The Relative Efficiency of Public and Private Bus Companies?

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By applying Data Envelopment Analysis (DEA), this study examines the efficiency of a subset of Norwegian bus companies in order to test the hypothesis that public companies are less efficient than private ones. DEA consists of constructing a piecewise linear best practice frontier enveloping the input-output combinations of the companies, efficiency being measured for each individual company in terms of its distance relative to the frontier. DEA is widely acclaimed for being flexible, letting the data reveal the unknown and possibly complex relationships between inputs and outputs. As a consequence, each company is most likely evaluated against similar companies being located in the 'neighbourhood' in the input-output space. If private and public companies are clustered in separate subspaces in the input-output space however, each company will most likely be evaluated against companies of its own rather than the opposite category of ownership. In order to avoid this pitfall, we identify and include in the study only those companies that are found to be either efficient or inefficient as compared to at least one company in the opposite category of ownership. The results from the study are compared to those obtained by the more conventional approach where all companies are included in the study.

1 Introduction

The property rights theory claims that as compared to private ownership, public ownership has disadvantageous effects on the incentives for managers and employees to fulfil the objectives set out by their principals.[1] Private companies should thus outperform public companies in terms of efficiency. Several empirical studies have been carried out in order to reveal whether this is true or not. The findings are rather mixed however. Borcherding et al (1982) in their widely quoted survey, concluded that the literature seems to indicate that private companies are more cost effective than their public counterparts, but that these differences accrue to differences in competition rather than ownership per se. Vining & Boardman (1992) on the other hand, claim that private companies outperform public companies even if competition is controlled for. Thus, the literature is inconclusive.

One of the industries that have been subject to examination, is the bus industry. In their reviews, both Perry et al (1988) and Berechman (1993) reaches conclusions similar to Borcherding et al (1982). The results from more recent studies are also mixed. For instance, Chang & Kao (1992) and Kerstens (1996) found that private bus operators outperformed public bus operators in Taiwan and France respectively. Cowie & Asenova (1999) reach the same conclusion in their study of British bus companies. Viton (1997) in his study of the US bus industry on the other hand, found no difference between private and public companies regarding efficiency. The latter results is confirmed by Jørgensen et al (1997) and by Odeck & Alkadi (forthcoming) in their studies of the Norwegian bus industry.

Except for Jørgensen et al (1997) (estimating a stochastic cost frontier), the more recent studies referred to above share a common feature in that they all apply Data Envelopment Analysis (DEA). DEA involves the construction of a piecewise linear best practice production frontier enveloping the data in the input-output space. The efficiency of each individual company is measured in terms of the relative distance to this best practice production frontier. The property rights theory is tested for by means

[1] See Furubotn and Pejovich (1974) for a review of the property rights theory.

of some statistical test (eg. Mann-Whitney rank test) comparing the efficiency scores of private and public companies.

One major reason for applying DEA is that the method is quite flexible, letting the data to a large extent reveal the possibly complex relationships between inputs and outputs. As a consequence, each company is most likely compared to similar companies being located in the 'neighbourhood' in the input-output space. If private and public companies are clustered in separate subspaces in the input-output space however, each company will most likely be compared to companies of its own rather than the opposite ownership category. In other words, comparisons of efficiency are made within rather than across the two categories of ownership. In such cases, comparisons of relative efficiency between private and public companies are at best dubious. The previous papers applying DEA in order to test for the significance of ownership in the bus industry do all ignore this possible pitfall. Therefore, the aim of this paper is to reconsider the issue of ownership in the bus industry, making sure that comparisons among bus companies are made between rather than within the two categories of ownership.

In section 2 we discuss the theoretical underpinnings of the hypothesis that public companies are less efficient than their public counterparts. In the subsequent section, section 3, we give a short presentation of efficiency measurement by means of DEA. In section 4 we discuss more thoroughly the problem of making comparisons between private and public companies if the two categories are clustered in separate subspaces in the input-output space. In section 5 we present a method that enables us to detect those companies that are either efficient or inefficient as compared to companies of the opposite category of ownership. In section 6 we present a data set for the Norwegian bus industry to which this method is applied in section 7 in order to test the significance of ownership. Section 8 concludes.

2 Why should ownership matter?

In economics, it is assumed that agents are rational, utility-maximising agents. In addition, it is quite common to assume that agents will pursue their own personal goals. This has serious implications for the relationship between employers and employees amongst others. If the personal goals of the management or the employees differ from the objectives of the company in which they are employed, they will act according to their own personal goals if given the opportunity. Asymmetric information provides such an opportunity. This is a central theme within the theory of principal-agent.[2]

The property rights theory argues that incentive problems are particularly severe in public companies. To see how, suppose that employees in a public company enjoys 'a quiet life' (eg. Migue & Belanger, 1974) that leads to cost- or X-inefficiency. This would ultimately lead to a loss of profits or alternatively an increase in the need for public subsidies. In both cases, this would eventually cause an increase in the tax bill to be paid by the public. Of course, as the employees in the company pay taxes as well, they will be adversely affected themselves. But as the number of taxpayers is quite substantial, their share of the tax bill will be quite small or even negligible. Thus, the employees reap the positive consequences of pursuing their own personal goals while the negative consequences are carried mainly by the remaining part of the public. As a consequence, employees in a public company will have weak or no incentives to abstain from a 'quiet life' or other personal goals they may have.

