Expresso	0.416	-	-	0.584	-	-
Deutsche Post	-	1	-	-	-	-
DHL Parcel UK	-	-	0.838	-	0.162	-
Econt Express	0.861	-	-	0.139	-	-
GLS Romania	0.436	-	-	0.564	-	-
InPost	-	-	1	-	-	-
La Poste	-	0.208	-	-	0.792	-
Latvijas Pasts	0.787	-	-	0.213	-	-
Lietuvos Pastas	0.932	-	-	0.068	-	-
Magyar Posta	-	-	0.572	-	0.428	-
Mondial Relay	0.599	-	0.387	-	0.014	-
Omniva	-	-	-	1	-	-
Osterreichische Post	-	0.013	-	-	0.987	-
Posti	-	-	-	-	1	-
PostNL	-	-	-	-	-	1
PostNord	-	0.001	-	-	0.999	-
Royal Mail	-	0.094	-	-	0.356	0.550
Seur-Geopost	-	-	0.949	-	0.051	-
Slovenska Posta	0.316	-	0.576	-	0.108	-

[1] Indicates that the efficient company (in the column) is not a peer for the given company (in the row).

As an example, to show how Table 4 should be interpreted, Bpost would have to use 1.8% and 98.2% of the inputs of Deutsche Post and Posti respectively. This shows that Bpost should look at both of these companies to imitate how they operate in order to improve their own efficiency.

As shown, Posti is the most used peer for other companies, with a total count of twelve, whereas PostNL is only a peer for one other company (Royal Mail). However, this does not mean that Posti is more efficient than PostNL, as Posti and PostNL are both on the efficient frontier. This only shows that Posti is a more suitable peer for a lot of companies, which is determined by the position of the peer on the frontier in comparison to the other companies (Johnes & Yu, 2008).

4.2 Private- and state-owned postal companies

The purpose of the second research question was to investigate whether differences exist between private and state-owned postal companies in Europe. The DEA results of the previous section (Chapter 4.1) were used to explore this question.

Figure 3 and Figure 4 are bar charts that were created to visualize a part of the relevant data.

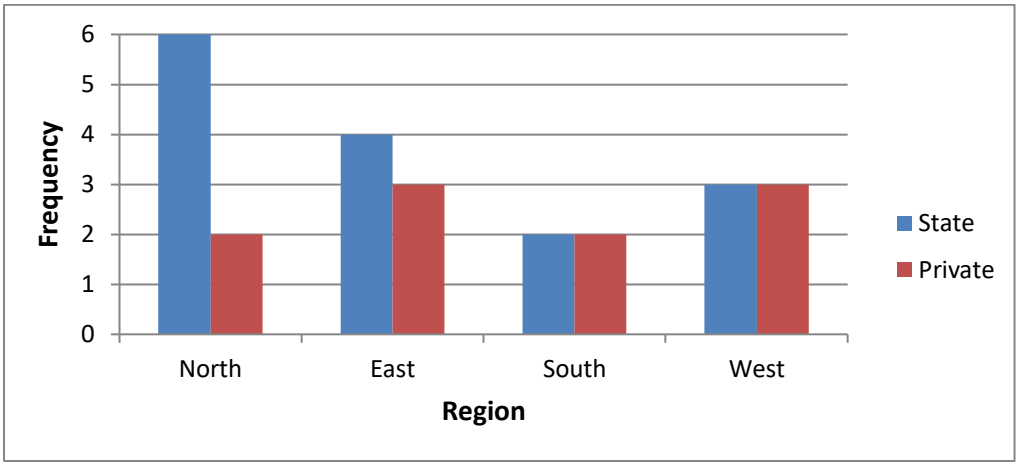

Figure 3. A bar chart that depicts the mix of private and state-owned companies per region.

