Outsourcing in Local Public Transport: A Hidden Efficiency Determinant

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Abstract

This paper evaluates cost efficiency and some of its determinants in Germany's local public transport. A heteroscedastic Stochastic Frontier approach reveals that high degrees of vehicle utilization and outsourcing positively influence the efficiency estimates. Mean efficiencies lie between 84.9% and 95.13%, depending on the applied panel data model. In this context, the modeling of the heterogeneous output characteristics of rail-bound services with tram, light railway and metro seems to be particularly important. The results impact corporate strategies and point to the need of a comprehensive and nationwide regulation.

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1 Introduction

Being local monopolies, local public transport networks have been a natural point of interest for researchers conducting efficiency analysis. However in this sector, the methods of scientific benchmarking have not found its way

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into practical regulation in Germany. In parts of it, like in other countries, competitive tendering, also boosted through the EU regulation 1370/2007, has rather become one of the instruments to give incentives for a more efficient way of providing services. Hence, the question arises what efficiency analysis can do for local public transport. Two possibilities emerge: Evaluation of market structure, and supporting strategic firm decisions. This paper relates to the second point, and evaluates cost efficiency of multi-output companies in Germany's local public transport. Multi-output means that these companies provide bus services on the one hand, and tram, light railway and metro (in the sense of underground) services, aggregated as rail-bound services, on the other hand.[1] The ultimate challenge of Germany's local public transport is its highly negative level of cost coverage across nearly all companies with a mean level of 73.8% (Verband Deutscher Verkehrsunternehmen, 2008). This may have its origin on the cost or the revenue side, probably on both. In this paper, the focus is on evaluating cost efficiency and some of its main determinants with Stochastic Frontier Analysis (SFA). I choose SFA instead of Data Envelopment Analysis (DEA) mainly because of applicability of panel data models with SFA, incorporating the time horizon into the analysis. Furthermore I choose SFA because of the possible derivations from the deployment of a functional form, like deriving factor elasticities, and because of its availability to handle data errors. I am aware that the a priori assumption of a special functional form imposes some restrictions on the analysis.

Pioneering studies in stochastic efficiency analysis of multi-output local public transport operators were carried out by Viton (1992, 1993), who evaluated economies of scale and scope and benefits from organizational restructuring in the San Francisco Bay Area. Viton applied a quadratic cost function to incorporate companies with zero outputs for some of the considered outputs motor bus, rapid or commuter rail, streetcar, trolley-bus, demand-responsive and other means of public transport. The cost frontier was estimated based on a pooled dataset of the years 1984 until 1986 following the model by Aigner et al. (1977), who first introduced the concept of Stochastic Frontier Analysis. Viton's results support the formation of larger entities. Bhattacharyya et al. (1995) focussed on bus operations analyzing the determinants of cost inefficiency in India. These determinants

[1] The companies in the dataset used in this paper do not offer suburban (e.g. S-Bahn) or regional railway services. The analysis is hence restricted to services based on the German passenger transportation law (PBefG; Bundesministerium der Justiz, 2007a) and the German Ordinance on the Construction and Operation of Rails-Systems for Light-Rail-Transit (BoStrab; Bundesministerium der Justiz, 2007b).

are included as heteroscedastic components of the inefficiency function. A translog variable cost function is estimated in a multi-step procedure with firm- and time-specific effects exploring the panel structure of the data. The results indicate that, under the threat of closure nationalized operators are most inefficient, followed by corporations with an independent administrative and managerial structure and the units that are run by transportation departments of state governments. As expected, the breakdown rate negatively influences efficiency whereas the rate of vehicle utilization positively influences efficiency estimates.

Farsi et al. (2006) compared cost efficiency estimates of several Stochastic Frontier models and calculated economies of scale and density for regional bus companies in Switzerland. They suggest that the True Random Effects model by Greene (2004, 2005) could be used as a benchmark model for regulation purposes, mainly because of its ability to differ between inefficiency and unobserved heterogeneity. Conventional models, in particular a pooled model fed with panel data, maybe also the applied Random Effects Model (Pitt & Lee, 1981) and the Fixed Effects Model (Schmidt & Sickles, 1984), could give inaccurate results.

