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Public Versus Private Production and Economies of Scale

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Abstract:
The cost of public and private production is compared in a case where the production technology is simple: The cleaning of Danish schools. Three forms of organization are used: decentral municipal, central municipal or private. For small schools the organizational form makes little difference for cost. For larger schools decentral municipal production is the most expensive. On average centralization reduces costs by 5%, while privatization reduces costs by 30%. Similar cost differences are reported in the literature for other cases, but it is a new result that the cost differences are due to economics of scale. The theoretical implications of the result are discussed in the context of public choice.

Keywords: Cost function, non-parametric regression, private vs public production, scale effects

JEL classification: C14, D78, H72, L33

I. Introduction

This paper compares public and private production in a case where the production technology is simple, and a large data set is obtained. Our case is the cleaning of Danish primary schools. They are owned by the municipalities, who have full freedom to decide how they are cleaned. Three forms of organization are used for cleaning: Most are cleaned by decentral municipal organizations at the individual school. The rest are cleaned either by central municipal production units or private companies. We analyze how these forms of organization influence cleaning costs for a given cleaning quality.

School cleaning is produced by a simple technology with a low capital-labor ratio. Cleaning has a fast circulation of personnel, and new technologies are rapidly disseminated. We therefore treat our data as a set of observations of one cost function with a fixed capital-labor ratio, and we estimate the cost function conditional on the form of organization, cleaning quality, scale and municipal characteristics.

For larger schools we find systematic cost differences. On average private cleaning is cheapest, while decentral municipal cleaning is the most expensive. A key prediction is that if the cleaning at all schools was privatized, it could lead to savings of roughly 25% of the present costs, corresponding to the salary of 1000 new schoolteachers.

The cost difference between public and private produced cleaning arises from differences in the ability to exploit economies of scale. This finding extends and refines the standard result found in the literature of an average cost difference of almost 30% in favor of private production. For surveys on earlier studies see, for example, Borcherding, Pommarehne and Schneider (1982), Domberger and Jensen (1997) and Vickers and Yarow (1988). Only few studies have been made for Denmark, see Kristensen (1982), Jensen and Rasmussen (1997), PLS Consult (1997) and Blom-Hansen (2000). While the empirical results in this paper show that the cost difference is due to the ability to exploit economies of scale, the reason why public producers do not find the economies of scale is more subtle. We discuss possible explanations in the context of the two basic public choice explanations, namely the monopoly explanation and the property right explanation.

Section II presents the data and institutional factors. The estimation of the cost function is reported in section III. Section IV investigates policy implications of changing organizational form and quality. In Section V, our findings are discussed in the context of public choice theories. The Appendix contains the details of the nonparametric estimation and bootstrapping.

II. Data and institutional facts

Table 1 shows the variables analyzed in this paper. The first four lines in the table are variables obtained from a questionnaire sent to all 275 Danish municipalities in the spring of 1998. The result is a sample of 1081 primary schools from 189 municipalities. The data covers half of the Danish primary schools. The issue of the representativity of the data is analyzed in Section III, where the estimates are presented. The municipal characteristics mentioned in the last line of the table are obtained from a database at AKF, see Christoffersen & Paldam (1998) for details.

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Table 1

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The dependent variable is the cost of cleaning the school measured per m^2 (c/s). The rest of the section describe the explanatory variables listed in the table.

Quality: It is crucial to control for the quality[1)] of the cleaning to make a fair comparison between the different forms of organization. About 70% of the schools use a well-defined cleaning standard called »511«. It is specified in the *cleaning manual* (1977), by the relevant trade unions and the National Union of Local Authorities. Subsequent technological developments have caused minor revisions. The reference standard describes how often various types of facilities should be cleaned, and the intensity by which this should be done. The manual also specifies the area a cleaner should cover an hour.

We define two cleaning qualities in addition to the reference standard »511«. One is a high quality. Schools using standards above »511« are all coded »high« since there are too few observations on each of these higher standards. The third cleaning quality is named »assessed«. This is not a well-defined standard, but it is usually a lower standard than »511«.

The quality variable in the data set is based on specifications in directives to schools or in contracts with employees, unions or firms. The quality actually delivered is unobserved. The monitoring of the cleaning quality is left to the schools. Presumably, if a private company does not deliver the required quality of cleaning, their contract is not renewed. Hence, we assume that the difference between the specified and the actual quality does not vary systematically with the organizational form.