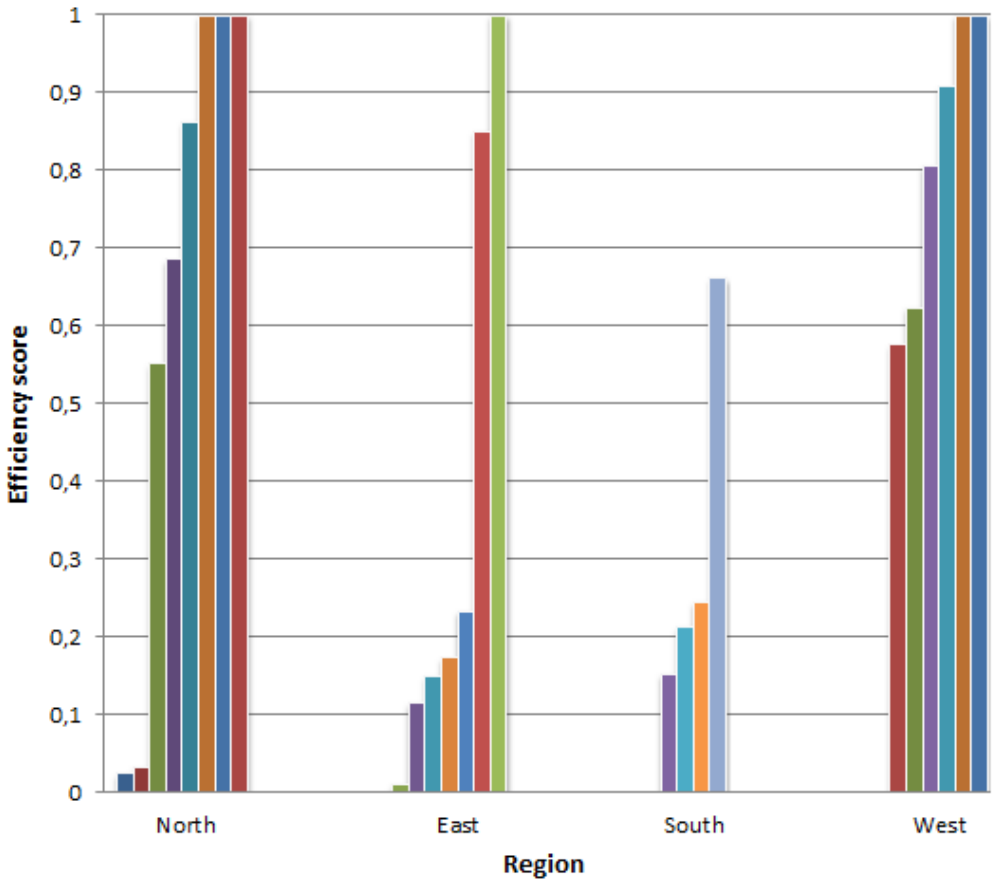

Figure 4. A bar chart that depicts the efficiency scores of the companies (y-axis) per region (x-axis) for 2018.

Judging by the results from Table 4, it seemed reasonable to investigate whether the EU region that a company belonged to had any influence on their efficiency score. The relevant data from the previous section was visualized to make this process easier (Figure 3 & Figure 4). These bar charts did not eliminate the suspicion that differences existed between the companies when they are grouped by region, as the Northern and Western regions generally had higher efficiency scores than the other two regions (judging by Figure 4). Before continuing to a comparison between private- and state-owned postal companies, a decision had to be made to either conduct T-tests per region or for all European companies at the same time.

It is evident from Figure 3 that the private and state-owned companies were not spread equally over the different regions. This is not an issue per se, but it makes it harder to draw conclusions from the data when the (already small) sample has to be divided into four groups, shrinking the sample size for the T-tests even further (as four different groups are used instead of one).

Multiple regression analysis was conducted to see if the suspicion had any statistical underpinning, which would ultimately determine the specification of the T-tests. The dependent variable was represented by the efficiency score and the independent variables were dummies for the EU regions (with the Northern region as the reference group).

```
Call:
lm(formula = eff_scores ~ dummy_east + dummy_south + dummy_west,
    data = model_data)

Residuals:
     Min       1Q   Median       3Q      Max
-0.61988 -0.19500 -0.07275  0.21812  0.63757

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)   0.6449     0.1208   5.337 2.72e-05 ***
dummy_east   -0.2824     0.1769  -1.597    0.125
dummy_south  -0.3261     0.2093  -1.558    0.134
dummy_west    0.1741     0.1846   0.943    0.356
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.3418 on 21 degrees of freedom
Multiple R-squared:  0.2825,    Adjusted R-squared:   0.18
F-statistic: 2.756 on 3 and 21 DF,  p-value: 0.0679
```

Figure 5. Descriptive statistics of the multiple regression analysis with the efficiency score as the dependent variable and dummies for the EU regions as independent variables (for 2018).

As shown in Figure 5, the adjusted R-squared of the multiple regression model was 0.18. This is a rather low score, which indicates that the model has little predictive power. Moreover, none of the dummy variables (EU regions) had a p-value that was low enough to reject the null hypothesis of no difference between the regions. For that to happen, the p-value for a region should be lower than 0.05 (the critical 5% level). As the p-values for the Eastern, Southern and Western regions were

0.125, 0.134 and 0.356 respectively, it could not be assumed that the region that a company belonged to had any influence on the efficiency score of the company.

It has to be noted that the sample size (25 companies) is relatively low for a regression model, meaning that it is hard to find significant effects of independent variables. The estimates of the coefficients do suggest that the Eastern and Southern regions have lower efficiency scores, but the sample size does not seem large enough to conclude that it is significant. Also, three out of four companies from the Southern region were based in Portugal, which does not reveal a lot about the actual effect (if any) of the entire region. Four observations are little (and therefore problematic) in any case.

As an effect of the EU region was not found, it was decided to compare the efficiency scores of private- and state-owned companies throughout Europe without dividing the companies into regions. An independent sample T-test was performed to compare the two groups (Figure 6).

```
        Two Sample t-test

data:  private_eff and state_eff
t = 1.332, df = 23, p-value = 0.1959
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -0.1117166  0.5157166
sample estimates:
mean of x mean of y
   0.6766    0.4746
```

Figure 6. Results from an independent sample T-test (or two sample T-test) that compared the means of the efficiency scores for private- and state-owned companies (private_eff and state_eff respectively) for 2018.

With an F-value of 1.384 and a p-value of 0.635 for the F-test, equal variances were assumed for the two groups. The independent sample T-test (or two sample T-test), of which the results are reported in Figure 6, compared the means of the efficiency scores for private- and state-owned companies for 2018. The means were 0.677 and 0.475 respectively. The null hypothesis of the T-test was that the difference between the means of the two groups was equal to zero. As shown in Figure 6, the p-value of the T-test was 0.196, which was not low enough to reject the null hypothesis at the critical 5% level ($p < 0.05$). Therefore, no difference was found between the efficiency scores of private- and state-owned companies for 2018 at the critical 5% level.