Moving back from pure bus considerations to multi-output analyses, Farsi et al. (2007) evaluated economies of scale and scope for a panel data sample of Swiss operators. The three modes of transport trolley-bus, motor-bus and tramways are captured by a quadratic cost function. The estimations are based on a pooled heteroscedastic model with autoregressive errors. Hence, this is purely econometric and not based on SFA. Farsi et al. (2007) found increasing returns to scale across all modes of transport and economies of scope. In this paper, I will not consider economies of scale and scope. The interested reader may consult Nieswand et al. (2008) for bus operators and Walter (2008) for multi-output companies in Germany.

The remainder of this paper is structured as follows. Section 2 provides the functional form with its specification as well as the econometric models. Section 4 describes the data in combination with the activity in the German local public transport sector. Section 5 gives the results as well as their interpretation and Section 6 concludes.

2 Methodology

2.1 Cost Function

The application of a cost function requires the assumption of cost minimizing behaviour with given input prices and output quantities (Coelli et al., 2005). Transport economists have typically applied a cost function instead of a profit function, probably also due to data constraints. Nowadays, it is much more difficult to state if local public transport companies in Germany minimize costs or maximize profits because of the increasing policy demands for fewer subsidies. The remaining political influence supports the cost minimization assumption. The exogeneity of output quantities can be justified with the definiteness of the supplied area, typical for a local monopoly, and the requirement to supply because local transport is a public service obligation (*Daseinsvorsorge*). In this case here, a total cost function can be written as

$$TC = f(Y, Q, P_L, P_K, ID, t) \tag{1}$$

dependent on two outputs, namely the number of seat-kilometres for buses (Y) and the number of seat kilometres in trams, light railways and metros (Q), on two input prices, namely for labour (P_L) and capital (P_K), on an inverse density index (ID) and on a time trend (t). The most commonly applied functional forms are the Cobb-Douglas, a first-order flexible form, and the translog function which is a second-order flexible form. Both functions have the advantage that the variables enter the estimation in logs (in contrast to the, e.g., quadratic function), which makes them linear in parameters and less fragile to extreme data points or heteroscedasticity. Increased flexibility is usually preferred if the function remains estimable. Additionally, for the Cobb-Douglas function the returns-to-scale technology has to be determined in advance. As economies of scale have proved to vary across output levels (e.g. Farsi et al., 2007, and Walter, 2008), one should avoid this restriction if possible. The translog function applied here requires the approximation at a local point which is chosen to be the mean here. The median is less influenced by extreme outliers, whereas the mean reflects better the actual position of all data points in the sample. After imposing the linear homogeneity in input prices of degree one by dividing costs and the capital price by the factor price,[2] the function can be written as

[2] The other properties of the cost function are verified in the data and the results sections.

$$
\begin{aligned}
ln\frac{TC_{it}}{P_{L_{it}}} = ln\ TC'_{it} &= \alpha_0 + \beta_Y\ ln\ Y_{it} + \beta_Q\ ln\ Q_{it} + \beta_K\ ln\frac{P_{K_{it}}}{P_{L_{it}}} \\
&= \frac{1}{2}\left(\beta_{YY}(ln\ Y_{it})^2 + \beta_{QQ}(ln\ Q_{it})^2 + \beta_{KK}\left(ln\frac{P_{K_{it}}}{P_{L_{it}}}\right)^2\right) \\
&= \beta_{YQ}\ ln\ Y_{it}\ ln\ Q_{it} + \beta_{YK}\ ln\ Y_{it}\ \frac{P_{K_{it}}}{P_{L_{it}}} + \beta_{QK}\ ln\ Q_{it}\frac{P_{K_{it}}}{P_{L_{it}}} \\
&= \beta_{ID}\ ID_{it} + \beta_t\ t
\end{aligned} \tag{2}
$$

with $i = 1, 2, \ldots, 39$ denoting the company and $t = 1, 2, \ldots, 10$ denoting the year.