Form of organization: The cleaning of primary schools is organized in three different ways. A majority of 66.5% of the schools is cleaned using decentral municipal labor. The municipality gives each school a budget[2)] and the school then employs and monitors the cleaning personnel. A smaller fraction of 19% of the schools is cleaned by personnel employed and monitored by a central cleaning bureau of the municipality. Finally, 14.5% of the schools are cleaned by a private company. Private companies are typically chosen after competitive bidding.

The number of private cleaning companies is large, and the school contracts are a small fraction only of their activities. There exists one very large multinational company, a second large one[3)], and many small companies. Entry costs to the cleaning market are low. In addition, many consultants organize tenders and advise municipalities about current market prices. Hence, the market for cleaning is rather competitive.[4)]

Our data include 30 central municipal production units. Each unit produces under controlled entry. Therefore, a production unit has some degree of monopoly but the production units are aware that the municipality can decide to tender the contract. Consequently, the municipal production units of school cleaning should not be treated as true monopolies. Similarly, the decentral organized cleaning units at the individual schools have a monopoly to a certain extent.

Table 2 shows the distribution of cleaning qualities and organizational form. For all three forms of organization, the majority of the schools are cleaned to standard »511«.

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Table 2

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Size: The schools differ more than fifteen times in size. Figure 1 shows the distribution of size. Of the total school area, 10% is in schools less than 3000 m^2, 20% in schools 3000 m^2 to 6000 m^2, 40% in schools 6000 m^2 to 9000 m^2, and 30% in schools above 9000 m^2. The measure of school size is the area, s, which is used in the *cleaning manual* (1977) and apparently in all cleaning contracts[5)].

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Figure 1

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One clearly relevant cost factor is the layout of the school, as is partly a result of the age of the school. Most of the schools have been renovated, reconstructed and expanded – often several times – so no meaningful measure was obtained. The school layout is thus an omitted variable and we assume that it is independent of the choice of organizational form.

Municipal characteristics: The municipalities are characterized by 24 variables. They cover 6 areas: (i) Modern/traditional economic structure, (ii) diffusion patterns for modernization such as distance from major town, (iii) economic pressure such as immigration to municipality and prior increases in taxes, (iv) size of public sector, (v) political orientation, (vi) stability of present rule.

One non-standard municipal characteristic of type (iv) is used. It is termed the welfare coalition. It measures the fraction of the population (of voting age) that depends upon the public sector – either as employee or as recipients of an income replacing social payment (including the old age pension).[6)] We include the welfare coalition to investigate the hypothesis[7)] that the larger this fraction, the harder it is for elected politicians to pursue cost-saving policies in the public sector. The effect of the welfare coalition is allowed to vary across the three different organizational forms. It follows from the hypothesis that the effect of the welfare coalition should disappear, when production is privatized.

To get an impression of the relationship between cost and the size of school, a set of non-parametric regressions of the log to unit cost on the log to the size of the school is performed using local polynomial regression. Under mild conditions this procedure provides a consistent estimate of any continuous regression function. The details of the non-parametric regression are reported in the Appendix.

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Figure 2

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Figure 2 shows the estimated 0.9-confidence intervals of these regressions in the case of cleaning quality »511«, which is the only cleaning quality with enough observations to allow the non-parametric regressions for the three organizational forms to be compared. The confidence intervals are estimated using the bootstrap which typically is a better estimator than the commonly used estimators based on the asymptotic distribution. Details on the bootstrap are also provided in the Appendix. The figure only shows schools larger than 1000 m^2 for graphical reasons. Few schools are smaller than 1000 m^2 and, hence, the confidence intervals are very wide for these school sizes.

The figure reveals two important characteristics. First, there is a clear downward trend in the unit cost of privately produced cleaning. Secondly, for schools larger than about 3000 m^2 ($Ln(3000) \approx 8.0$), the unit cost of privately produced cleaning is below the unit cost of both central municipal and decentral municipal organized cleaning. Schools larger than 3000 m^2 represent more than 90% of the total school area in the sample.

Figure 2 suggests that a linear regression function of the logs to cost and size may be a good functional specification. That is, it is likely that a Cobb-Douglas cost function will work.