To test the robustness of the results, another T-test was performed. The second T-test compared efficiency scores of private- and state-owned companies over a period of 5 years (2014-2018), as opposed to 2018 alone. The results for this T-test are shown in Figure 7 and the efficiency scores for the 5-year period between 2014 and 2018 (the inputs for the T-test) are shown in Table 5.

```
        Two Sample t-test

data:  private_eff and state_eff
t = 0.98005, df = 123, p-value = 0.329
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -0.06772982  0.20056842
sample estimates:
mean of x mean of y
0.5580957 0.4916764
```

Figure 7. Results from an independent sample T-test (or two sample T-test) that compared the means of the efficiency scores for private- and state-owned companies (private_eff and state_eff respectively) for the 5-year period between 2014 and 2018.

With an F-value of 0.756 and a p-value of 0.297 for the F-test, equal variances were assumed for the 2014-2018 data of the two groups. The means of the private- and state-owned companies were 0.558 and 0.492 respectively. As shown in Figure 7, the p-value of the T-test was 0.329, which was not low enough to reject the null hypothesis at the critical 5% level ($p < 0.05$). Therefore, no difference was found between the efficiency scores of private- and state-owned companies for the 5-year period between 2014 and 2018.

Table 5. Efficiency scores (from DEA) for the 5-year period between 2014 and 2018.

Company name	Ownership	2014	2015	2016	2017	2018
Bpost	State	0.493	0.479	0.521	0.499	0.624
Bring Parcels	State	1.000	1.000	1.000	1.000	1.000
Bulgarian Posts	State	0.041	0.035	0.022	0.011	0.012
Ceska posta	State	0.500	0.426	0.565	0.175	0.150
Chronopost Portugal	State	0.100	0.124	0.104	0.129	0.153
CTT Correios	Private	0.237	0.206	0.268	0.231	0.214
CTT Expresso	Private	0.096	0.099	0.141	0.195	0.246
Deutsche Post	Private	1.000	1.000	1.000	1.000	1.000
DHL Parcel UK	Private	1.000	1.000	0.777	1.000	0.863
Econt Express	Private	0.069	0.074	0.155	0.191	0.234
GLS Romania	Private	0.623	0.656	0.849	0.876	0.851
InPost	Private	0.779	1.000	0.126	0.621	1.000
La Poste	State	0.584	0.594	0.646	0.643	0.576
Latvijas Pasts	State	0.034	0.033	0.022	0.028	0.033
Lietuvos Pastas	State	0.025	0.025	0.018	0.022	0.025
Magyar Posta	State	0.226	0.209	0.234	0.199	0.174
Mondial Relay	Private	0.169	0.183	0.375	0.287	0.806
Omniva	State	1.000	1.000	1.000	1.000	1.000
Osterreichische Post	State	1.000	1.000	0.979	0.944	0.908
Posti	State	1.000	1.000	1.000	1.000	1.000
PostNL	Private	0.571	0.632	0.853	0.745	1.000
PostNord	State	0.833	0.973	0.963	0.785	0.686
Royal Mail	Private	0.500	0.541	0.518	0.494	0.552
Seur-Geopost	State	0.259	0.209	0.779	0.709	0.662
Slovenska Posta	State	0.154	0.120	0.150	0.133	0.116

4.3 Trend analysis

This section describes the results of the simple regression analyses, which were used to investigate the development of the efficiency levels of the postal companies. This was done for the private- and state-owned companies as groups, as well as all companies individually. The trend analysis was done in different ways, for different purposes, which is why this section is split up in two parts.

4.3.1 Relative changes in efficiency scores

The DEA results from Table 5 were used as the inputs for the simple regression analyses in this section, which is why it must be noted that these trends only indicate a relative change in the efficiency scores (relative to other companies in the sample). It was therefore not possible to identify whether a change in the efficiency score of a company was a result of a change in the input/output ratio of the company itself or a change in the input/output ratio of other companies in the sample. This is a result of the way in which DEA works, with the premise that the efficiency score of a company is based on its peers (i.e. dependent on the efficiency scores of other companies).

As a continuation of the previous section (Chapter 4.2), the companies were firstly grouped as private-and state-owned companies. The averages of the groups were then computed for all years and used as the input for the dependent variable in the simple regression analysis.

```
Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.44670    0.04849   9.211  0.00271 **
year         0.03710    0.01462   2.537  0.08488 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.04624 on 3 degrees of freedom
Multiple R-squared:  0.6821,    Adjusted R-squared:  0.5762
F-statistic: 6.438 on 1 and 3 DF,  p-value: 0.08488
```

Figure 8. Results from the simple regression analysis for private companies over the 5-year period between 2014 and 2018 (relative changes).