2.2 Econometric Models

So far we have only looked at the deterministic part of the function. The focus here is on Stochastic Frontier models exploiting the panel structure of our data. The first proposed models were the Random Effects Model (Pitt & Lee, 1981) and the Fixed Effects Model (Schmidt & Sickles, 1984). As the amount of within variation in our data is considerably low (at most 6% within variation based on overall variation for costs, outputs and the remaining factor price)[3] and the Fixed Effects Model does not allow the incorporation of efficiency determinants as heteroscedastic factors in the inefficiency function (Kumbhakar & Lovell, 2000), I will not consider this model in the following. I will also neither consider a pooled model (Aigner et al., 1977) nor a so-called time-varying inefficiency model (see Kumbhakar, 1990, and Battese & Coelli, 1992). The time-varying inefficiency models assume inefficiency to change systematically over time, which is often not the case in reality, e.g. due to technological or economic shocks. Instead I will consider the Random Effects Model and its advancements. The details of the Random Effects Model estimated in this paper are as follows:

$$
ln\ TC'_{it} = \alpha_0 + x'_{it}\beta + v_{it} + u_i \tag{3}
$$

with normal-half-normal distribution of the stochastic term. The time-variant, firm-specific error part $v_{it} \sim iid\ \mathcal{N}(0, \sigma_v^2)$ is independently and

[3] I calculated the within variation following Farsi et al. (2005a). For further discussion see also Farsi et al. (2005b).

identically distributed. $u_i \sim iid\ \mathcal{N}^+(0, \sigma_u^2)$ represents the time-invariant, firm-specific inefficiency component. In its variance $\sigma_{u_i}^2$, according to Greene (2007), I introduce inefficiency determinants z_i also capturing heteroscedasticity, so that $\sigma_{u_i}^2 = \delta' z_i$ with δ' including an estimated coefficient for a constant.[4] z_i are the degree of tramcar utilization and the outsourcing grade and are hence variables incorporating management quality (cp. Bhattacharyya et al., 1995, and Hadri et al., 2003). The model is estimated using the Maximum Likelihood Method. From the composed error term, the inefficiencies are attained through the Jondrow et al. (1982) estimator. Disadvantageous to the Random Effects Model, the inefficiency is time-invariant and unobserved heterogeneity (likely to exist through the omittance of structural variables) is not accounted for. An example in our case is the track gauge of tram systems which differs from 1000 mm (*Meterspur*) to 1435 mm standard railway gauge in Germany. 1000 mm lead to a constant disadvantage in service provision as vehicles have to be smaller with smaller gauges.
The limitations of the Random Effects Model can be overcome with the True Random Effects model proposed by Greene (2004, 2005). The details of the True Random Effects Model estimated in this paper are as followed:

$$ln\ TC'_{it} = \alpha_0 + \alpha_i + x'_{it}\beta + v_{it} + u_{it} \tag{4}$$

with $\alpha_i \sim iid\ \mathcal{N}(0, \sigma_\alpha^2)$, $v_{it} \sim iid\ \mathcal{N}(0, \sigma_v^2)$ and $u_{it} \sim iid\ \mathcal{N}^+(0, \sigma_u^2)$. There are two main differences to the Random Effects Model. The True Random Effects model has a random intercept being normally distributed and the inefficiency term is time-variant, allowing a much more realistic image of reality. For the True Random Effects Model, all estimations using simulated maximum likelihood are done in one step. Apart from this, the model is very similar to that proposed by Kumbhakar (1991), also applied by Kumbhakar & Hjalmarsson (1995), who use a two-step estimation.
The estimations presented in the following again allow for heteroscedasticity in the inefficiency component, so that $\sigma_{u_{it}}^2 = \delta' z_{it}$. The model is a special case of the random parameter model. A random parameter model with not only random intercept, but also random output parameter is the third model estimated in this paper. The randomness of output parameters is justified by the different technological systems summarized in the rail-bound output category. A relatively slow overground tram in Dresden definitely uses a

[4] I also estimated a model in which I allowed for heteroscedasticity in the stochastic error term by letting the variance of it being dependent on the total volume of seat-kilometers. However, this parameter has not proven to be significant.

different technology than a metro-similar light railway system in Stuttgart, with lots of tunnels and a railroad embankment totally separated from motorized individual transport (MIT). All the models estimated here assume that the regressors are uncorrelated with the explanatory variables.[5]