Although incentive problems are expected to be present in private companies as well, the property rights theory argue that the incentive problems are more severe in public companies, implicitly promoting privatisation of public companies. A major argument is that private ownership allows the managers of and the employees in a private company to own a substantial share of the company in which they are employed. The ownership of a public company on the other hand, is dispersed on the public or the citizens. To see the importance of this, suppose that the managers and employees of a company enjoy 'a quiet life' at work, thereby decreasing profits. If the management and the employees own a substantial share of the company however, they will carry a substantial share of the costs associated with their 'quiet life'. As a consequence, employees in a private company may have strong incentives to abstain from pursuing their own personal goals. As already noted, this is precluded in the case of public ownership, but not in the case of private ownership.

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[2] For an introduction to the theory of principal-agent, see for instance Arrow (1986).

Even though private ownership allows employees to own a substantial share of the company in which they are employed, this is by no means the rule. According to advocates of private ownership, we may still expect private ownership to be superior to public ownership. One reason is that private ownership makes concentrated ownership possible. Since the owner or the owners reap all the gains from making sure that the firm is efficiently run, they have strong incentives to monitor the firm. In the case of public ownership however, ownership is dispersed as the ultimate owners are the general public. Thus, the gains from monitoring are dispersed as well. Since monitoring presumably involve non-negligible costs, each citizen will probably not find it worthwhile to monitor. And even worse; each citizen will have an incentive to free-ride. Hence, the incentives to monitor publicly owned firms are weak and possibly non-existent as compared to private firms with concentrated ownership (Alchian, 1965).

The above arguments have been contradicted however. Concerning the advantages of management or employee ownership, Holmstrom (1982) argue that common ownership among the managers and employees may give rise to free rider problems, causing weak and possibly no incentives for managers and employees to abstain from pursuing their own goals. Concerning the advantages of concentrated ownership for monitoring, a significant share of private firms are public in the sense that there are many owners, each with a small stake or share in the firm. Although such an ownership structure is efficient by means of risk sharing, each owner's incentive to monitor is weak or possibly even absent as in the case of public ownership. Advocates of private ownership have responded to this by arguing that the monitoring need not come from the owners. Since the ownership of privately owned firms may be transferred, there may be investors or raiders searching for inefficient firms in order to take over the firms, ensuring that they are efficiently run, thereby increasing the stockprice in order to make profits. The threat of such take-overs may discipline the managers and the employees to be efficient. Grossman & Hart (1980) on the other hand, argue that the threat of take-over may be empty due to free-rider problems: By not selling its shares, a shareowner will reap the gains from the raid at no cost. Hence, they will not sell at a lower price than the expected 'post-raid' stockprice. In that case, there is nothing to gain for raiders and the threat of take-over is empty. Even if the threat of take over is non-empty as argued by others, the threat of a take over may not be empty for a public firm either as long as privatisation is an option. The threat of privatisation may therefore discipline employees in public firms to be efficient as the threat of take over of private firms may discipline employees in private firms to be efficient.

As is evident from the discussion above, it is not obvious that private firms are more efficient than public firms. This calls for empirical tests in order to reveal whether public ownership is inferior to private ownership or not. With regard to this, recall that the property rights theory claims that as compared to private ownership, public ownership has disadvantageous effects on the incentives for managers and employees to fulfil the objectives set out by their owners. Thus, if one is to make a proper test of the property rights theory, the performance of each company should be compared to the objectives for that particular company. For private companies, the owners are presumably requesting maximum profits. Although economists commend that public companies should strive for economic efficiency, the public choice theory argues forcefully that one can hardly expect this to be the case in practice.[3] Unfortunately, the public choice theorists have not come up with a generally accepted theory regarding what objectives to expect in practice. As a consequence, one is forced to refrain from evaluating each company's capability to fulfil its superior goals.

The solution to this problem is to focus on subgoals that are unambiguous for both kinds of ownership. Cost minimisation might be a candidate in this respect. There are several reasons why this should not be favoured as a measure of relative efficiency however. For instance, if combating unemployment is one of the main goals of the public authorities, a public company might be instructed to employ a larger staff than what is strictly cost minimising. In that case, such a company would be considered inefficient despite the fact that it actually fulfils the main objectives set by its principals.[4] Therefore, we are in line with Pestieau & Tulkens (1990) suggestomg that such comparisons should be based on technical efficiency as technical efficiency is

[3] For a review of the public choice theory, see Mueller (1989).

[4] Despite this, comparisons of costs where quite common in the earlier literature dealing with comparisons of private and public ownership.

presumably a common subgoal for both public and private companies. Measuring technical efficiency by means of DEA is the subject in the subsequent section.

