Cost Efficiency in Swedish Public Transport

Andreas Vigren[a]

[a] *Transport Economics, Swedish National Road and Transport Research Institute (VTI), Box 55685, SE-102 15 Stockholm, Sweden. +46 (0)70-943 04 38. andreas.vigren@vti.se*

Keywords:
Cost, Efficiency, Public Transport, Bus, Stochastic Frontier, Public Transport Authorities, Tendering

Classification codes:
R40, D24, C13, C21

ABSTRACT

The last couple of years, costs in Swedish public transport have increased substantially, and there are little knowledge in what affect the same. This study aims at determining how different contractual and environmental factors affect cost efficiency, and whether cost efficiency differs between Public Transport Authorities (PTA). A cost frontier is estimated using stochastic frontier analysis and contract-level data from year 2013 for the 21 PTAs. The main findings are that cost efficiency is lower if the contract is operating in areas with high population density, or if the traffic is supplied by a publicly owned operator without having used competitive tendering. Further, no major differences in cost efficiency across PTAs are found, with the exception of the counties of Stockholm and Skåne, both counties with high population density, and the county of Västmanland where all public transport is provided without competitive tendering. The finding of lower cost efficiency in high-dense areas calls for further investigation in why this is. Potential explanations are the need for higher peak-capacity, or more complex transportation systems. Finally, usage of direct-awarding of public transport should be clearly motivated as this seem affect cost efficiency.

1. Introduction

For about two decades, competitive tendering has been the dominating tool for providing public transport services in Sweden. Competitive tendering initially lowered costs in tendered contracts, but have later increased with additional tendering rounds (Alexandersson and Pyddoke, 2010). National statistics also suggest that CPI-adjusted costs have increased with 50 percent the last seven years[1], compared to a 20 percent increase in patronage and supply (Transport Analysis, 2015). Further, Nilsson (2011) discuss the public transport providers' lack of monitoring outcomes in contract-design. Policy makers do not seldom lack knowledge about what the effects are from different specifications in tendered contracts, and control mechanisms are often missing. For example, new types of contracts could be introduced without having a plan for how these should be evaluated.

The purpose of this paper is to investigate how common contract-types (the gross-cost and incentives contracts) and contract-design factors in the Swedish public transport system affect the cost efficiency in the Public Transport Authorities' (PTA) bus contracts. The purpose is also to make a comparison across PTAs in order to evaluate if some PTAs are systematically less efficient.

There are few studies investigating how contract-design factors affect cost efficiency for Sweden. The reason for this is most probably lack of data at lower aggregation than county-level, something that this paper have access to. Holmgren (2013) estimate the average cost efficiency for Swedish counties between 1986 and 2009 using a stochastic frontier approach. The data is on county-level, and for all transport modes. The main finding is that the overall inefficiencies have increased during the time period, but due to the aggregate level of the data no conclusions can be made on what have caused the development. Cost drivers in public transport are analyzed in Vigren (2014) where the main findings are that costs increase with density, as well as providing the services with publicly owned operators. Further, the use of incentives payment do not yield higher costs compared to gross-cost contracts. While Vigren (2014) is concerned with what affect costs in general, the present paper will focus on what factors are driving inefficiency. This in turn allows for comparison across PTAs and can provide policy implications for how contracts can be better designed to get more public transport for the money. Compared to Holmgren (2013), this paper will also be concerned with more disaggregate data, and only one transportation mode, bus, which allows for more detailed and heterogeneous analysis.

Studies analyzing cost efficiency are more common internationally, including studies focusing on the effects from operational and contract factors. The dominating analysis method is the stochastic frontier analysis which all the studies discussed in this section use, if not stated otherwise. For multi-modal operators in Germany, Walter (2011) finds that a higher degree of outsourcing (paying, for example, subsidiaries for materials) and higher vehicle utilization rate of rail cars both increase cost efficiency. Cost efficiency in private versus public operator ownership have been investigated for Italy by Ottoz et al. (2009), and Filippini and Prioni (2003) for Switzerland. Both find evidence of lower cost efficiency in publicly owned operators, compared to the privately owned. Using a dynamic ARCH error structure methodology, Karlaftis (2010) has similar findings for a set of European cities where regulatory schemes introducing competition for public transport services are associated with higher cost efficiency than direct awarding processes. Also, on the issue of contracting schemes, Dalen and Gómez-

[1] Official statistics for Swedish public transport are only comparable from year 2007 and later.

Lobo (2003) find for Norway that an operator-yard-stick competition (competition between operators) type of contract, which have a high-powered incentives component, is more cost efficient that its counterparts. Similar findings for Italy are made by Piacenza (2006) where the traditional cost-plus contract yield lower cost efficiency estimates than the gross-cost contract.

The present paper will use the same methodology as most cost efficiency studies mentioned above, the stochastic frontier analysis. The data presented later, is on contract-level, and allows to include contract specific factors in the analysis. This will give a more disaggregate analysis than previously made in Swedish public transport, and will also allow for investigation of various contracting factors affecting cost efficiency.

The remaining paper is organized as follows: Section 2 describes the Swedish public transport system, and Section 3 discusses the methodological approach in model and variables. Section 4 presents the data used in the model, Section 5 presents the results from the estimated model, and Section 6 concludes the paper.