III. Estimation of the Cobb-Douglas cost function

This section shows that a Cobb-Douglas cost function is a good specification. It is extended with a vector of municipal characteristics. After a series of experiments with other functional forms and interaction term the following cost function was chosen:

(1) $\ln (c_i/s_i) = \alpha'\mathbf{z_i} + \beta'\mathbf{z_i}\ln(s_i) + \gamma'\mathbf{q_i} + \varphi'\ln(\mathbf{m}_i) + \varepsilon_i$,
where ε_i is the residuals, with $E(\varepsilon_i|\mathbf{z}, s, \mathbf{q}, \mathbf{m}) = 0$.

Table 3 shows the estimation results for this cost function. Two municipal characteristics are reported. They were the only ones found to be significant on a 0.05 nominal significance level using a general-to-specific approach. The first is the logarithm to the average tax base, and the second is the welfare coalition. The welfare coalition was significant only for the two municipally organized forms of cleaning, and the effect was the same. Hence, the reported coefficient for the welfare coalition is for both central and decentral municipally organized cleaning.

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Table 3
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Before interpreting the results, different specification issues are considered.

A potentially serious problem is the presence of selection bias. Our analysis is based on a sample, which covers 189 of the 275 municipalities. Given the questionnaire was sent to and returned from the municipalities, the choice to return the questionnaire is mainly made in the administration of the municipality, not at the individual schools. Therefore, we check for selection bias using a modified Heckman two-step estimator, see Heckman (1979) or Vella (1998) for a survey. First, a probit model is estimated using a general-to-specific approach to explain the choice to return the questionnaire using the municipalities as observational units. This has the nice property that many characteristics are available for all the municipalities.[8)] Secondly, based on the estimates of the probit model a selection correction – the inverse Mills ratio – is incorporated in the estimation of the cost function. Consequently, schools in the same municipalities have the same selection correction.

The only significant explanatory variable in the choice to return the questionnaire is the degree of urbanization. This is in accordance with the fact that relatively many among the non-participating municipalities are small. None of the economic or political characteristics of the municipalities turned out to have any statistical significant explanatory power. The selection correction is insignificant suggesting that no serious selection bias is present in the estimators of the scale effects. Hence, we use the results for model (1) in the discussion below.

The diagnostic tests in Table 3 point to two potential problems. First, the tests for heteroskedasticity are significant using a 0.05 significance level. Therefore, to avoid inconsistent estimates of the standard errors, they are estimated by robust heteroskedasticity consistent standard errors obtained by the Huber-White sandwich estimator. Secondly, the residuals are non-normal. This has implications for the distribution of the t-test. By using robust standard errors, however, the t-tests are asymptotically standard normal distributed. The RESET test for functional form does not indicate any misspecification. This is as suggested by the non-parametric results in Section II.

The estimated Cobb-Douglas cost function has a straightforward economic interpretation. It has a constant elasticity of scale given by (1+$), see (1). School cleaning produced by form of organization z^j has economies to scale if $\$_j < 0$, constant return to scale if $\$_j = 0$, and diseconomy to scale if $\$_j > 0$. In Table 3 it is seen that the estimates of the $'s are different and negative in the three cases. School cleaning has significant economies of scale, but the scale effect depends significantly upon the organizational form. For decentral organized cleaning the effect of scale is small. For central organized cleaning the effect is a little larger, but for private organized cleaning the effect is large. It should be noted that the difference between the scale effect in public and private cleaning is significant.

The ('s are quality factors. To estimate the model, $(_2$ is normalized to 0. The two other qualities are defined relatively to quality »511«. That is, when $(_1 = 0.118$ and $(_3 = -0.048$ it means that on average it costs 12% more to use a higher quality than »511«, while 5% are saved by using a lower quality. The structure of the model implies that these relations are the same for all three forms of organization. We tried to include the interaction-term $0'\mathbf{q}_i \ln(s_i)$, but it was not statistically significant.

Rich municipalities have higher cleaning costs. The main reason for the cost effect is that wages are higher in the richer municipalities, notably in the Copenhagen Metropolitan Area. The rich municipalities north of Copenhagen have average incomes more than DKK 50000 higher than the rest of the country. Apart from this extreme case, DKK 50000 is a large difference.