3 Data Envelopment Analysis

A company is said to be technically efficient if it is impossible to increase any output and/or decrease any input without simultaneously reducing at least one other output and/or increasing at least one other input (Koopmans, 1951). Debreu (1951) offered a measure of technical efficiency being one minus the maximum proportional reduction in all inputs consistent with continued production of existing outputs. Farrell (1957) suggested that the Debreu (1951) measure of technical efficiency could easily be computed as an index or ratio: Let z_k be the vector of inputs for DMU k and z_k^* a second vector of inputs such that $z_k^* = \theta_k z_k$ where θ_k is a scalar. Further, let y_k be the vector of outputs for DMU k and y_k^* a second vector of outputs associated with z_k^*. The measure of technical efficiency is defined as the minimal value that θ_k can attain provided that $y_k^* \geq y_k$. As $0 < z_k^* \leq z_k$, it follows that $0 < \theta_k \leq 1$. DMU k is technically efficient if $\theta_k = 1$, otherwise (that is; $0 < \theta_k < 1$) it is inefficient. The lower the value of θ_k, the less efficient is DMU k.

According to the definition in Koopmans (1951) however, technical efficiency might just as well be measured in terms of the maximum proportional increase in all outputs consistent with existing inputs: Let μ_k be such that $y^* = \mu_k y_k$. The measure of technical efficiency is defined as the maximum value that μ_k can attain provided that $z^* \leq z_k$. As $y_k^* \geq y_k$, it follows that $\mu_k \geq 1$. DMU k is technically efficient if $\mu_k = 1$, otherwise (that is; $\mu_k > 1$) it is inefficient. The higher the value of μ_k, the less efficient is DMU k. This latter measure of efficiency is termed the output-increasing measure of technical efficiency, while the former is termed the input-saving (or –decreasing) measure of technical efficiency.

In order to evaluate the technical efficiency of companies, we need to know the maximum output that can be generated from a given input or alternatively, the minimum input required to produce a given output. In more technical terms, we need to know the frontier of the production possibility set. Such information is rarely available however. As a consequence, it is common to construct a so-called best practice frontier based on available data, representing the technically most efficient production practices to be found in practice. As a consequence of this, some of the companies will necessarily be on the best practice frontier. Such companies are termed best practice efficient and obtain efficiency scores equal to unity.

Several methods have been proposed and applied in order to obtain best practice frontiers. One option is to assume that the production possibility set may be represented by a parametric production function, e.g. Cobb-Douglas. This allows one to estimate the best practice production frontier by means of well-established econometric methods. However, parametric production functions may be too restrictive, not least if flexible functional forms are prohibited due to data limitations. This calls for applying a so-called non-parametric frontier analysis, amongst which the data envelopment analysis or DEA has gained considerable popularity in recent years. DEA is acclaimed for resting on rather weak assumptions concerning the properties of the production technology, thus letting the data to a large extent reveal the possibly complex relationship between inputs and outputs. More specifically, DEA consists of enveloping the input-output observations by a piecewise linear frontier. Although the method allows multiple for outputs as well as multiple inputs, figure 1 illustrates a DEA frontier for a single input – single output case, z measuring the quantity of input, y the quantity of output while A, B, C etc. are input-output combinations for the companies to be evaluated.

The input-saving and output-increasing measures of technical efficiency can be illustrated by means of figure 1. Consider company B whose quantities of input and output is z_B and y_B respectively. The minimum quantity of input associated with producing at least y_B, is z^*_B. Thus, the input-saving measure of technical efficiency is z^*_B/z_B. The maximum quantity of output that is attainable with the quantity z_B of inputs, is y^*_B. Thus, the output-increasing measure of technical efficiency is y^*_B/y_B.