3 Data and Sector Characteristics

The dataset consists of an unbalanced panel of 254 observations of German multi-output local public transport operators from 1997 until 2006. In total, 39 companies are included with a mean of 6.5 observations per company. The physical data (output quantities, input quantities etc.) was taken from the annual statistics of the Association of German Transport Undertakings (Verband Deutscher Verkehrsunternehmen (VDV), 2007, and preceding years). All monetary data was extracted separately from annual reports. Table 1 shows the descriptive statistics for the dataset. The monetary values are given in 2006 prices and were inflated by the German producer-price-index (Destatis, 2008). Total costs comprise expenses for personnel, for material, other operating expenses, depreciations and interests on borrowed capital.[6] For the purpose of calculating factor prices, the four latter cost items are summed into *capital and operating expenses*. The shares for personnel costs as well as capital and other operating expenses show a relatively vast range from 0.20 to 0.66 and 0.34 to 0.80 respectively. The reason for this lies in the outsourcing of services to private partners and, in particular, to privately organized subsidiaries. These companies often employ significant parts of the personnel stock. In the P/L statement, expenses for such employments are classified as expenses for purchased services. The labour price is calculated as personnel costs divided by the number of full-time-equivalents (FTEs). The high range from 30 639 EUR to 82 610 EUR is related to regional wage differences, to different age structures, to the outsourcing of low-paid functions and to different handling of pension accruals. The capital price is calculated as residual costs (total costs minus personnel costs) divided by the number of seats in buses and rail-bound cars following Farsi et al. (2007).[7]

[5] For a more detailed and a structured overview of panel data models see the publications by Farsi et al., e.g. 2006.

[6] Self-speaking total costs are positive across all observations which is an import property of the cost function.

[7] The number of seats was not directly available from the VDV statistics, but approximated by the number of seat-kilometers multiplied by the number of buses and cars divided by the number of vehicle-kilometers. The underlying assumption is that the

Table 1: Descriptive Statistics

	Sum[a]	Min.	Mean	Median	Max.	Std. Dev.
Total cost (TC) in m EUR	2715.30	10.61	106.47	68.23	350.22	83.12
Share personnel costs		0.20	0.48	0.48	0.66	0.90
Share operating and capital costs		0.34	0.52	0.52	0.80	0.09
Labor Price P_L in EUR/FTE		30 639	49 636	50 409	82 610	8714
Capital Price P_K in EUR/seat		761	1774	1555	4964	762
Output in m seat-kilometers						
Bus(Y)	27 482	50	1018	644	4800	974
Rail-bound(Q)	17 122	4	656	459	2303	503
Inverse density index (ID)[b]		138	862	787	2958	458
Outsourcing share (OUT)[c]		0.00	0.57	0.57	1.00	0.19
Railcar utilization rate (UR)[d]		47.33	135.66	128.11	250.23	39.27
Vehicles						
Bus	3650	2	146	103	470	106
Rail-bound	2855	6	124	85	513	106

[a] *Sum values for 2006* [b] *Inhabitants per km network length* [c] *Based on material costs*
[d] *Vehicle-km per day and vehicle*

Source: Author's own calculation

Obviously, this approach has two shortcomings. First, buses and rail-bound cars are treated equally which may divert from actual fixed and variable costs proportions. Second, dividing through the number of seats is a pure capital measure neglecting operational costs like energy costs. However, in the absence of more detailed information on the structure of non-personnel costs, this is the best approach available.[8] There are two outputs: seat-kilometres in buses, and seat-kilometres in rail-bound cars. The use of seat-kilometres instead of vehicle-kilometres has the advantage that the size of vehicles is taken into account and hence efficiency differences are not based on the deployment of different vehicle sizes. Both measures are however a pure supply side consideration. A more appropriate measure would be passenger-kilometres. This variable is available as aggregate only and the cost of applying an aggregate for loosing one output is too high and would not reflect the production technology of local public transport adequately. Furthermore, tram, light railway, and metro services are not split into different outputs as there is no clear definitional separation between these services, and transitions are smooth.[9] The inverse density index is defined

deployment of each bus and railcar is uniformly distributed.

[8] See Walter (2008) for an approach separating capital from operations price. In the presence of cross-terms of outputs and factor prices within the translog function, this separation approach is likely to lead to multi-collinearity problems.