As shown in Figure 8, the p-value of 0.085 for 'year' was not low enough to reject the null hypothesis at the critical 5% level ($p < 0.05$). This means that no trend was found for the average efficiency scores of private companies for the 5-year period between 2014 and 2018. However, if the critical level was relaxed to 10%, a significant (positive) trend would have in fact been found.

```
Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.495700   0.028824   17.20 0.000428 ***
year        -0.001300   0.008691   -0.15 0.890584
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.02748 on 3 degrees of freedom
Multiple R-squared:  0.007403,  Adjusted R-squared:  -0.3235
F-statistic: 0.02238 on 1 and 3 DF,  p-value: 0.8906
```

Figure 9. Results from the simple regression analysis for state-owned companies over the 5-year period between 2014 and 2018 (relative changes).

As shown in Figure 9, the p-value of 0.891 for ‘year’ was not low enough to reject the null hypothesis at the critical 5% level ($p < 0.05$). This means that no trend was found for the average efficiency scores of state-owned companies for the 5-year period between 2014 and 2018.

To test whether there was a difference between the trends of private- and state-owned companies, a multiple regression model was used. The variable ‘year’ in this model represented the change between year ‘x’ and year ‘x+1’. A dummy variable was added, variable ‘dummy_private’, which indicated whether the change belonged to a private company (dummy = 1) or a state-owned company (dummy = 0). The value of variable ‘dummy_private’ represented the difference between the trends of private- and state-owned companies (state-owned companies as the reference group).

```
Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)   -0.02662    0.05155  -0.516    0.628
year           0.00985    0.01743   0.565    0.596
dummy_private  0.04525    0.03897   1.161    0.298

Residual standard error: 0.05511 on 5 degrees of freedom
Multiple R-squared:  0.2501,    Adjusted R-squared:  -0.0498
F-statistic: 0.834 on 2 and 5 DF,  p-value: 0.4869
```

Figure 10. Results from the multiple regression analysis for private- and state-owned companies over the 5-year period between 2014 and 2018 (relative changes).

As shown in Figure 10, the p-value of 0.298 for ‘dummy_private’ was not low enough to reject the null hypothesis at the critical 5% level ($p < 0.05$). This means that no difference was found between the trends of private- and state-owned companies.

Simple regression analyses were also done for all the companies individually (Table 6).

Table 6. Coefficients from the (relative) simple regression analyses (2014-2018).[1]

Company name	Ownership	Constant	Year	Adjusted R-squared
Bpost	State	0.439 (**9.624**)	0.028 (2.052)	0.445
Bring Parcels	State	1.000 (**Inf.**)[2]	0.000 (1.732)	0.373
Bulgarian Posts	State	0.049 (**10.927**)	-0.008 (**-6.98**)	0.900
Ceska posta	State	0.648 (**4.617**)	-0.095 (-2.245)	0.503
Chronopost Portugal	State	0.089 (**6.031**)	0.011 (2.503)	0.568
La Poste	State	0.599 (**14.984**)	0.003 (0.274)	-0.301
Latvijas Pasts	State	0.032 (**5.380**)	-0.001 (-0.389)	-0.269
Lietuvos Pastas	State	0.024 (**6.480**)	-0.003 (-0.27)	-0.302
Magyar Posta	State	0.243 (**13.084**)	-0.011 (-2.039)	0.441
Omniva	State	1.000 (**Inf.**)	0.000 (1.732)	0.373
Osterreichische Post	State	1.038 (**71.89**)	-0.024 (**-5.512**)	0.880
Posti	State	1.000 (**Inf.**)	0.000 (1.732)	0.373
PostNord	State	0.993 (**8.633**)	-0.048 (-1.39)	0.189
Seur-Geopost	State	0.132 (0.636)	0.131 (2.090)	0.457
Slovenska Posta	State	0.154 (**9.087**)	-0.006 (-1.237)	0.117
CTT Correios	Private	0.238 (**8.224**)	-0.002 (-0.241)	-0.308
CTT Expresso	Private	0.037 (1.900)	0.040 (**6.819**)	0.919
Deutsche Post	Private	1.000 (**Inf.**)	0.000 (1.732)	0.373
DHL Parcel UK	Private	1.010 (**8.908**)	-0.027 (-0.801)	-0.098
Econt Express	Private	0.010 (0.556)	0.045 (**7.852**)	0.938
GLS Romania	Private	0.568 (**8.249**)	0.068 (**3.255**)	0.706
InPost	Private	0.686 (1.570)	0.006 (0.048)	-0.332
Mondial Relay	Private	-0.049 (-0.284)	0.138 (2.631)	0.597
PostNL	Private	0.469 (**4.968**)	0.097 (**3.412**)	0.727
Royal Mail	Private	0.504 (**17.681**)	0.006 (0.663)	-0.163

[1] T-values (between parentheses) are bolded when significant at the critical 5% level.

[2] Infinite values for the constant are a result of unchanged efficiency scores (1.000 each time).

As shown in Table 6, significant values for the variable 'year' (indicating a trend) were only found for Bulgarian Posts, Osterreichische Post, CTT Expresso, Econt Express, GLS Romania and PostNL.

For Bulgarian Posts and Osterreichische Post, the values for the variable 'year' were -0.008 and -0.024 respectively, indicating a slightly negative trend in the efficiency scores of these companies. This means that the efficiency scores for these companies annually decreased by 0.8% and 2.4%.

The adjusted R-squared was 0.900 and 0.880, respectively, indicating that 90% and 88% of the variation in the dependent variable was explained by the independent variable 'year'. This indicates that the independent variable 'year' was a good predictor for both companies.