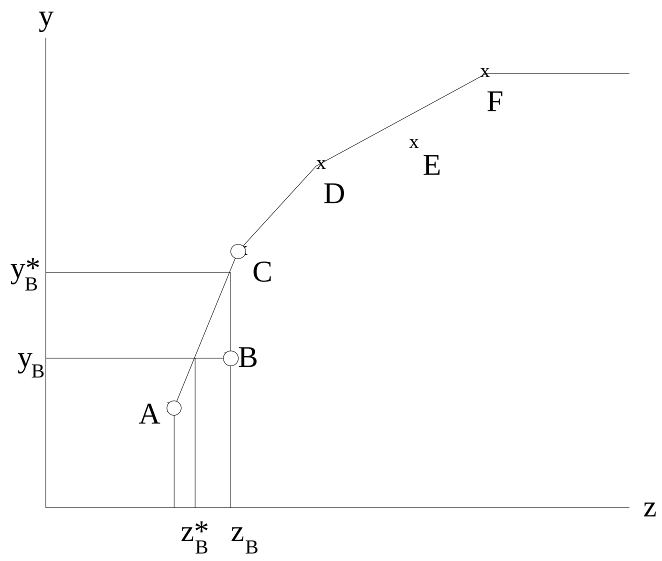

Figure 1

The idea to envelop the data by linear facets was pioneered by Farrell (1957). However, the method did not gain ground until Charnes, Cooper and Rhodes (1978) ingeniously applied linear programming techniques in order to jointly calculate the efficiency measures and the relevant part of the frontier for each company (or more generally; Decision Making Unit) in turn. This is the method that has come to be known as DEA. Although their study was restricted to constant returns to scale, the methodology has been generalised by Bankers, Charnes and Cooper (1984) to handle variable returns to scale as is the case illustrated in figure 1. As the latter is more flexible than the former, we concentrate on the latter model for which input-saving measures of technical efficiency may be obtained by computing the following linear programming problem for each individual company:

(3.1) $$\min_{\lambda} imise\ \theta_k$$

subject to:

(3.2) $$\theta_k z_k - \sum_{i \in N} \lambda_i z_i \geq 0$$

(3.3) $$\sum_{i \in N} \lambda_i y_i - y_k \geq 0$$

(3.4) $$\lambda_i \geq 0, \forall i \in N$$

(3.5) $$\sum_{i \in N} \lambda_i = 1$$

where N = 1,..,n is the total number of companies, θ_k is the Farrell input-saving measure of technical efficiency for company k, z_i is the vector of actual inputs used by company i, y_i is the vector of actual production of company i, while $\lambda_1, ..., \lambda_n$ are scalar weights to be optimised. (2.2) guarantees that the technical efficient input combination $\theta_k z_k$ is technically feasible, while (2.3) guarantees that production does not fall short of the actual output y_k. (2.4) merely restricts the weights to be positive, while (2.5) determines the scale properties, in this case variables returns to scale. The output-increasing measures of technical efficiency may be obtained by computing the following linear programming problem for each individual company:

(3.6) $$\max_{\lambda} imise\ \mu_k$$

subject to:

(3.7) $$z_k - \sum_{i \in N} \lambda_i z_i \geq 0$$

(3.8) $$\sum_{i \in N} \lambda_i y_i - \mu_k y_k \geq 0$$

(3.9) $$\lambda_i \geq 0, \forall i \in N$$

(3.10) $$\sum_{i \in N} \lambda_i = 1$$

where μ_k is the Farrell output-increasing measure of technical efficiency for company k. (3.7) – (3.10) corresponds to (3.2) – (3.5). A thorough introduction to the various DEA models can be found in Cooper, Seiford and Tone (2000).

4 The relative efficiency of private and public companies?

Conventionally, applying DEA in order to evaluate the relative efficiency of private and public companies comprises two steps. In the first step, efficiency measures for each individual company are obtained by means of DEA. In the second step, statistical analysis (eg. Mann-Whitney rank test) is applied in order to test whether there are significant differences in average efficiency between private and public companies. For instance, suppose that in the example depicted in figure 1, A, B and C are all public companies whereas D, E and F are all private companies. Suppose further that input-saving measures of efficiency are obtained for each company. In that case, A, C, E and F would turn out to be best practice efficient, whereas B and E would turn out to be almost equally inefficient. Thus, both categories contains two efficient companies and one equally inefficient company. Although such a sample would be far too small for obtaining statistically significant results, it may still seem reasonable to conclude that private and public companies tends to be equally efficient.

However, such a conclusion may be hasty. To see why, note that as DEA is quite flexible, each company tends to be compared to rather similar companies located in the 'neighbourhood' in the input-output space. For instance, B is evaluated against a linear combination of its 'neighbours' A and C while E is evaluated against a linear combination of its 'neighbours' D and F. Now, as A and C are public companies, the public company B is in effect evaluated against public companies. Correspondingly, the private company E is evaluated against the private companies D and F. Thus, as the two categories of companies are clustered in separate subspaces in the input-output space, each company tends to be evaluated against companies of the same rather than the opposite category of ownership. In such circumstances, making statistical inferences concerning the importance of ownership for efficiency seems dubious. To see why, suppose for the moment that there existed private companies G and H and public companies I and J producing at scales comparable to that of the public and private companies respectively. Such a situation is depicted in figure 2. As can be seen from the figure, the private companies D, E, F, G and H are all best practice efficient except for E. The public companies A, B, C, I and J on the other hand, are all being inefficient. Although such a sample would be too small for obtaining statistically significant results, it may still seem reasonable to conclude that public companies tends to be less efficient that their private counterparts.