2. The Swedish Public Transport System

In Sweden, local and regional public transport services can be provided in three ways: tendered and subsidized by the PTA, directly awarded (usually to a publicly owned operator), or commercially by the operators themselves. As it is hard to operate commercial traffic alongside subsidized, the share of commercial public transport is only about two percent of the total regional public transport provision by bus (Transport Analysis, 2014). For the remainder of the paper, the term public transport will refer to public transport provided by bus if not stated otherwise.

All subsidized public transport services are provided by the 21 PTAs, which are responsible for the traffic in their respective county. That is, there is one PTA in each county meaning that the expressions PTA and county can be used interchangeably. The PTAs regularly establish a "traffic supply program" in which the needs of public transport are projected, and how these needs are met. The PTA can choose to provide all, or parts, of the traffic by competitive tendering, through operators owned by themselves (or via the county or municipal administration), or in principle let commercial actors provide the traffic and abstain public involvement. The last case is yet very rare.

Competitive tendering in public transport has been used in Sweden since the reform of public transport in 1989 when the system of operator exclusive licenses was gradually abolished and the PTAs were given responsibility for the traffic provision in each county (Jansson and Wallin, 1991). While competitive tendering was not mandatory, the supply share of competitively tendered traffic increased from seven percent in the late 1980's, to 70 percent in 1995 (Alexandersson et al., 1998). Today, competitive tendering constitute over 90 percent of the total supply of public transport services, while provision via publicly owned operators and commercial public transport represent about five percent each. The high share of competitive tendering imply that there exist many private operators, which operate the traffic. The operators supply most of the input factors themselves, such as buses and labor, which leaves the PTA as a pure purchaser of traffic.

2.1 Contract-types

In practice, there are three different types of contract in Swedish public transport: gross-cost (fixed-price), concession (net-cost), and incentives contracts where the main differences are on the degree of influence by the operator, and the share of payment based on performance. Below, each contract-type is described based on the model contract and bus specification norms (Buss 2010) set up by the industry co-operation project "The Doubling Project", a project in which most parties of the Swedish public transport sector is involved in. The project tries to set contracting standards for the PTAs to use when tendering bus contracts. See Nilsson and Jonsson (2011) for a discussion on tendered rail contracts.

In the gross-cost contract, the operator receives a fixed payment based on the supply of, for example, vehicle kilometers driven in the specific contracting area. After the tendering round, this payment is independent of the ex-post costs of the operator and is therefore by itself an incentive to keep costs low compared to a cost-plus scheme. Also, the PTA to a large extent specifies the routes to be operated, the time table, and what bus specifications to use. The operator's influence is limited, and it does not carry much risk apart from production. In 2013, about 80 percent of all tendered public transport contracts had the gross-cost setup according to the data.

In contrast to the gross-cost, the concession contract lets the operator influence the service to a much higher degree in order to create incentives to, for example, increase patronage, improve the service quality, and punctuality. When the influence of the operator increases, so does also its risk. In the concession contract, the majority of the payment comes from ticketing revenues associated with the traffic, which is thought to trigger an improved quality from the operator. However, a subsidy is usually needed and is paid by the PTA. This type of contract in practice only exist in three instances in Sweden.

Finally, the incentives contract is a mix of the two previous contract-types. There is no clear definition of the contract-type, but the main idea is to base some of the operator's payment on a performance measure in order to get the same to improve some aspects of the public transport system. Such performance do, most often, relate to patronage, or quality aspects such as customer satisfaction. The performance enters the operator's payment by affecting, most commonly, a share of the total payment, or by constituting a per unit payment. The model contracts agreed upon by the industry states that this share should not be lower than 25 percent, but in practice the incentives contract usually have smaller shares. With performance affecting payment, and thus increasing the risk for the operator, the PTA is also expected to give the operator more influence in the operations. As there is no clear separation between a gross-cost and incentives contract, this paper will use the term gross-cost contract for contracts with a share of incentives payment lower than five percent. In the remainder of the paper, the term incentives contract will refer to contract with a payment based on performance. That is, no distinction is made with respect to type or size of incentives.

Even though the industry has agreed upon these definitions and model contracts, the compliance varies across PTAs. While about 60 percent of the PTAs involve the operator in the time table design, only 30 percent follow the bus specification norms (The Swedish Bus and Coach Federation, 2014). Further, from the data to be used in the empirical analysis it is evident that the recommendation to use at least a 25 percent share of incentives payment in incentives contracts is not complied with. These circumstances indicate that the planning and contract-design process are heterogeneous across the PTAs, and that there might exist good or worse examples in the public transport provision.

Next, a methodological framework used to study the efficiencies and factors driving the same is presented.