Finally, the welfare coalition variable becomes statistically significant for public production. This shows that municipalities dominated by voters who depend upon the public sector have substantially higher cleaning costs. This is in accordance with our hypothesis that such voters form an implicit *welfare coalition*, which defend public spending. In accordance with our hypothesis the relationship between the welfare coalition and cleaning costs disappears for private companies.

IV. Policy Analysis

In this section, we compare different policy scenarios. In particular, we predict the potential gain of using the cheapest form of organization.

In Figure 3, the estimated regression lines are transformed to area (m^2) and cost in DKK for the most commonly used quality of cleaning, »511«. The values chosen for the municipal characteristics are the average of each of them, respectively.[9] The cost functions drawn on Figure 3 should not be interpreted as the average cost functions since the model is estimated logarithmically.[10] When doing relative comparisons, however, a difference can be interpreted as an average cost difference.

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Figure 3

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Part of the same information shown in Figure 3 is also given in Table 4 for selected school sizes but for all three types of qualities of cleaning.

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Table 4

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It is seen that for all schools larger than 2000 m^2, private organized cleaning is on average cheaper than both of the two public forms of organizations for all the cleaning qualities.

In Table 5, the effect of changing the quality of cleaning is calculated. Given the structure of the estimated Cobb-Douglas cost function, the relative differences in unit cost due to changing quality of cleaning do not depend on the form of organization or size of school. Not surprisingly, the better quality, the higher cost.

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Table 5

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The main policy decision is the choice of organizational form. Table 6 shows the cost savings for different sizes of schools depending on organizational form. Municipalities can on average save by centralizing the cleaning function for schools larger than about 3000 m^2. A much larger gain results from using the market. The break-even point is around 1000 m^2. For small schools (with 2000 m^2) the savings are 16.5%, and then it rises over 50% for the largest schools.

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Table 6

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The average municipality has a size distribution of its schools as shown on Figure 1. From these data we have calculated a standardized size distribution and then calculated a relative school cleaning budget (RB) assuming the same quality throughout:

$RB = \Sigma(c_k s_k f_k)$, where k is an index over all school sizes and f is their frequency.

By calculating such an average normalized budget we can estimate the changes in cost for the average municipality when changing organizational form. The results are shown in Table 7.

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Table 7
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The small schools have a small weight in the average municipal school-cleaning budget. Even if there are no savings here, it matters little for the total budget. Also, the effect of changing from a decentral to a central organization is small. What matters is whether the market is used or not used.

From table 2 it is known that approximately 66.5% of municipalities use decentral and 19.1% use central municipal cleaning. If they all privatized their cleaning, while keeping quality constant, the savings could be 29.6×0.665 + 25.7×0.191 = ap 25% of the present cleaning costs. This corresponds to about DKK 300 million.

V. Discussion

The main finding in this study is that the cost differences depend on economies of scale. This challenges the existing theories for cost differences between public and private producers. The question is why public producers on average fail to find economies of scale. The theory of public choice provides two basic explanations, namely, the monopoly explanation and the property right explanation. In the following, we use these two basic explanations to develop a theoretical understanding of our empirical results. This is important in order to find guidelines on how to improve the cost efficiency of public producers.

The monopoly explanation is developed from the observation that monopoly producers often have higher production costs than the cost minimizing solution. This was first described by Leibenstein (1966) and named X-efficiency. As reasons for X-efficiency, Leibenstein mentioned incomplete contracts for labor, unknown production functions and non-marketed inputs. Later developments starting with Tullock 1967, see Tullock (1993), changed the wording to X-inefficiency, which is explained by rent sharing used to build coalitions of stakeholders to uphold the monopoly. The monopoly rents are thus partly converted to and hidden as extra costs. According to Niskanen 1971, see Niskanen (1994), public monopolies tend to hide cost information and rents. The process of rent sharing is seen also for private monopolies, but they are rarer since they have to fear entry.

The property rights explanation focuses on the incentives of the owners to minimize costs. Private producers have owners, who are the residual claimant while the residual claimants in public production are much more vaguely defined. Private producers thus have a much larger interest in knowing and controlling costs. The property rights theory goes back to Alchian (1969) and Pejovich 1969, see Pejovich (1997) for a survey.