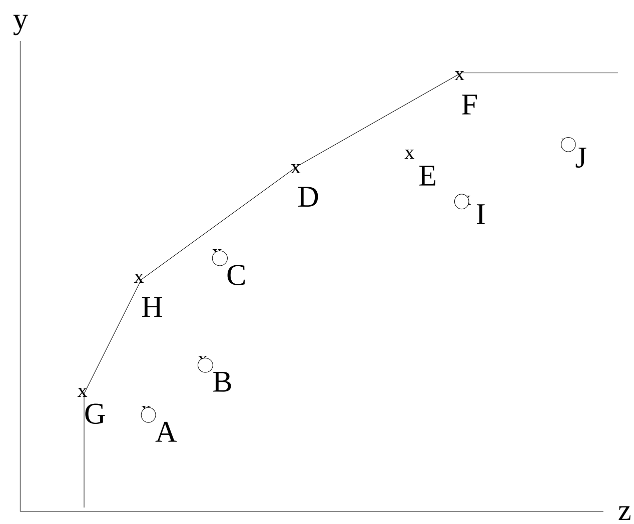

Figure 2

As can be seen by comparing the two examples as depicted in figure 1 and 2, clustering of private and public companies in separate subspaces in the input-output space may have severe effects on the conclusions concerning the importance of ownership for efficiency. Thus, if clustering is present, then making statistical inferences concerning the importance of ownership for efficiency seems dubious. Although in the simple single input - single output case, private and public companies may differ systematically only with respect to scale of production, in a multi input – multi output case the two categories of companies may also differ systematically regarding their composition of both outputs and inputs (in addition to scale of production).

The problem of clustering is of course only a potential problem. Regarding the comparison of private and public companies however, it may very well turn out to be a real problem for at least two reasons. Firstly, private and public companies may be expected to have divergent superior objectives possibly affecting their choice of scale of production or the composition of outputs or inputs. For instance, if the public authorities are concerned with unemployment, public companies may be more staff intensive than private companies solely concerned with maximising profits. Secondly, if the property rights theory is correct, managers of and employees in public companies will pursue their own personal goals to a larger extent then their counterparts in private companies. Several hypothesis have been put forward that may lead to systematic differences between public and private companies regarding the composition of inputs and outputs and the scale of production. For instance, Williamson (1964), De Alessi (1969) and Weatherby jr. (1971) argue that managers may have preferences for specific inputs (although they do not agree whether managers prefer capital intensive or labour intensive production) while Baumol (1959) and Niskanen (1971) argue that managers may have preferences for the size of their company.[5] Thus, one may expect private and public companies to differ regarding the scale of production and the composition of inputs and outputs. Consequently, we are in need of a method that detects clustering in order to make proper evaluations of the relative efficiency of private and public companies. This is the subject in the subsequent section.

5 Obtaining a proper subset of companies for cross-group evaluations of efficiency

The problem of clustering is a genuine data problem. Thus, if private and public companies are clustered in separate subspaces in the input-output space, the data does not permit a proper evaluation of the relative efficiency of the two categories of ownership. Although some clustering may be present, it may not be complete however, thus permitting comparisons to be undertaken on a subset of companies. More specifically, in Sunde (2001) it is suggested that a study comparing two categories of companies should include those companies that are found to be either efficient or inefficient as compared to at least one company in the opposite category. According to Sunde (2001), those companies that are technically inefficient as compared to at least one company in the opposite category, may be singled out by means of the following inclusion rule:

[5] One should also be aware of Migue & Belanger (1974) arguing that employees may have preferences for a "quiet life", leading to excess use of inputs and hence a technical inefficient production. However, this has a ‘neutral’ effect with regard to the composition of inputs and outputs and the scale of production.

Inclusion rule number 1: For each company in category J, construct a non-parametric frontier based on data for that company and all companies in the opposite category –J. Include those companies in category j obtaining an efficiency score unequal to unity.

The first inclusion rule simply involves evaluating each individual company against the companies in the opposite category. This may be illustrated by means of figure 3 where A, B and C are public companies while D, E and F are private companies. Consider the evaluation of the private companies relative to the public companies. According to inclusion rule number one, this involves the construction of a DEA frontier for each individual company based on data for that particular company and all public companies. In our case, we obtain DEA_D, DEA_E and DEA_F for the private companies D, E and F respectively. As can be seen, both E and F are located on their respective frontiers, thus being best practice efficient, obtaining an efficiency score equal to unity. This means that neither E nor F are inefficient as compared to any of the public companies. However, D is located off its corresponding frontier, thus being inefficient, obtaining an input-saving efficiency score less than unity or an output-increasing efficiency score exceeding unity. As a consequence, the private company D should be included. A similar procedure undertaken for the public companies will reveal that the public company C should be included.