3. Methodology

Inefficiency analysis often estimate a cost or production frontier, where some of the deviation from the frontier are attributed as inefficiency. In distinguishing between actual inefficiencies and random noise, Aigner et al. (1977) and Meeusen and Van der Broeck (1977) estimated a parametric model where these two effects could be separated and created the foundation of the stochastic frontier analysis (SFA). A standard cost frontier model could be defined as

$$C_{rs} = f(y_{rs}, w_{io}, z_{rs}; \beta) + \exp(v_{rs}) + \exp(u_{rs}) \quad (1)$$

where C_{rs} is total costs for contract *s* in region *r* and *f(.)* a cost function which can take different functional forms, for example Cobb-Douglas or translog. y_{rs} is a vector of output, w_{io} is a vector of input prices for operator *o*, z_{rs} a set of environmental and contract specific variables, β is a vector of parameters to be estimated, v_{rs} is a random noise term, and $u_{rs} \geq 0$ is contract specific inefficiency term. v_{rs} is assumed to have a two-sided normal distribution with zero mean and constant variance, and also to be independent of the regressors in *f(.)* and u_{rs}. The other components in Equation (1) will be discussed in detail in the remainder of this section.

As for the selection of output variable, there is a discussion in the literature whether to use demand or supply-related measures. De Borger et al. (2002) note that demand-related indicators do not vary with inputs and that the operator cannot control the demand to a great extent. Thus, using passenger kilometers as output measure would only account for the kilometers actually traveled by passengers, not the distance driven by the bus which a supply-related measure would capture. Supply-related measures are also common in the previous literature, for example in Farsi et al. (2006), Sakano and Obeng (2012), and Walter (2011). Here, the supply-related measure vehicle kilometers is used as output variable.

Two input factor prices are included in the model: price of labor and capital. As noted earlier, most input factors are supplied by the operators themselves, not the PTAs. Having information of which operator is charge of which contract, operator specific information can be mapped with the contract data. The price of labor is obtained by dividing total labor expenses of the operator with the number of employees from the annual reports for year 2013.

The capital input factor refer to the capital stock used by the operator, in this case the buses. Neither the contract data set, nor the operators' annual reports contain explicit information about any other expenses except labor. This restricts the calculation of more input prices as expenses for separate inputs are not possible to disentangle. However, an approach by Obeng (2013) define a user price for capital which will be utilized in this analysis. A standard cost of each of the operator's buses *b* in one year is calculated as $w_b = P_b(r + d)\exp(-d\lambda)$ where P_b is the price of the bus, *r* the prime rate, *d* the depreciation rate, and λ the age of the bus. The buses of each operator in year 2013 and their technical information is identified using the Swedish Road and Transport Agency's Road Traffic Registry (Transportstyrelsens Vägtrafikregister). The depreciation rate is set to 0.15, which is an average measure from the operators' annual reports. The prime rate is 0.02 (2 percent). P_b of each bus is not observed in the registry data. Therefore, four different bus types are defined (mini-bus, city bus, regional bus, and coach) and identified in the registry data by VIN[2] or model type. Also, a standard price for each category is set using bus price data from tendering specifications or retail prices which forms P_b. Summing over all buses B of operator o, the total cost of capital (TCC_o) for single operator is calculated as

$$TCC_O = \sum_{b=1}^{B} w_b = \sum_{b=1}^{B} P_b(r+d)\exp(-d\lambda) = \sum_{b=1}^{B} P_b(0.02+0.15)\exp(-0.15\lambda)$$

Finally, the price of capital (w_{co}) is defined as the mean of TCC_o and represent the average capital cost for operator o. In the analysis, this input factor is referred to as expenses related to capital (that is, for example, fuel and maintenance as well) as more input factors are hard to define. Both the price of labor and capital are, in a sense, averages of the operators' prices for each factor. This means that these two variables do not take into account county heterogeneity. In order to cope with this potential problem, county-specific dummy variables are introduced which could capture some of this variation.

The inefficiency term u_{rs} introduced in Equation (1) is of particular interest in this paper, as contract and county efficiency are analyzed. As mentioned in Section 2, county efficiency is equivalent to efficiency of each PTA. Whatever variance that cannot be attributed to the cost frontier or random noise term is labeled inefficiency, which in turn means that differences in operating and contract environment (heterogeneity) must be accounted for (Kumbhakar et al., 2015). There will be five variables included intended to capture such effects, and is referred to as environmental variables, in line with Coelli et al. (1999). The five variables are discussed in turn.

The density of a contracting area could affect costs in several ways. For example, higher dwell-time and associated delays (Balcombe et al., 2004) increase demand for buses in peak-hour and specific bus design requirements, which in turn increase costs. Walter (2011) include population in each area to account for this effect, while Piacenza (2006) measure similar effects using average commercial vehicle speed. From the data, the municipalities each contract is operated in can be identified which allows for construction of a density measure. The measure used is the population density per square kilometer.

Filippini and Prioni (2003) investigate the impact of ownership on firm cost efficiency when the traffic is operated by a publicly owned operator and some evidence of lower cost for private firms. Ottoz et al. (2009) perform a similar analysis, but do also include variables indicating the size of the operators and find that both public and large operators are less efficient. In this analysis, two dummy variables are included indicating contracts that are directly awarded to a publicly owned operator[3], and the five largest operators in terms of turnover in year 2013[4].

Finally, two contract specific variables are included; one measuring the contracting term in number of years, and another indicating contracts with a share of incentives payment over five percent. As contract terms differ both within and between PTAs, the former variable is included in order to account for potential differences in agreed-upon contracting length. The latter variable capture effects related to the behavior of the operator, as discussed in Vigren (2014).