For CTT Expresso, Econt Express, GLS Romania and PostNL, the values for the variable 'year' were 0.04, 0.045, 0.068 and 0.097 respectively, indicating a positive trend for all of these companies. The

annual increases of 4%, 4.5%, 6.8% and 9.7% respectively, indicated that PostNL was improving the most throughout the years. Their relative efficiency increase was more than double compared to CTT Expresso and Econt Express.

The adjusted R-squared was 0.919, 0.938, 0.706 and 0.727, respectively, indicating that 91.9%, 93.8%, 70.6% and 72.7% of the variation in the dependent variable was explained by the independent variable 'year'. This indicates that the independent variable 'year' was a good predictor for all companies.

Finally, to give an overview of the entire postal market, a simple regression analysis was done for the averages of all companies over the 5-year period between 2014 and 2018 (Figure 11).

```
Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) 0.477000   0.011080  43.052 2.76e-05 ***
year        0.013800   0.003341   4.131   0.0257 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.01056 on 3 degrees of freedom
Multiple R-squared:  0.8505,    Adjusted R-squared:  0.8006
F-statistic: 17.06 on 1 and 3 DF,  p-value: 0.02574
```

Figure 11. Results from the simple regression analysis for the averages of all companies over the 5-year period between 2014 and 2018.

As shown in Figure 11, the p-value of 0.026 for 'year' was low enough to reject the null hypothesis at the critical 5% level ($p < 0.05$). This means that a positive trend of 0.014 was found for the averages of all companies over the 5-year period. This translates to an average increase in efficiency of 1.4% per year for the European postal market (based on the 25 companies in the sample).

4.3.2 Absolute changes in efficiency scores

For the second part of this section (Chapter 4.3), the DEA models were slightly changed. Instead of measuring the efficiency levels based on a changing frontier, the frontier was now fixed. The frontier of efficient companies was based on all observations (125 in total, 5x25 companies). This procedure enabled the measurement of the absolute changes in the efficiency scores of a company, because the reference frontier did not shift. A company was therefore compared with the same observation (same efficient peer with the same input/output ratio) for each year between 2014 and 2018 (Table 7). These results therefore show how much of the change in the efficiency score of a company was attributed to their own actions. It is interesting to compare these results with the results of the first part of this section, which showed the relative changes in the efficiency scores.

Table 7. Absolute efficiency scores for the 5-year period between 2014 and 2018 (fixed frontier).

Company name	Ownership	2014	2015	2016	2017	2018
Bpost	State	0.488	0.440	0.404	0.463	0.559
Bring Parcels	State	1.000	1.000	0.983	1.000	0.889
Bulgarian Posts	State	0.012	0.013	0.014	0.010	0.010
Ceska posta	State	0.500	0.399	0.376	0.157	0.144
Chronopost Portugal	State	0.067	0.070	0.074	0.073	0.071
CTT Correios	Private	0.213	0.193	0.165	0.187	0.169
CTT Expresso	Private	0.096	0.084	0.095	0.111	0.116
Deutsche Post	Private	1.000	1.000	0.944	1.000	0.872
DHL Parcel UK	Private	1.000	0.983	0.447	0.832	0.652
Econt Express	Private	0.069	0.065	0.111	0.130	0.156
GLS Romania	Private	0.623	0.537	0.526	0.468	0.408
InPost	Private	0.546	1.000	0.113	0.523	0.709
La Poste	State	0.584	0.544	0.536	0.616	0.504
Latvijas Pasts	State	0.020	0.019	0.019	0.023	0.025
Lietuvos Pastas	State	0.015	0.017	0.016	0.019	0.019
Magyar Posta	State	0.174	0.154	0.155	0.180	0.166
Mondial Relay	Private	0.169	0.170	0.208	0.257	0.568
Omniva	State	1.000	0.783	1.000	0.981	0.553
Osterreichische Post	State	1.000	0.915	0.773	0.880	0.817
Posti	State	1.000	0.829	0.815	1.000	1.000
PostNL	Private	0.515	0.561	0.667	0.739	0.712
PostNord	State	0.620	0.705	0.669	0.737	0.679
Royal Mail	Private	0.500	0.495	0.428	0.471	0.433
Seur-Geopost	State	0.184	0.190	0.373	0.492	0.461
Slovenska Posta	State	0.112	0.094	0.093	0.113	0.102

In the same order as before, the companies were grouped as private-and state-owned companies in order to investigate the trend in their averages.

```
Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.46810    0.06383   7.334  0.00524 **
year        -0.00250    0.01925  -0.130  0.90486
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.06086 on 3 degrees of freedom
Multiple R-squared:  0.005594,  Adjusted R-squared:  -0.3259
F-statistic: 0.01688 on 1 and 3 DF,  p-value: 0.9049
```

Figure 12. Results from the simple regression analysis for private companies over the 5-year period between 2014 and 2018 (absolute changes).

As shown in Figure 12, the p-value of 0.905 for 'year' was not low enough to reject the null hypothesis at the critical 5% level ($p < 0.05$). This means that no trend was found for the average efficiency scores of private companies for the 5-year period between 2014 and 2018.

```
Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.44610    0.02544  17.537 0.000404 ***
year        -0.00650    0.00767  -0.847 0.458976
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.02425 on 3 degrees of freedom
Multiple R-squared:  0.1932,    Adjusted R-squared:  -0.07577
F-statistic: 0.7183 on 1 and 3 DF,  p-value: 0.459
```

Figure 13. Results from the simple regression analysis for state-owned companies over the 5-year period between 2014 and 2018 (absolute changes).