[9] Tram services are usually characterized as pure overground services with often no separate railroad embankment (from MIT). Examples include the major East German cities like Dresden and Leipzig and the smaller West German cities. Light railway services are usually characterized through higher average speeds and tunnels in the inner-city, though running similarly to trams in the suburbs. In the 1970s, lots of the

as population in the supplied area divided by the sum of bus line length and rail-bound track length.
The outsourcing share is defined as purchased services divided by material costs. According to the German Commercial Code (Bundesministerium der Justiz (German Federal Ministry of Justice), 2008), purchased services, be it e.g. line services or energy costs, are always part of material costs. In the past years this outsourcing share has steadily increased from 0.47 in 1997 to 0.66 in 2006.[10] Some companies like Leipziger Verkehrsbetriebe (LVB) or Verkehrsgesellschaft Frankfurt (VGF) have founded subsidiaries, in particular for operations of bus and tram lines. In these subsidiaries, Leobus and Leipziger Stadtverkehrsvertriebe (LSVB) or In-der-City-Bus (ICB), lower wages, not bound to tariffs of civil services, can be paid (see Walter et al., 2009, also for a description of other strategies to react on local public transport challenges).[11] These subsidiary operations have been classified as purchased services. The second heteroscedastic component is the vehicle utilization rate of railcars defined as vehicle-kilometres divided by the number of railcars and 365 days. The broad range from 47.33 for Jena in 1997[12] to 250.23 for Oberhausen (STOAG) in 2005 indicates an improvement potential. The indicator is a measure not only for the actual deployment time, but also for the average speed of these transport systems.[13] The quality of services throughout Germany is generally perceived quite high, but speed differences of services exist, leading many potential customers to rather taking the car.

bigger West German cities invested a lot in new infrastructure for light railways to transform their existing tram services.

[10] I am aware that, in an unbalanced panel, this increase can also be due to the data structure, i.e. observations in early years with low outsourcing share and observations in late years with high outsourcing share. However, a closer look on the data gives no evidence to defend this hypothesis.

[11] LVB achieved an outsourcing share of approximately 90% in 2006 with 133 m EUR of purchased services.

[12] 47.33 relies on construction activities in Jena's inner city in 1997, though many trams services were replaced by bus services in that year. The second-lowest value is 72.98 with similar other values in the near range.

[13] A similar vehicle utilization rate could be calculated for bus operations. However, I was not able to estimate a model in which all managerial variables, i.e. the outsourcing share, the utilization rate for railcars and the vehicle utilization rate for buses, came out to be significant. This may lie in the high dependency between outsourcing and bus utilization. Many firms employ subcontractors, private small-and-medium sized bus companies from the surrounding area, which can be ordered on short notice.

4 Results and Interpretation

4.1 Regression Results

Table 2 shows the regression results for the Random Effects, for the True Random Effects and for the Random Parameter model.[14] All first-order coefficients show the expected signs and are significant. In particular, the positive coefficients of output quantities and input prices verify the non-decreasing-conditions of the cost function. As all model parameters are in logs, the output coefficients can be interpreted as cost elasticities at the local point of approximation, which is here represented by the mean. Across all models, the cost elasticities for rail-bound services are substantially higher (between 0.494 and 0.502) than for bus services (between 0.406 and 0.434). An additional seat-kilometre in a bus is hence ca. 25% cheaper than in a tram, light railway or metro. This may be reflected by the high fixed cost proportion in rail-bound services for the network and the cars which are mostly custom-made for each single operator. These higher cost elasticities go along with higher comfort in rail-bound cars which are broader and less rumpling. The capital price coefficient varies slightly around 0.450 representing the 52% share of capital and operational costs quite good.[15] The time trend coefficient is significantly negative at the 1% significance level across all models indicating that costs have decreased over time, with the amplitude of the coefficient being considerably high. The coefficient of the inverse density index is significantly positive indicating that higher population per network length leads to higher costs, e.g. through reduced speed in urban areas, waiting times at traffic lights, higher wages and so on.

So far the coefficients across all models are quite similar. I will now consider the model-specific heteroscedastic variables and the random parameter.[16] The heteroscedastic variables for the random effects model are not significant. Moreover, the coefficient for outsourcing is very low, so that I abstain from interpreting it. As expected, the coefficient for railcar utilization rate is negative indicating that a higher rate leads to lower costs. For the true

[14] I have done the estimations with Limdep 9.0, using 1000 Halton draws for the Random Parameter models. There have not been any significant estimation changes compared to 50 Halton draws.

[15] Through imposing the linear homogeneity in input prices, a labor price coefficient of 0.550 follows.