[2] Vehicle Identification Number

[3] In Sweden, only publicly owned operators have directly awarded contracts.

[4] The five largest operators in terms of turnover are (in order): Nobina, Keolis, Transdev (Veolia Transport), Arriva, and Nettbuss.

When using an incentives contract, some of the risk is levied from the PTA to the operator, and imply that the operator will account for a risk premium in its bid. This would in turn cause higher costs for this type of contract, compared to a gross-cost contract. Similar approaches are used in, for example, Roy and Yvrande-Billon (2007). Up to this point, the model can be defined as

$$\ln C_{rs} = \beta_0 + \beta_y \ln y_{rs} + \sum_{i=1}^{I} \beta_i \ln w_{io} + \frac{1}{2}\left(\sum_{i=1}^{I}\sum_{j=1}^{I} \zeta_{ij} \ln w_{io} \ln w_{jo} + \zeta_{yy} \ln y_{rs}^2 \right) + \sum_{i=1}^{I} \zeta_{iy} \ln w_{io} \ln y_{rs} + \sum_{k=1}^{K} \theta_k z_{krs} + \tau_r R + \epsilon_{rs} \quad (2)$$

with I = 2 input factor prices and K = 5 environmental variables defined above. Further, $\epsilon_{rs} = u_{rs} + v_{rs}$, R is a vector of county dummy variables, and the Greek letters is parameters to be estimated. A translog functional form evaluated at the mean is imposed, which include cross-multiplications of the output and input price variables. The coefficients associated with these variables (ζ) affect the curvature of the cost function. Finally, three constraints are imposed to ensure linear homogeneity in input prices

$$\sum_{i=1}^{I} \beta_i = 1, \text{ and } \sum_{i=1}^{I}\sum_{j=1}^{I} \zeta_{ij} = \sum_{i=1}^{I} \zeta_{iy} = 0$$

The model is estimated using a one-step maximum likelihood estimator. For this, a distributional assumptions for the inefficiency term u_{rs} is needed, which will be discussed next.

3.1 Inefficiency and environmental variables

The two most popular distributions in the cost frontier modeling and public transport efficiency literature are the half-normal and truncated normal distribution where the main difference is in how the mean of the normal distribution is handled. The truncated normal distribution can be written as

$$u_{rs} \sim N^{+}[m, \sigma_u^2], \quad (3)$$

which is a non-negative truncation of a normal distribution with mean *m* and constant variance σ^2_u. As *m* is not fixed, the mean of the truncated normal distribution is allowed to vary. Further, an appealing feature of the truncated-normal distribution is the possibility to model the mean by including exogenous explanatory variables and have observation specific m_{rs} (Battese and Coelli, 1995). This allows for investigation in how different factors affect the shape of the inefficiency, which could be used to make inferences for the same. In contrast to the truncated-normal, the half-normal distribution is a truncation of a normal distribution with zero mean (*m=0*). This imposes limitations on the flexibility of the model, but decreases the complexity of the maximum likelihood estimator (Kumbhakar et al., 2015). Although the choice of distribution varies in previous studies, we acknowledge that the estimated efficiencies are very robust across distributions (Greene, 2008).

The possibility to include explanatory variables in m_{rs} gives two approaches for where to put the environmental variables *z*: directly in the cost frontier (Model I), or in the inefficiency term

m_{rs} (Model II). In Model II, m is defined as $\delta_0 + \sum_{k=1}^{K} \delta_k z_{krs}$,[5] where the δs' are coefficients to be estimated. In the forthcoming analysis, Model I is estimated using a half-normal distribution, and Model II using a truncated normal distribution. The reason for this is problems of convergence using the truncated normal distribution for Model I. This problem is also noted by, for example, Kumbhakar et al. (2015).

In order to determine where to put *z*, the testing procedure outlined in Coelli et al. (1999) is used. The two models are nested in each other, thus creating a Model III with *z* in both the cost frontier and inefficiency term. A LR-test of each model against Model III is performed, with null hypothesis that neither of the two other models differ from Model III. If only one model (for example Model I) has a significant test statistic, the other model (Model II) is more appropriate to use.

Related to the placement of the *z* variables, Coelli et al. (1999) note two important issues regarding the estimated efficiencies. First, including *z* in the frontier produces "net efficiencies". Here all environmental effects are accounted for in the cost frontier, and the estimated efficiencies are "purged" of the environmental conditions. Second, including *z* in the inefficiency term produces "gross efficiencies". That is, the estimated efficiencies from the estimation include the effects of the environmental conditions and are thus gross measures of efficiency. Coelli et al. (1999) propose that net efficiencies are measures of managerial skill as all contracts, and thus PTAs, are compared using the most favorable operating conditions. Those skills could relate to, for example, tendering. Further, the ratio between net and gross efficiency provide a measure for how much environmental factors affect the contract.