To apply parts of the above basic explanations to our case, it is necessary to include the time dimension since institutional arrangements are history dependent. The current decision process to allocate resources to school cleaning can be seen as a result of past X-inefficiency, which arose from the production function being unknown. If the belief was that there are no economies of scale, then one optimal way of allocating resources is by means of cost norms and standards. For the school cleaning, the norms are given in the *cleaning manual* (1977) as linear. The norm is that a cleaner should cover a certain number of square meters an hour. A special section deals with mini-schools, but apart from that everything is linear. Figure 4 depicts a political system managed by general cost norms and standards.

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Figure 4
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Municipalities know that productivity advances occur in many fields. Therefore, they frequently apply pressure to reduce costs. This is shown as a pressure line on Figure 4. The typical process of savings is to cut everybody by the same percentage. This is generally taken as fair. The equality of treatment also follows from the use of norms and standards. Given the municipal authorities do not know the true cost curve, they apply pressures till someone protests. This will first happen with the small schools. This stops the pressure. Unfortunately, there are few small schools, so the pressure stops before it really start to bite into the costs of the larger schools and the possibility of finding economies of scale is missed. In contrast, when the market is used, costs are determined by competitive bidding. This process is likely to reveal the true costs.[11)]

To explain why such a decision process persists, elements of the property rights explanation can be invoked. The incentives to change the system may not be too strong because the residual claimant – the taxpayer – is not directly involved in the decision process, and when voting many other issues play a role in choosing a representative. The property right explanation can be used to explain directly why the true cost function has not been found. Finally, there is likely to be interplay with another aspect of X-inefficiency, namely, the coalition of stakeholders. Such a coalition would have an interest in keeping the decision process. Our empirical result on the importance of the welfare coalition on cost of municipally produced cleaning supports the possible existence of a coalition of stakeholders.

For policy purposes it is important to identify the explanations for the current decision process. If the cost difference solely arises from unawareness of the true cost function, only a small fraction of the school contracts may need to be privatized in order to identify the cost function. If, on the other hand, the property right explanation is the main responsible, then throughout privatization is necessary.

When the working paper version of this paper became available 1999, our results were widely covered by Danish newspapers. A recent study by Kommunernes Landsforening (2000) shows a rapid increase in the privatization of school cleaning since 1999. This suggests that the municipalities were unaware of the true costs, but once they learned, many took action to reduce costs. In view of the two basic public choice explanations, the property right explanation has lost validity once the true cost was revealed. In contrast, the monopoly explanation has gained support in the fact that municipalities seem to choose to privatize which suggests they do not see themselves able to deal with existing stakeholder alliances.

Appendix. Nonparametric regression and bootstrapping

The regression function is estimated using local polynomial regression, see Fan (1992), Härdle (1990) or for surveys Blundell and Duncan (1998) and Yatchew (1998). The estimator of the regression function at s is $m(s, \hat{\alpha})$, where $m(s, \alpha) = \alpha_0 + \alpha_1 s + \alpha_2 s^2$ and $\hat{\alpha}$ minimizes the criterion function

$$\frac{1}{n} \sum_{i=1}^{n} (\ln(s_i/c_i) - m(\ln(s_i), \alpha))^2 K_h(\ln(s_i) - \ln(s)),$$

where K_h is a normalized kernel function and h the bandwidth. If the terms α_1 and α_2 are excluded, then the estimate of α_0 is the Nadaraya-Watson estimator. Compared to the Nadaraya-Watson estimator, local polynomial regression usually is less biased. For a given kernel K_h and bandwidth h, $\hat{\alpha}$ can be solved for by ordinary least squares.

For some organizational forms and qualities, the data can be sparse for a range of school sizes. We therefore modify the kernel to an adaptive kernel estimator. In essence, the adaptive kernel estimator uses a bandwidth which varies inversely with the density of the data. The bandwidth which is used on observation i is $(h\lambda_i)$, where

$$\lambda_i = \left[\frac{f_{h_p}(\ln(s_i))}{Exp\left(\dfrac{\sum_{j=1}^{n} \ln(f_{h_p}(\ln(s_j)))}{n} \right)} \right]^{-\rho},$$

and f_{h_p} is the standard estimator of the density of the data using a pilot bandwidth h_p. We used $\rho = 0.5$ and the standard normal density as kernel function.