[16] I also tried to estimate the true random effects model without heteroscedastic components in order to conduct Likelihood-Ratio-Tests. However this model did not converge. I interpret this the way that heteroscedasticity is not only present in the data, but so strong that other models become inestimable.

Table 2: Regression Results

Model	**Random Effects**	**True Random Effects**	**Random Parameter**	
Parameter	Estimate	Estimate	Mean estimate	Std. dev. estimate
α_0	$-.287^{***}(.027)$	$.057^{***,a}(.013)$	$.040^{***}(.013)$	$.092^{***}(.004)$
β_Y	$.434^{***}(.036)$	$.406^{***}(.007)$	$.413^{***}(.097)$	$.109^{***}(.005)$
β_Q	$.494^{***}(.023)$	$.502^{***}(.007)$	$.501^{***}(.006)$	$.018^{***}(.003)$
β_K	$.445^{***}(.027)$	$.450^{***}(.011)$	$.457^{***}(.010)$	
β_{YY}	$.140^{*}(.072)$	$.158^{***}(.007)$	$.149^{***}(.006)$	
β_{QQ}	$.153^{***}(.033)$	$.148^{***}(.007)$	$.157^{***}(.007)$	
β_{KK}	$.404^{***}(.118)$	$.301^{***}(.040)$	$.281^{***}(.037)$	
β_{YQ}	$-.091^{**}(.034)$	$-.139^{***}(.008)$	$-.121^{***}(.007)$	
β_{YK}	$-.046(.034)$	$.012(.014)$	$.015(.014)$	
β_{QK}	$-.056^{*}(.031)$	$-.054^{***}(.013)$	$-.054^{***}(.012)$	
β_t	$-.159^{***}(.011)$	$-.128^{***}(.005)$	$-.129^{***}(.005)$	
β_{ID}	$.058^{**}(.027)$	$.041^{***}(.008)$	$-.042^{***}(.008)$	
γ_0		$5.972^{***}(1.434)$	$6.079^{***}(1.378)$	
γ_{OUT}	$.075(1.667)$	$-.888^{***}(.426)$	$-.890^{***}(.408)$	
γ_{UR}	$-2.630(1.645)$	$-6.809^{***}(1.913)$	$-6.871^{***}(1.851)$	
λ	11.096	.745		

****significant at 1%,* ***significant at 5%,* **significant at 10%; standard errors in parentheses;*
^{a}*coefficient of the standard deviation .093*** with standard deviation of .004*

Source: Author's own calculation

random effects and the random parameter model, the interpretation for this coefficient is the same. Also for both models, the coefficient for outsourcing is significantly negative meaning that a higher outsourcing share can decrease costs. This variable has to interpreted with great care. Compared with the vehicle utilization rate, higher values do not necessarily mean better values. There could be an optimal outsourcing grade. It can be concluded that those companies in the dataset with an higher outsourcing grade seem to be the more efficient ones. As can be seen by the amplitude of the coefficients, the impact is somehow much smaller as for the railcar utilization rate. The random output parameter for the random parameter model are both significant supporting the use of this model. However, the variation for bus services seems even higher than for tram, light railway and metro services. This can be related inter alia to the deployment of standard buses on the one hand and articulated buses on the other hand.

4.2 Efficiencies

Table 3 shows statistics for the efficiency estimates. As expected, the mean for the Random Effects Model is much lower than the mean for the True Random Effects Model, because the latter treats all persistent inefficiency (as Kumbhakar, 1991, calls it) as unobserved heterogeneity. From the descriptive statistics, the True Random Effects Model and the Random Parameter Model seem to be quite similar with a slightly higher standard deviation of efficiency estimates for the Random Parameter Model which allows more

Table 3: Descriptive Efficiencies

Model	Random Effects	True Random Effects	Random Parameter
Minimum	66.91%	86.49%	83.53%
Mean	84.92%	95.13%	94.25%
Median	85.45%	96.01%	95.26%
Maximum	98.92%	99.19%	99.22%
Standard deviation	8.95%	2.96%	3.59%

Source: Author's own calculation

Table 4: Efficiency Correlations

Model	Random Effects	True Random Effects	Random Parameter
Random Effects	100.00%	84.26%	81.27%
True Random Effects		100.00%	96.52%
Random Parameter			100.00%