The net efficiencies for Model I is obtained using the Jondrow et al. (1982) estimator with the residual term ε_{rs} of Equation (2). Following Coelli et al. (1999) and Abdul-Majid et al. (2011), the gross efficiencies of Model I is obtained replacing ε_{rs} with

$$\epsilon_{\text{rs}}^{\text{gross}} = \epsilon_{rs} + \sum_{k=1}^{K} \theta_k z_{krs} - \min\left[\sum_{k=1}^{K} \theta_k z_{krs}\right].$$

Following Battese and Coelli (1993), the gross efficiency for Model II can be calculated as

$$CE_{rs} = \mathbb{E}[\exp(-u_{rs}|\epsilon_{rs})]$$

$$= \left[\exp\left(-\mu_{rs} + \frac{1}{2}\sigma_*^2\right)\right]\left[\Phi\left(\frac{\mu_{rs}}{\sqrt{\sigma_*^2}} - \sigma_*\right) / \, \Phi\left(\frac{\mu_{rs}}{\sqrt{\sigma_*^2}}\right)\right] \in (0,1)$$

where ϕ is the cumulative standard normal distribution function,

$$\mu_{rs} = (1-\gamma) \cdot m_{rs} + \gamma\epsilon_{rs}\,, \qquad (4)$$

$$\gamma = \sigma_u^2/\sigma^2,$$

$$\sigma^2 = \sigma_u^2 + \sigma_v^2$$

and

[5] When *z* is included in the inefficiency term in Model II, all θs in Equation (2) are zero.

$$\sigma_*^2 = \gamma(1-\gamma)\sigma^2.$$

In order to obtain the net efficiency, m_{rs} in Equation (4) is replaced by $\min[m_{rs}]$ (Coelli et al., 1999).

Finally, both the gross and net efficiencies take values between 0 and 1, where higher numbers indicate higher cost efficiency.

3.2 Heteroscedasticity in the error terms

Wang and Schmidt (2002) discuss the issue of heteroscedasticity and note that heteroscedastic error terms in the stochastic frontier model could affect the estimates. The fact that logs are used in the model, as well as the variables being standardized with their means should, however, decrease the seriousness of potential heteroscedasticity. Wang (2002) propose a model where the vector of explanatory variables in m_{rs} is included as explanatory variables in the variance term σ^2_u. When using this approach in the analysis, no larger changes in coefficient estimates in the model, nor in the efficiencies, are found. The same holds for the level of significance of the coefficients and AIC (Akaike Information Criterion). This suggest no major influence of potential heteroscedasticity. A possible explanation for this is the logarithmic scaling and normalizing by the mean of all continuous variables, as well as using robust standard errors.

4. Data

The data used in the analysis is a cross-section of 282 active public transport bus contracts in year 2013 operated by all 21 PTAs. This is the database of active public transport contracts collected by the Swedish authority Transport Analysis (Trafikanalys) contains information about cost, supply, and design factors for each public transport contract in Sweden and are reported by the PTAs themselves. The data is the same as used in Vigren (2014), but for year 2013 in the present study. In addition, three more data sources are merged into the contract data in order to create a richer set of variables. These three data sources are annual report data from the Swedish Companies and Registration Office (Bolagsverket), vehicle data from the Swedish Road and Transport Agency's Road Traffic Registry (RTR) (Transportstyrelsens vägtrafikregister), and population density information from Statistics Sweden (SCB).

Table 1 shows descriptive statistics for contractual variables at county (PTA) level and shows contract types, operator types, and county characteristics in terms of payment, supply, contracting length, and density. The first column shows that the number of contracts varies substantially between counties. Although a few contracts are missing, the variation in number of contracts is not due to missing observations, but rather differences in how the PTAs choose to divide the county into contracting areas. For example, in the county of Dalarna, all public transport is organized in one single contract, while Västra Götaland, which is of similar area size, has an approach with 52 contracting areas.

Column two and three show the number of gross-cost and incentives contracts used by the PTA. The gross-cost contracts dominate, and the data suggests that the most high-powered incentives is found in Stockholm and Gävleborg, while many other PTAs let a much smaller share of the total payment to depend on performance.

	Total	Contract type Gross-C	Inc.	Operator type Public	Large	Mean payment Mkr	Mean vehicle km. kkm	Mean length years	Mean density pop/km²
Blekinge	1	1	0	0	0	178	8,734	8.63	57
Dalarna	1	1	0	0	1	387	15,900	8.00	18
Gotland	2	2	0	0	0	16	1,162	10.02	18
Gävleborg	3	0	3	0	0	127	5,476	7.67	34
Halland	7	5	2	0	2	44	1,612	8.04	55
Jämtland	7	6	1	0	0	34	1,629	5.56	10
Jönköping	2	1	1	0	2	170	5,761	9.00	64
Kalmar	6	6	0	0	1	39	1,488	6.00	15
Kronoberg	23	23	0	0	2	15	644	9.44	23
Norrbotten	50	40	10	1	2	7	276	5.02	7
Skåne	29	22	7	0	22	80	2,067	8.52	380
Stockholm	19	12	7	0	18	289	6,741	9.99	1,351
Södermanland	4	2	2	0	3	107	4,016	6.08	52
Uppsala	5	3	2	1	1	186	7,808	7.15	71
Värmland	9	8	1	0	4	45	1,849	9.95	39
Västerbotten	18	18	0	0	1	8	434	6.83	6
Västernorrland	16	15	1	0	10	23	771	9.34	15
Västmanland	2	2	0	1	0	162	4,372	7.32	31
Västra Götland	52	28	24	0	36	65	2,148	8.55	263
Örebro	4	4	0	0	3	82	2,650	6.75	58
Östergötland	21	21	0	0	6	26	766	4.66	54

Table 1. County-wise descriptive statistics

Only three of 282 contracts are operated by publicly owned operators[6], that is, an operator owned by a Swedish municipal or county council, as shown in column six. While two of the operators provide traffic only in urban areas, the county of Västmanland use a public operator (Västerås Lokaltrafik) for almost all public transport in the county. Further, the traffic operated by these companies are awarded without competitive tendering, and the operators could also have lower incentives for profit maximizing behavior. Column seven show the number of contracts operated by one of the five largest operators in Sweden. The large operators are present in almost all counties, and often operate more than half of the total number of contracts.