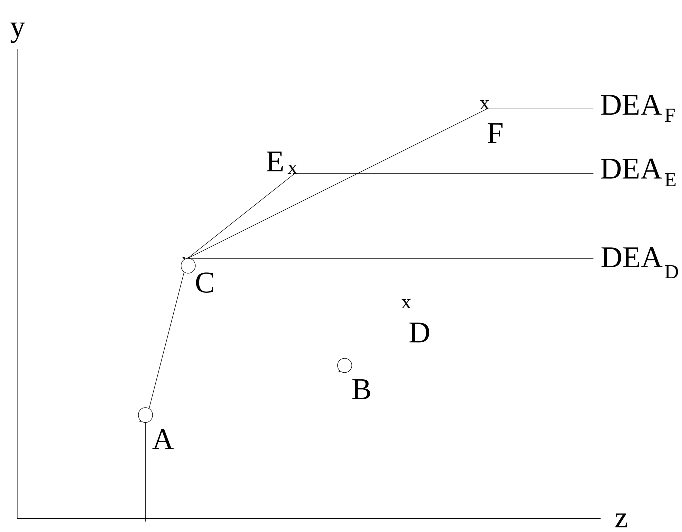

Figure 3

Now consider the detection of those companies that are technically efficient as compared to at least one company in the opposite category. From the definition of efficiency (Koopmans, 1951), it follows that if a company is to efficient as compared to a second company, then it must be possible to increase at least one output and/or decrease at least one input without simultaneously being forced to reduce at least one other output and/or increasing at least one other input. This calls for the construction of an 'inverse' DEA frontier enveloping the data from beneath rather than from above where the area north-west of the frontier contains those companies that are efficient. In figure 4, we have illustrated three such 'inverse' frontiers denoted by DEA_D^{-1}, DEA_E^{-1} and DEA_F^{-1} based on data for the public companies and the private companies D, E and F respectively.

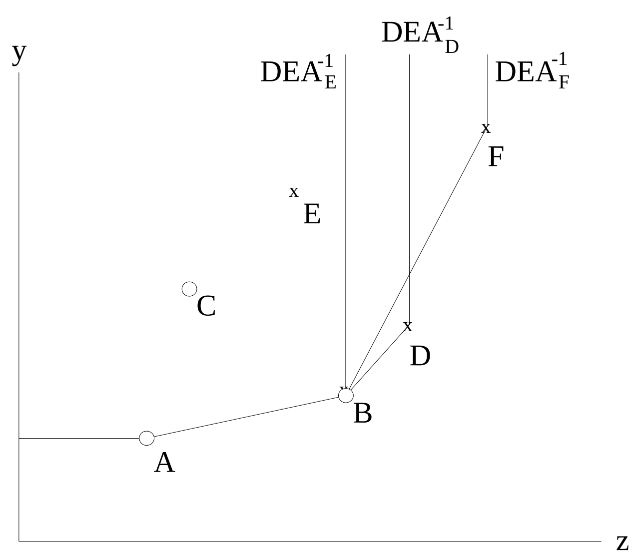

Figure 4

As can be seen, both D and F are located on their respective 'inverse' frontiers while E is located off its corresponding 'inverse' frontier. This means that only E is technically efficient as compared to at least one public company and should therefore be included according to Sunde (2001). In Sunde (2001) it is argued that such 'inverse' frontiers are straightforwardly obtained if inputs are substituted for outputs and vice versa. Further, it is argued that those companies that are technically efficient as compared to at least one company in the opposite category, may be singled out by means of the following inclusion rule:

Inclusion rule number 2: For each company in category j, construct a non-parametric frontier based on data for that company and all companies in the opposite category –J where inputs are treated as outputs and vice versa. Include those companies of category j obtaining an efficiency score unequal to unity.

Consequently, those companies that fails to survive neither of the two inclusion rules should be censored from the data set prior to making comparisons of the relative efficiency of private and public companies. Such a censoring may affect the results in two ways (Sunde, 2001). Firstly, as censoring necessarily implies that less companies are included in the study, statistical results may become less robust. Secondly, censoring may affect the efficiency scores for at least some of the individual companies.

6 The Data

DEA has previously been applied to the Norwegian bus industry by Odeck & Alkadi (forthcoming) in order to test for the importance of ownership for efficiency amongst others. In order to make the results in our study comparable to those of Odeck & Alkadi (forthcoming), we apply the same data set.

The data are obtained from the Norwegian Central Bureau of Statistics (CBS) for the year 1994. The database consists of data for 171 bus companies. However, quite a substantial share of the companies are very small companies whose main activities are school and/or charter transport. Also, some of the companies are also involved in sea and goods transport as well as public passenger transport by bus. In order to make sure that the companies are comparable, these bus companies where excluded from the data set, leaving us with 47 bus companies. Although these companies constitutes a rather modest share (about 27%) of the total number of bus companies, they are producing a major share (about 75%) of the total number of seat kilometers.

A study of the bus industry should include at least the major inputs and outputs associated with public transport. Essential inputs are buses, labour, fuel and various equipment (eg. tyres). All these inputs are obtainable from the CBS. As buses may vary in size, buses are measured in terms of the total number of seats. Labour is divided into drivers and staff, the latter reflecting both management and operational personnel excluding drivers. As wages differ among companies, drivers and staff is measured in terms of driving hours and the number of employees respectively. As the same holds for fuel, fuel is measured in litres. Equipment is a composite of various equipment and is thus measured in monetary terms.