As shown in Figure 13, the p-value of 0.459 for 'year' was not low enough to reject the null hypothesis at the critical 5% level ($p < 0.05$). This means that no trend was found for the average efficiency scores of state-owned companies for the 5-year period between 2014 and 2018.

Simple regression analyses were done in the same way for all the companies individually (Table 8).

Table 8. Coefficients from the (absolute) simple regression analyses (2014-2018).[1]

Company name	Ownership	Constant	Year	Adjusted R-squared
Bpost	State	0.421 (**6.687**)	0.016 (0.869)	-0.065
Bring Parcels	State	1.041 (**25.903**)	-0.022 (-1.832)	0.371
Bulgarian Posts	State	0.014 (**8.167**)	-0.001 (-1.364)	0.177
Ceska posta	State	0.601 (**10.971**)	-0.095 (**-5.772**)	0.890
Chronopost Portugal	State	0.068 (**26.426**)	0.001 (1.424)	0.204
La Poste	State	0.583 (**11.633**)	-0.009 (-0.582)	-0.198
Latvijas Pasts	State	0.017 (**9.256**)	0.001 (2.528)	0.574
Lietuvos Pastas	State	0.014 (**14.014**)	0.001 (**3.273**)	0.708
Magyar Posta	State	0.163 (**11.849**)	0.001 (0.241)	-0.308
Omniva	State	1.072 (**5.451**)	-0.07 (-1.174)	0.086
Osterreichische Post	State	0.997 (**13.485**)	-0.04 (-1.798)	0.358
Posti	State	0.878 (**7.725**)	0.017 (0.499)	-0.231
PostNord	State	0.637 (**14.415**)	0.015 (1.126)	0.063
Seur-Geopost	State	0.083 (1.234)	0.086 (**4.211**)	0.807
Slovenska Posta	State	0.103 (**8.94**)	-0.000 (-0.029)	-0.333
CTT Correios	Private	0.214 (**14.126**)	-0.009 (-2.062)	0.448
CTT Expresso	Private	0.080 (**8.855**)	0.007 (2.45)	0.556
Deutsche Post	Private	1.04 (**21.821**)	-0.026 (-1.781)	0.352
DHL Parcel UK	Private	1.037 (**4.454**)	-0.085 (-1.207)	0.102
Econt Express	Private	0.034 (2.72)	0.024 (**6.25**)	0.905
GLS Romania	Private	0.662 (**34.697**)	-0.050 (**-8.673**)	0.949
InPost	Private	0.624 (1.602)	-0.015 (-0.129)	-0.326
Mondial Relay	Private	0.009 (0.079)	0.088 (2.606)	0.592
PostNL	Private	0.467 (**11.074**)	0.057 (**4.497**)	0.828
Royal Mail	Private	0.513 (**18.673**)	-0.016 (-1.908)	0.398

[1] T-values (between parentheses) are bolded when significant at the critical 5% level.

As shown in Table 8, significant values for the variable ‘year’ (indicating a trend) were found for Ceska posta, Lietuvos Pastas, Seur-Geopost, Econt Express, GLS Romania and PostNL.

For Ceska posta and GLS Romania, the values for the variable ‘year’ were -0.095 and -0.050 respectively, indicating a slightly negative trend in the efficiency scores of these companies. This means that the efficiency scores for these companies annually decreased by 9.5% and 5%.

The adjusted R-squared was 0.890 and 0.949, respectively, indicating that 89% and 94.9% of the variation in the dependent variable was explained by the independent variable ‘year’. This indicates that the independent variable ‘year’ was a good predictor for both companies.

For Lietuvos Pastas, Seur-Geopost, Econt Express and PostNL, the values for the variable ‘year’ were 0.001, 0.086, 0.024 and 0.057 respectively, indicating a positive trend for all of these companies. The annual increases of 0.1%, 8.6%, 2.4% and 5.7%, respectively, indicated a wide range in the changing efficiency score. The annual change for Lietuvos Pastas was only 0.1%, whereas the annual change for Seur-Geopost was 8.6%.
The adjusted R-squared was 0.708, 0.807, 0.905 and 0.828, respectively, indicating that 70.8%, 80.7%, 90.5% and 82.8% of the variation in the dependent variable was explained by the independent variable ‘year’. This indicates that the independent variable ‘year’ was a good predictor for all companies.

Comparing these absolute changes (Tables 7 & 8) to the relative changes (Tables 5 & 6) gives a deeper understanding of why the efficiency scores changed. For example, no trend was found for Seur-Geopost for the relative changes, even though a positive trend was found for the absolute changes. Relatively speaking, the efficiency score of Seur-Geopost decreased by roughly 9% between 2016 and 2017, while the absolute efficiency score improved by roughly 32%. This difference indicates that, even though Seur-Geopost improved a lot on its own, the company was outperformed by the other companies in the sample. The fact that the company did not improve in relative terms therefore does not mean that they did not effectively change their own input/output ratio(s). This example shows that it is important to compare the results of Chapter 4.3.1 and Chapter 4.3.2 in order to understand more about the changing efficiency scores.