The four last columns show the average annual payment, supply, contracting length and population density per contract for each PTA. The average payment and supply of course depend on the total number of contracts in the county. The average contracting length for Swedish bus contracts is almost eight years. Three PTAs (Jämtland, Norrbotten, and Östergötland) stand out with comparatively short average contracting lengths, about five years. In contrast, Stockholm and Gotland have an average contracting length of ten years. Finally, the last column show the average population density of the contracts which are highest in the

[6] The public operators are, in order of turnover: Gamla Uppsala Buss, Västerås Lokaltrafik, Luleå Lokaltrafik.

urban regions (Stockholm, Västra Götaland, and Skåne) and lowest in the most northern counties (Norrbotten, Västerbotten, and Jämtland).

5. Results

In this section, the results from estimating the models outlined in Section 3 and its auxiliary equations are presented, as well as a ranking of the average efficiency for each PTA. However, specification tests determining the most appropriate model are first discussed.

First, one should note that the estimates are very similar in model I and II and that the effect of environmental variables in the two models shift efficiency in the same direction for the significant variables. Further, the Spearman correlation coefficients provided in Table 2 are high across models, with exception of the correlation between the net efficiency in model I and gross efficiency in model II. This would suggest that the models do not differ very much, and should provide similar results.

		I		II	
		Gross	**Net**	**Gross**	**Net**
I	**Gross**	1			
	Net	0.840	1		
II	**Gross**	0.945	0.645	1	
	Net	0.985	0.876	0.917	1

Table 2. Spearman correlation matrix for efficiency estimates

Two log-likelihood-ratio (LR) tests are carried out where model I and II are tested against model III. The null hypothesis is rejected for model I, while the opposite is true for model II[7]. Thus, model II is preferred and will be in focus of the discussion in this section. Results for all models are provided in Table 1.

Linear homogeneity in factor prices is fulfilled as the coefficients sum to one. Further, the output and labor price is monotonic, while this is not the case for about ten percent of the observations in price of capital. Despite this, the assumption of monotonicity is regarded as validated in the cost function as the fraction of negative values in capital price is small compared to the overall sample.

Turning to the output and input factors, all three estimates are positive and significant at the 1 percent level. All estimates are in logs which mean that coefficients can be interpreted as elasticities evaluated at the mean. The output estimate is equal to unity, implying that increasing vehicle kilometers with one percent gives rise to an equally large increase in costs, and that no economies of scale are present. Costs are increased with 0.308 percent with a one percent increase in capital price, and 0.692 percent with labor price. To give an idea whether these numbers are plausible, they can be compared to the index model agreed upon in the PTAs' trade organization The Swedish Public Transport Association (SPTA) 2014.

[7] I vs. III: $\chi^2 = 16.02$ with 6 degrees of freedom. II vs. III: $\chi^2 = 9.91$ with 5 degrees of freedom

	Model I		Model II		Model III	
β_{output}	1.007**	(0.02)	1.000**	(0.02)	1.009**	(0.03)
$\beta_{capital(c)}$	0.295**	(0.09)	0.308**	(0.09)	0.286**	(0.09)
$\beta_{labor(l)}$	0.705**	(0.09)	0.692**	(0.09)	0.714**	(0.09)
β_0	-0.851**	(0.20)	-0.967**	(0.09)	-1.334*	(0.60)
ζ_{cc}	0.723**	(0.16)	0.679**	(0.15)	0.666**	(0.14)
ζ_{ll}	-0.766**	(0.16)	-0.722**	(0.15)	-0.712**	(0.14)
ζ_{yy}	0.043**	(0.01)	0.042**	(0.01)	0.046**	(0.01)
ζ_{cl}	-0.215**	(0.05)	-0.182**	(0.04)	-0.202**	(0.06)
ζ_{yc}	0.045	(0.03)	0.039	(0.02)	0.040	(0.02)
ζ_{yl}	0.170**	(0.05)	0.143**	(0.04)	0.163**	(0.05)
$\theta_{density}$	0.077**	(0.02)			0.016	(0.08)
$\theta_{contract\ term}$	0.013	(0.08)			0.210	(0.20)
θ_{large}	-0.017	(0.05)			0.013	(0.12)
θ_{public}	0.462**	(0.12)			0.725**	(0.28)
$\theta_{incentive}$	-0.089	(0.06)			-0.172	(0.14)
$\delta_{density}$			0.163**	(0.05)	0.191	(0.14)
$\delta_{contract\ term}$			-0.042	(0.09)	-0.358	(0.35)
δ_{large}			-0.054	(0.11)	-0.098	(0.31)
δ_{public}			0.656**	(0.23)	-13.923	(10.81)
$\delta_{incentive}$			-0.103	(0.11)	0.234	(0.38)
δ_0			0.460*	(0.19)	0.834	(0.79)
σ_u	0.286	(0.04)	0.279	(0.06)	0.376	(0.25)
σ_v	0.213	(0.07)	0.205	(0.01)	0.185	(0.01)
γ	0.590	(0.01)	0.649	(0.19)	0.805	(0.25)
Log-Likelihood	-33.874		-30.821		-25.866	
AIC	132		128		128	
Observations	281		281		281	
Counties	21		21		21	