The choice of outputs is however a highly controversial issue in the literature dealing with the measurement of efficiency in the bus industry; see for instance De Borger & Kerstens (2000). Several alternative output measures have been proposed and applied, amongst which seat kilometers and passenger kilometers are most common, the former being related to supply while the latter being related to demand. As DEA readily accommodates multiple outputs however, this problem may be side-stepped by simply including both measures of output which are available from the CBS. This is in line with Odeck & Alkadi (forthcomming) [6] Summary statistics for the outputs and inputs for the uncensored (original) data set is given in table 1.

Table 1: Summary statistics for uncensored data

	Inputs					Outputs	
	Fuel	Equip.*	Staff	Driving Hours	Seats	Seat Km**	Pass. Km**
Total	51135	205084	1390	7340163	143353	7568792	1605421
Min	165	464	2	17395	133	16347	2399
Average	1088	4364	30	156174	3050	161038	34158
Max	2920	16463	141	532581	15750	586045	124596
SD	715	3391	25	124641	2496	135659	28656

* In 1000 NOK
** In 1000 km

By applying the procedure described in section 5, we revealed 15 bus companies that should be censored from the data set of which 5 where public and the remaining 10 where private. This left us with 16 public companies and 16 private companies, a total of 32 companies. In other words, 68% of the companies in the original data set where found to be sufficiently similar to companies of the opposite category so as to be included in the study. Summary statistics for the outputs and inputs for the censored data set is given in table 2.

Table 2: Summary statistics for censored data

	Inputs					Outputs	
	Fuel	Equip.*	Staff	Driving Hours	Seats	Seat Km**	Pass. km**
Total	36831	151476	1069	5433547	104952	5553252	1153138
Min	165	464	4	17395	133	16347	2399
Average	1150	4734	33	169798	3280	173539	36036
Max	2920	16463	141	532581	15750	586045	124596
SD	762	3663	29	138209	2843	148278	31504

* In 1000 NOK
** In 1000 km

7 Empirical results

As both Odeck & Alkadi (forthcomming) and Jørgensen et al (1995) have rejected the assumption of constant returns to scale in the Norwegian bus industry, we applied the variable returns to scale model.[7] Both input-saving and output-increasing measures of efficiency were obtained by solving (3.1) – (3.5) and (3.6) – (3.10) respectively for each individual company for both the censored and the uncensored data set. The summary results are presented for public bus companies, private bus companies and the pool of both public and private bus companies in tables 3,4 and 5 respectively. Column 1 and 4 presents the summary results for the efficiency scores obtained from the uncensored data set for the input-saving and output-increasing model respectively. Column 3 and 6 presents the corresponding summary results for the efficiency scores obtained from the censored data set. In addition, column 2 and 5 presents the summary results for the efficiency scores obtained from the uncensored data set, but censored for the companies found to be excluded in the previous section.

[6] It should be noted that passenger kilometers are highly correlated with seat kilometers.
[7] More specifically, Odeck & Alkadi (forthcomming) and Jørgensen et al (1995) have rejected constant returns to scale for small companies.

Table 3: Summary results – Public Bus Companies

	Input-saving			Output-increasing		
	1	2	3	4	5	6
Min	0,55	0,55	0,59	1	1	1
Mean	0,88	0,84	0,89	1,21	1,27	1,20
Median	0,95	0,90	0,99	1,05	1,12	1,01
Max	1	1	1	1,89	1,89	1,57
SD	0,16	0,17	0,14	0,28	0,31	0,25
No. of efficient units	9	6	8	9	6	8
No. of units	21	16	16	21	16	16

Table 4: Summary results – Private Bus Companies

	Input-saving			Output-increasing		
	1	2	3	4	5	6
Min	0,58	0,58	0,61	1	1	1
Mean	0,81	0,76	0,84	1,29	1,38	1,23
Median	0,78	0,77	0,82	1,33	1,36	1,17
Max	1	1	1	1,76	1,76	1,69
SD	0,15	0,14	0,14	0,25	0,25	0,24
No. of efficient units	8	3	4	8	3	4
No. of units	26	16	16	26	16	16

Table 5: Summary results – Pooled

	Input-saving			Output-increasing		
	1	2	3	4	5	6
Min	0,55	0,55	0,59	1	1	1
Mean	0,84	0,80	0,86	1,25	1,32	1,21
Median	0,87	0,79	0,86	1,18	1,33	1,12
Max	1	1	1	1,89	1,89	1,69
SD	0,16	0,16	0,14	0,27	0,28	0,24
No. of efficient units	17	9	12	17	9	12
No. of units	47	32	32	47	32	32

First, consider the importance of censoring for the efficiency scores. Recall that a total of 15 companies have been censored from the data set. Further, recall that this may affect not only the statistical robustness of the study, but possibly also the efficiency scores of at least some of the companies. By comparing models 2 and 3 and models 5 and 6 respectively, we can infer from table 2 that mean efficiency scores for both private and public companies are improved by censoring, a finding that is hardly surprising. Concerning the influence on individual efficiency scores however, the correlation coefficients are found to be 0,88 and 0,84 for the input-saving and the output-increasing models respectively.