5. Discussion

The discussion is split up in a section about the methods and a section about the results.

5.1 Methods

This section reflects on the methods that were used for this study.

It is important to note that it was rather difficult to accurately measure the efficiency of postal companies in Europe, which has several reasons.

The small sample size was one of the main issues, which made it relatively difficult to check the assumptions for the trend analysis (simple regression). This was especially the case for the separate groups, as the total of 25 companies was split in groups of 10 private- and 15 state-owned companies. The same issue had an influence on the results of the T-tests, because it is generally difficult to get significant results with a small sample size.

This issue of a small sample size was mainly attributed to the Orbis database, as it simply did not contain relevant information about more than the 25 selected companies. Within the capacity of this study, the Orbis database was the best source of information. However, it is not clear if more suitable databases exist. Moreover, most of the databases (like Orbis) inherently contain data about relatively large companies, which limits the sample size. However, it is unlikely that very small companies are worth the effort to investigate. Especially in terms of efficiency, it is unlikely that (very) small companies are able to operate optimally (due to the concept of 'economies of scale').

Another issue is the fact that there were missing inputs for the DEA model(s). As explained in Chapter 2.1.2, there was not enough data to include material costs in the model, even though this would have been a highly relevant input. It is unclear whether this limitation was caused by the chosen database or that this data was simply not available at all. In the case of material costs it was assumed that this would not cause a lot of issues (based on Appendix Table B), but it certainly highlights that the DEA model was not perfect. It goes without saying that such models are almost never perfect, though, as it is highly unlikely that a study is able to capture all of the real inputs and outputs.

Also, the relation between the inputs and outputs of the DEA model (fixed assets, number of employees and turnover) was rather indirect. Postal companies mainly provide a wide range of services, which makes it much harder to classify inputs and outputs for postal companies than it is for companies that sell (a small number of) products. To allow for a feasible measurement method within a 6-month time frame, balance sheets and P&L statements were used to retrieve the inputs and outputs of the companies. This limitation results in a more indirect measure of efficiency, which unfortunately leaves more room for error.

The best approach to tackle some of these issues would likely be to look for different databases, as these might contain more data. These databases might contain more inputs and outputs overall, which could result in a more direct relation between the inputs and outputs. Being able to include more inputs would also improve the model as it reduces the risk of "missing inputs". Expert elicitation could also be used in the process to reduce the risk of missing relevant data, especially if available databases seem to be insufficient on their own. Such a process requires time, but it would certainly increase the confidence in the results. This is especially important when results are used for policy implementation or policy adjustments, which could be the case here.

As a result of these points, one must be careful trying to generalize the results of this study.

5.2 Results

This section gives further explanation about some of the results of this study.

The results of this study could have several policy implications. Efficiency gains are often mentioned as a reason to privatize a company, but the hypothesis that private companies are more efficient than state-owned companies (in the postal sector) was rejected based on the results of the T-tests. This is a useful insight for governments, as increasing efficiency is often a reason to choose for privatization and might therefore not be a suitable option for the postal sector. However, the results show an average increase in efficiency of 1.4% per year for the postal sector overall. This is in line with the resource-efficient goals of the European Commission, although it seems that no specific targets have been set for the efficiency levels of the European postal sector. The combination of all results gives insight to the management level of the postal companies, as these results map the position of the company with respect to competitors (in terms of efficiency) and indicate where efficiency improvements could be made.

As shown in Table 3 (Chapter 4.1), there was more slack in the fixed assets than in the number of employees for each of the inefficient companies in the sample. It makes sense for fixed assets to show the most slack, as these are often fixed for a long period of time and not easily disposed of. This does not necessarily mean that it is easier to dispose of employees, though, as this is dependent on the company and the country that it operates in. However, it is common for the postal market to use subcontracting in parcel delivery to deal with fluctuating demand (WIK-Consult, 2019b). While subcontractors are likely not included in the 'number of employees' input for the DEA model (the ORBIS database does not make this clear), it might still be easier to replace these employees by subcontractors (in the long term) than it is to dispose of fixed assets. It is generally easier to terminate a contract with subcontractors, meaning that they are more flexible than a company's own employees.

No difference was found between the efficiency scores of private- and state-owned companies, for both 2018 and the 5-year period between 2014 and 2018 (at the critical 5% level). However, this may have been partly influenced by the small sample size, which makes it hard to find significant results.

The same goes for the fact that no relationship was found between the EU region of a company and its efficiency score. An additional problem here was that three out of four companies from the Southern region were from Portugal, which might not be very representative.

Also, mainly as a recommendation for future research, it would be a good idea to pay attention to specific details about private companies. For an accurate measurement of the performance of private companies, especially when they are compared to state-owned companies, it is important to note how long the company has been privately owned. If a private company was formerly state-owned, which is highly likely in the postal sector, the full effects of privatization might not yet be visible. Either way, a simple regression model could be used to measure whether the performance of a company changed after it was privatized. A case study of a private company (or multiple private companies) would therefore be an interesting topic. This could unfortunately not be done in this study, as the private companies in the sample were either privatized outside of Orbis' data range (before 2009) or were subject to missing data.