Source: Author's own calculation

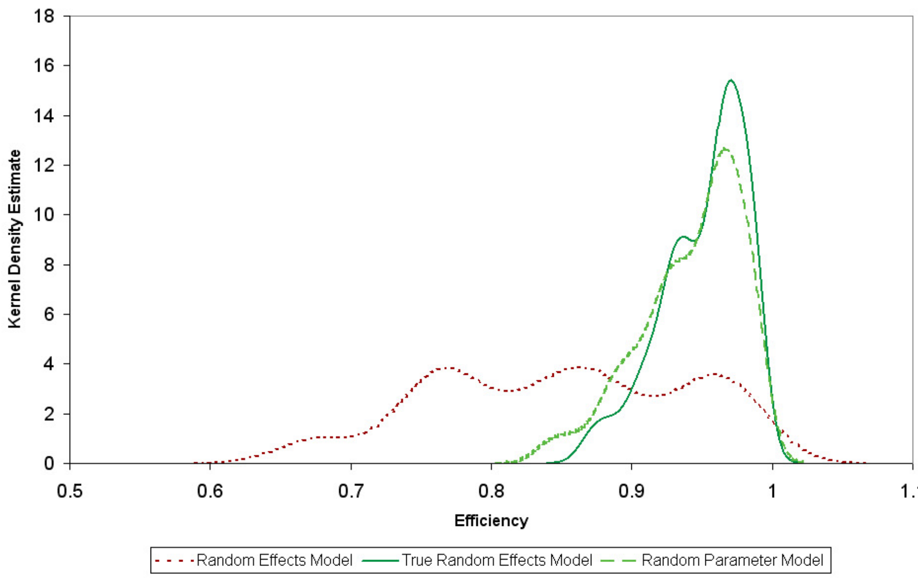
diversity. As Farsi & Filippini (2009) point out, the true efficiencies should lie somewhere in between the Random Effects and the True Random Effects Model. This would lead to a mean level around 90%, which is in a realistic albeit relatively high range. The efforts for restructuring and increased cost efficiency in Germany's local public transport seem to have had some success. Around 90% were also found to be mean efficiencies in the beginning of the incentive regulation for German electricity and gas distribution companies (Agrell et al., 2008, taking a best-of value of SFA and DEA values), seeming a reasonable value for local network monopolies.
Table 4 shows the rank correlations between the models. The minimum rank correlation is found between the Random Effects Model and the Random Parameter Model with 81.27%. This is a considerably high value with promising implications for a possible regulation based on scientific benchmarking. A close look at the Kernel Density Estimate in Figure 1 however reveals that the distribution of efficiency estimates still differs between these two models. Between the True Random Effects Model and the Random Parameter Model, the distribution is much more similar.[17]

5 Conclusions

I estimated state-of-the-art models of Stochastic Frontier Analysis incorporating unobserved heterogeneity and allowing for heteroscedasticity in the

[17] A similar pattern with humps was observed by Farsi & Filippini (2009).

Figure 1: Kernel density of efficiency estimates



Source: Author's own calculation

inefficiency function. Incorporating unobserved heterogeneity is important when the dataset omits variables which are likely to influence the production process. Considering the relatively low number of variables which are available, this is an important application. In the presence of heteroscedasticity, the approach chosen here should improve both coefficient as well as inefficiency estimates. While mean efficiencies are around 90%, the significant coefficients for the outsourcing share and the utilization rate of railcars has important potential for improvements. Optimization of outsourcing should be in focus for businessmen in companies that have been neglecting this topic in the past. Options are to set up subsidiaries or to cooperate with SMEs. The vast differences in the vehicle utilization rate for railcars (shown in the descriptive data statistics) are somehow surprising. Improvement options can be related to enhancing speed through infrastructure measures (separate rail embankments, prioritization at traffic lights, tunnels in inner-city areas, new tracks, express trains like practiced in Karlsruhe, etc.). Furthermore maintenance times could be reduced and procurement optimized. Considering the low mean level of cost coverage with 73.8% (Verband Deutscher Verkehrsunternehmen, 2008), the problem is likely to be not only on the cost side, where improvements have happened in the past and have often been mainly attributed to wage reductions. The revenue side should bear further optimization potential and should be analyzed in the future.

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