Robust standard errors in parenthesis

** p<0.05, ** p<0.01*

Table 3. Results from stochastic frontier analysis

In the index model, the operator specifies weights to different input factor prices when placing a bid, which are applied when indexing (or deflating) the yearly payments during the contracting period. Thus, the index shares can be interpreted as a form of cost shares in input prices. The SPTA recommendation is a weight for labor between 50–60 percent. When comparing numbers in detail in contracts, the upper bound is dominating. Turning to the capital price coefficient of 0.308, fuel and vehicle can be weighted about 15–45 percent, an interval that includes this estimate. Ideally, one would like to include all input factor prices, but as was discussed earlier this is not possible due to limitations in data.

Turning to the efficiency estimates, the γ parameter in the bottom of the table is relatively high and statistically significant implying that there are indeed inefficiencies, which in turn validates the use of SFA. For the δ estimates, the population density variables show a statistically significant relationship. This is in line with the findings in Vigren (2014) where high density areas were associated with higher costs, an interpretation that carries over directly to efficiency. That is, high density areas exhibit lower efficiency. Similar results are found in Walter (2011) and Piacenza (2006) as well. In line with the findings in Ottoz et al. (2009), direct awarding to publicly owned operators imply lower cost efficiency. Roy and Yvrande-Billon (2007) conclude the same thing when considering technical efficiency.

The three other coefficients (contract term, large operator, and incentives) are not significant at the 5 percent level. The insignificant coefficient of using incentives payment is somewhat unexpected as the contracting scheme imposes risk on the operator, which in turn would be expected to price this risk. Different combinations of incentives levels and type of incentives has been included in the model, in order to determine whether this finding is stable The different sets of dummy variables have, however, turned out to yield no different results. If comparing these coefficients with the ones when including the environmental variables in the cost frontier, the same results hold, which is also in line with the high efficiency correlations across models showed in Table 5.

5.1 PTA Efficiency

The estimated efficiencies from model II are used in order to compare the efficiency level of each PTA or, equivalently, county efficiency. Recall the definition of gross and net efficiency from Section 3, where the former is the efficiency scores including impact from the environmental factors, whereas the latter have these effects purged out and could illustrate a managerial performance measure.

When calculating the PTA's overall efficiency, the estimated efficiencies are weighted with respect to total payments in the contracts. This implies that larger contracts affect the PTA's efficiency more than smaller ones. The cost efficiency (CE) for PTA *r* is calculated as

$$CE_r = \sum_{\forall s \in r} \frac{C_{rs} \cdot CE_{rs}}{\sum_{\forall s \in r} C_{rs}} \in (0,1),$$

where higher figures indicate higher cost efficiency. The weighted efficiency and ranking of all 21 PTAs is presented in Table 4, along with a map illustrating the net efficiency levels with colors from bright (low) to dark (high). Note that the legend goes between 0.6–1.0. The third column shows the gross efficiency, the fourth net efficiency, and the last column the ratio between the two. A higher ratio implies that the PTA is affected more if the environmental factors are accounted for.

Starting with the gross efficiencies, these are by definition much related to the efficiency estimates in Table 3. Note that the rankings in Table 4 is based on the net efficiency score. Many counties with large cities get low scores, for example Stockholm, Skåne, Västra Götaland and Uppland. The lowest cost efficiency is, however, found in the county of Västmanland where all public transport is provided by a publicly owned operator. A similar impact can be found in Uppland and Norrbotten who also uses the same type of regulation.

	County	Gross score	Net score	Net/Gross
1.	Dalarna	0.852	0.915	1.07
2.	Gotland	0.851	0.911	1.07
3.	Halland	0.822	0.910	1.10
4.	Södermanland	0.818	0.910	1.11
5.	Gävleborg	0.834	0.909	1.09
6.	Kalmar	0.830	0.903	1.08
7.	Blekinge	0.785	0.903	1.15
8.	Västerbotten	0.843	0.900	1.06
9.	Jönköping	0.796	0.899	1.12
10.	Jämtland	0.802	0.893	1.11
11.	Värmland	0.788	0.893	1.13
12.	Örebro	0.766	0.892	1.16
13.	Västernorrland	0.803	0.885	1.10
14.	Uppsala	0.710	0.876	1.23
15.	Västra Götland	0.699	0.870	1.24
16.	Kronoberg	0.747	0.864	1.15
17.	Norrbotten	0.745	0.864	1.16
18.	Östergötland	0.686	0.850	1.24
19.	Stockholm	0.578	0.797	1.37
20.	Skåne	0.589	0.791	1.34
21.	Västmanland	0.374	0.633	1.69