The differences between the relative and the absolute efficiency scores (Chapters 4.3.1 and 4.3.2) are also something that future research could investigate. The given example at the end of that section illustrates why this could be useful, as the relative changes in efficiency do not show the full picture. It would be very useful and insightful if a method were to be developed that could accurately distinguish the causes of an efficiency change for a company, so that it is clear to which extent the change was a result of the company's own efforts.

6. Conclusion

This study analyzed the efficiency levels of companies operating in the European postal sector. The first research question used DEA to measure the most current efficiency levels of the companies (in 2018). The second research question used T-tests to investigate whether there was a difference between the efficiency levels of private- and state-owned companies. The third research question used simple- and multiple regression to investigate the development of the efficiency levels over time (trend analysis).

Bring Parcels, Deutsche Post, InPost, Omniva, Posti and PostNL were the most efficient companies in 2018 (most current) and acted as peers to the other 19 companies in the sample. All companies showed the most slack in fixed assets (or an equal amount of slack to that of the 'number of employees' input). The average efficiency score for the entire sample was 0.555 or 55.5%.

No significant relationship was found between the EU region that a company belonged to and the efficiency score of that company (at the critical 5% level). As a result, the sample was split up in 10 private- and 15 state-owned companies (regardless of their region) for the T-tests.

No difference was found between the efficiency scores of private- and state-owned companies for 2018 (means of 0.677 and 0.475 respectively). Another T-test was performed for the 5-year period between 2014 and 2018 to test the robustness of the results. No difference was found between the efficiency scores of private- and state-owned companies for the 5-year period either (means of 0.588 and 0.492 respectively). The hypothesis from Chapter 2.2, which stated that "private companies are more efficient than state-owned companies", was therefore rejected.

The results of the trend analysis showed that no trend was found for the average efficiency scores of private companies for the 5-year period between 2014 and 2018 (at the critical 5% level), unless the critical level was relaxed to 10%. No trend was found for the average efficiency scores of state-owned companies for the 5-year period either (at the critical 5% level). However, for the averages of all companies over the 5-year period, a positive trend of 0.014 was found. This translates to an average increase in efficiency of 1.4% per year for the European postal sector (based on the 25 companies in the sample). This is in line with the resource-efficient goals of the European Commission that were set out in the postal directives.

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8. Appendix

Table A. Conversion of the 2018 turnover for all companies based on the PLI of their home country.

Company name	Country	PLI[1]	Turnover multiplier	Initial turnover	Adjusted turnover[2]
Bpost	Belgium	114.75	0.87	4373788000	3811443829
Bring Parcels	Sweden	96.72	1.03	210933000	218083271
Bulgarian Posts	Bulgaria	55.74	1.79	97388480	174726391
Ceska posta	Czech republic	83.61	1.20	849550000	1016128431
Chronopost Portugal	Portugal	98.36	1.02	53620860	54514541
CTT Correios	Portugal	98.36	1.02	628672870	639150751
CTT Expresso	Portugal	98.36	1.02	92649140	94193292
Deutsche Post	Germany	82.79	1.21	72006796000	86978506059
DHL Parcel UK	United Kingdom	90.16	1.11	608258934	674614454
Econt Express	Bulgaria	55.74	1.79	105131718	188618671
GLS Romania	Romania	41.80	2.39	41178244	98504819
InPost	Poland	36.89	2.71	133481127	361882167
La Poste	France	79.51	1.26	15861693000	19949758206
Latvijas Pasts	Latvia	59.84	1.67	103503387	172978263
Lietuvos Pastas	Lithuania	50.00	2.00	101870233	203740466
Magyar Posta	Hungary	68.85	1.45	820193000	1191232690
Mondial Relay	France	79.51	1.26	240522996	302513459
Omniva	Latvia	59.84	1.67	3632438	6070650
Osterreichische Post	Austria	68.85	1.45	2339465000	3397794405
Posti	Finland	66.39	1.51	1525908000	2298281185
PostNL	The Netherlands	**100.00**	**1.00**	4064752000	4064752000
PostNord	Sweden	96.72	1.03	2287904000	2365460068
Royal Mail	United Kingdom	90.16	1.11	10154147000	11261872127
Seur-Geopost	Spain	114.75	0.87	527982747	460099251
Slovenska Posta	Slovakia	69.67	1.44	366473465	525997209

[1] Price Level Index for postal services (base = The Netherlands), adapted from Eurostat (2019).

[2] Any difference between the initial- and adjusted turnover (based on the multiplier) is a result of rounding.

Table B. Efficiency scores (from DEA) for the 15 companies with data for material costs.

Company name	Country	Including material costs	Excluding material costs
Bulgarian Posts	Bulgaria	0.323	0.171
Ceska posta	Czech republic	0.235	0.151
CTT Correios	Portugal	0.282	0.214
Deutsche Post	Germany	1.000	1.000
DHL Parcel UK	United Kingdom	0.863	0.863
GLS Romania	Romania	1.000	1.000
InPost	Poland	1.000	1.000
La Poste	France	1.000	0.576
Latvijas Pasts	Latvia	0.401	0.401
Mondial Relay	France	1.000	1.000
Omniva	Latvia	1.000	1.000
Posti	Finland	1.000	1.000
PostNL	The Netherlands	1.000	1.000
PostNord	Sweden	0.725	0.686
Slovenska Posta	Slovakia	0.121	0.121