The choice of kernel is less important than the choice of bandwidth h. In short, a large bandwidth gives a smooth estimate of the regression function, but also a high bias whereas a small bandwidth gives a wiggly estimate with a high variance. The tradeoff between bias and variance is solved by minimizing the integrated mean square error. In practice, this can be done by minimizing a cross-validation function, which mimics the behavior of the mean squared error. Hence, we used this (mechanically) way to select the bandwidth.

The confidence intervals for the regression functions are estimated using the bootstrap. The usual asymptotic based symmetric 90%-confidence interval at ln(s) is constructed as $(m(\ln(s), \hat{\alpha}) - a_{0.95}\sqrt{v(\ln(s))}\ ,\ m(\ln(s), \hat{\alpha}) + a_{0.95}\sqrt{v(\ln(s))})$, where v(ln(s)) is the variance[12)] of $m(\ln(s), \hat{\alpha})$

$$v(s) = \sum_{i=1}^{n} \left[\frac{K\left(\dfrac{\ln(s) - \ln(s_i)}{h} \right)}{\sum_{i=1}^{n} K\left(\dfrac{\ln(s) - \ln(s_i)}{h} \right)} \right]^2 (\ln(c_i) - m(\ln(s), \hat{\alpha}))^2,$$

and $a_{0.95}$ is the 0.95-quantile of the standard normal distribution. The bootstrap confidence interval is constructed by replacing the 0.95-quantile of the standard normal distribution by the 0.95-quantile of the bootstrap distribution found the following way.

1. Make a random sample of pairs (c_i,s_i) from the (original) sample. Denote this a bootstrap sample $((c_1^*,s_1^*) , (c_2^*,s_2^*),..., (c_n^*,s_n^*))$.
2. Using the bootstrap sample from 1, calculate the regression function $m^*(\ln(s), \tilde{\alpha})$ and the variance $v^*(\ln(s))$. Then calculate the absolute t-ratio $|t^*| = \left| \frac{m^*(\ln(s),\tilde{\alpha}) - m(\ln(s),\hat{\alpha})}{\sqrt{v^*(\ln(s))}} \right|$.
3. Repeat step 1 and 2 for 1000 times. The 950th largest value of the 1000 *t^** values is the 0.95-quantile $a_{0.95}$ of the bootstrap distribution.

The bootstrap confidence interval is constructed using the t-ratio in step 2, because an asymptotic refinement can be obtained compared to the usual (first-order) asymptotic approximation, see Horowitz (1999) for details.

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Notes:

1. Quality refers to the product supplied to the consumers (schools). The quality of the workplace – though important – is not considered.
2. The cleaning budget might be integrated in some broader budget, allowing the school some substitution between various budget accounts. In such cases, it is possible that not all the administrative costs are included in the cleaning budget.
3. The second largest company has been purchased by the largest after the data was collected. Already after a few weeks the managing director started to speak about higher prices and that cutthroat competition was socially undesirable.
4. The market is not perfect though. Christoffersen, Larsen & Paldam (2001) reports a DEA analysis of the data for private cleaning showing a potential for a further savings of 33% even disregarding extreme points.
5. We also considered the number of classes taught at the school as an alternative measure of size. We found much the same results.
6. This variable has considerable variation, with a range from 40% to 90%. This variable has a low correlation to the other variables included.
7. Presented and discussed in Christoffersen & Paldam (1998), which shows that the market orientation – the use of private companies after competitive bidding – is smaller in municipalities with a large welfare coalition.
8. The Heckman's two-step estimator often does not produce a good result due to 'weak' identification since the same variables need to be used in both steps. Here, we avoid this problem.
9. For the log welfare coalition the average is 4.22 for the two types of public cleaning. The average to the log tax base is 4.5.
10. This follows from Jensen's inequality: Exp(E(Ln(C)) # E(C). If normality is assumed, Exp(E(Ln(C)) can be corrected by the factor Exp(0.5F^2) to give an estimate of the average cost function, where F is the standard error of the regression. We do not make such distributional assumptions and, hence, we report Exp(E(Ln(C)).
11. See the survey on competitive bidding by McAfee & McMillan (1987).
12. Assuming the regression function is undersmoothed.