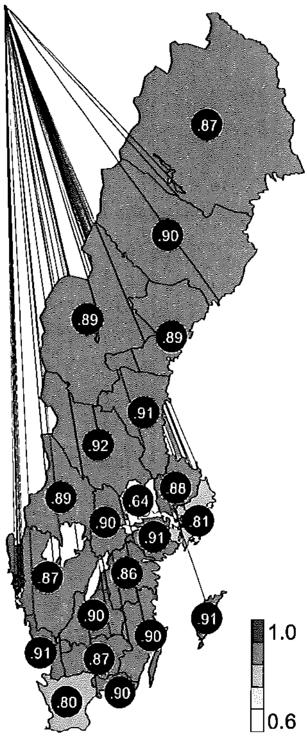

Table 4. Ranking of PTA cost efficiency scores with map illustration

Using Norrbotten as an example, the public transport in the city of Luleå accounts for 30 percent of the total transport provision in the county, and affect the PTA's overall score consequently. In the top-rankings, no clear pattern can be distinguished and the differences are small.

Turning to the net efficiency scores, which are purged of environmental factors, the efficiencies becomes higher. The net-gross ratios in Table 4 suggest that these factors affect the lowest ranked PTAs the most, and increase efficiency scores with up to 69 percent. The median increase is 13 percent. From column two, one can notice that the difference between the first ranked PTA, Dalarna, and 18th ranked, Västernorrland, is only 0.065, which means the cost efficiencies are very similar across most PTAs. The two counties with top-three highest populations, Stockholm and Malmö, exhibit slightly lower estimates than the others. Although the difference is larger in the gross efficiency measure, accounting for the environmental factors increase the cost efficiency with over 30 percent for both PTAs and decrease the relative distance. However, there still seem to be a slightly lower efficiency score than the rest of the country. The lowest net efficiency score is found for the county of Västmanland where the difference between the highest ranked county is over 0.28. Västmanland also has the greatest percentage increase in efficiency when calculating the net efficiency, but do still have a much lower estimate than all other PTAs.

6. Conclusions

During the last decade, costs have increased substantially in the Swedish public transport sector. In addition, contract design and public transport management differs across Public Transport Authorities (PTA) (Nilsson, 2011). Holmgren (2013) also show that the average cost efficiency in the system has decreased substantially since the 1980's. In this paper, Swedish bus contracts are analyzed using a stochastic frontier model in order to determine how different contracting factors affect cost efficiency.

One of the main findings is that service provision in areas with high population density are associated with lower cost efficiency. Further, the efficiencies are also lower if the traffic is subject to direct awarding to a publicly owned operator. When comparing the weighted average net cost efficiency across PTAs, efficiencies do not differ much. One exception is the county of Västmanland which has a lower cost efficiency estimate than the rest.

The result that high dense areas are less efficient is common in the previous literature, but the result is not very constructive and calls for further investigation in why this is the case. A possible explanation is the need for higher capacity in peak-hour, which could give a higher number of buses and labor than optimal and thus higher bids from the operator. In order to cope with this issue, the PTA could take measures to smoothen the peak-load curve, that is, steer public transport trips towards times before or after peak-hour. Examples of such measures are fare differentiation with respect to time, or rescheduling of starting times of schools. Another explanation could be the increased complexity in urban environments with coordination of multiple transportation modes.

The use of publicly owned operators is, in an international perspective, not very common in Swedish public transport. However, this form of public transport provision is still used by some PTAs, most notably Västmanland. As these operators do not have the same incentives for profit maximization, the lower cost efficiency found for these was not unexpected. In the contracting areas where no competitive tendering is performed at all, the PTA need to consider the reasons for why it is important to provide the traffic themselves. An interesting case is the public transport in the city of Luleå which is provided by a public operator and have the highest rankings in national surveys of customer satisfaction. Results in this paper suggest that cost efficiency are indeed higher, but other factors such as quality of the public transport system do also matter when evaluating the service. The causality is not straightforward: are the high ranking in the survey due to the arrangement and ability to control a publicly owned operator, or other factors that can be incorporated in a competitive tendering process?

Finally, the small differences in cost efficiency between PTAs indicate that the managerial skills seem not to differ much. If the efficiency scores would differ more, differences in tendering skills and contract design could have been possible explanations. However, the fact that Swedish PTAs have used competitive tendering for many years may explain this finding. One should also note that this is a cross-section study, and that national panel-data for contracts could reveal other patterns. This type of data would also allow for the possibility to analyze the impact of new tendering rounds, and also give better insights in how incentives contracts perform over more years. However, at this point in time, these data are not easily available in Sweden which makes such an analysis difficult to perform.

Acknowledgements

The author is grateful to Svante Mandell, Jan-Eric Nilsson, Mats Wilhelmsson, and Andrew Smith for valuable comments and advice. Thanks also to Maria Melkersson at Transport Analysis for assistance on the data, and to session participants at the 2015 edition of the ITEA Annual Conference in Oslo for valuable comments. Financial support from the Swedish Competition Authority is gratefully acknowledged.

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