Now we turn to the main issue being the importance of ownership. By comparing the mean efficiency scores reported in tables 3 and 4, we note that private companies seems to be somewhat less efficient than their public counterparts, a finding that counters the property rights hypothesis. In order to test whether this difference is significant however, we apply the non-parametric Mann-Whitney (or Wilcoxon) rank test in order to infer whether two groups have identical populations or not. This is obtained by the following procedure:

1. Split the efficiency scores in the two groups that are to be compared.
2. Pool the groups and rank in increasing order of magnitude.
3. Calculate the rank sum S of the first group

The distribution of the rank sum statistic S is approximately normal with mean m(m + n + 1)/2 and variance mn(m + n + 1)/12 where m is the number of observations in the first group and n is the number of observations in the second group. By normalising S, we obtain the test statistics:

$$Z = \frac{S - \frac{n+m+1}{2}}{\sqrt{\frac{mn(m+n+1)}{12}}}$$

The rejection region for the Z statistics can be determined by using the standard normal distribution. More specifically, we reject the hypothesis that the two groups have the same population if Z is less than minus $Z_{\alpha/2}$ or greater than $Z_{\alpha/2}$ where α is the level of significance. The results of the various Mann-Whitney tests undertaken in this study are reported in table 6.

Table 6: Summary of Mann-Whitney tests

	Input-saving			Output-increasing		
	1	2	3	4	5	6
Ownership	-1,393 (0,164)	-1,296 (0,195)	-1,201 (0,230)	-0,921 (0,357)	-1,048 (0,294)	-0,910 (0,363)

For a level of significance of α = 0,05 (5%), we obtain $Z_{0,025}$ = 1,96. Thus, unless test statistics exceeds 1,96 or falls below –1,96, we cannot reject the null hypotheses that the efficiency scores for private and public companies come from the same sample. As can be seen, none of the test statistics falls outside this interval. This goes for both the censored and the uncensored (original) data set. Thus, we must conclude that censoring the data set as suggested in Sunde (2001) does not seem to have any significant effect on the findings in this case. Further, we cannot reject the null hypothesis that the efficiency scores for private and public companies come from the same sample. Consequently, we conclude that ownership seems to have no significant effect on efficiency. This finding is in line with several of the more recent DEA studies of the bus industry dealing with the importance of ownership for efficiency, amongst others Odeck & Alkadi (forthcoming) applying DEA on the data set used in this study.

8 Concluding remarks

The aim of this paper has been to throw some further light on the significance of ownership for efficiency, both in general and for the bus industry in particular. The motivation for this study has been twofold. Firstly, although several studies have been undertaken, the literature is inconclusive. Secondly and more importantly, most of the recent studies apply DEA without making sure that private and public companies are sufficiently similar to be comparable by means of DEA. More specifically, several hypothesis have been put forward that if the property rights theory is correct, then we may expect private and public companies to differ systematically regarding their scale of production and/or their composition of inputs and outputs. This being the case, private and public companies will tend to be clustered in separate subspaces in the input-output space. As DEA is acclaimed for being a flexible tool for efficiency measurement, letting the data reveal the possibly complex relationship between inputs and outputs, each company is most likely to be evaluated to similar companies being located in the ‘neighbourhood’ in the production possibility space. As a consequence, clustering will imply that most companies will be evaluated against companies in their own category rather than the opposite category. In order to avoid this pitfall, we have applied a method that allows us to reveal those private and public companies that are comparable and consequently should be included in a DEA study. The method has been applied on a sample of 47 Norwegian bus companies of which 15 where censored due to being too dissimilar to be included in a test of the property rights theory.

Based on the censored data set, input-saving efficiency measures where obtained for each and every company. The property rights theory was tested by means of non-parametric Mann-Whitney rank tests. Albeit public bus companies turned out to be more efficient than their private counterparts on average, a finding contradicting the property rights hypothesis, the difference is quite small and statistically insignificant. Thus, our study does not support the property rights hypothesis that private ownership is superior to public ownership. This is a finding in line with several of the more recent studies applying DEA on the bus industry.

Efficiency scores were also obtained for the uncensored data. As for the censored data set, ownership had no significant influence on average efficiency. Thus, the censoring seems to have had no (or at least minor) effect on the results. This is not to say that censoring might be unimportant when evaluating the relative efficiency of private and public companies in other industries. We can think of several reasons for this. For instance, in the Norwegian bus industry output is determined by the local authorities and not left to the discretion of the companies. As a consequence, the companies are not free to escalate the scale of their production. Further, there are quite small possibilities of substitution in the bus industry (Berechman, 1993) so that the managers in the bus industry lacks the opportunity to pursue their desire for specific inputs. Thus, in other industries where output is less regulated and possibilities of substitution more significant, censoring may turn out to be of major importance.

It should be noted that although censoring enables one to control for the possibility that private and public companies are too dissimilar to be compared by means of DEA, several unresolved issues remain. A fundamental issue is causality, that is whether ownership affects efficiency or the other way round (that is, efficiency affects ownership).

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