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EXPLAINING DIFFERENCES IN PRODUCTIVE EFFICIENCY : AN APPLICATION TO BELGIAN MUNICIPALITIES

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Abstract :

The purpose of this paper is to measure and explain variations in productive efficiency of municipal governments in Belgium. Technical efficiency is evaluated using a non-parametric method based on the Free Disposal Hull (FDH) reference technology. We first calculate input, output, and global Farrell efficiency measures for a cross-section of all 589 Belgian municipalities. In a second stage of the analysis we explain the calculated differences in efficiency in terms of variables related to the structural characteristics of municipalities and to the institutional environment.

1. Introduction

An abundant literature deals with measuring efficiency in both the private and the public sector and compares their relative performance (see, e.g., Atkinson and Halvorsen [1]; Borcherding, Pommerehne and Schneider [4]; Färe, Grosskopf and Logan [7]). The efficiency of the local public sector has not been studied intensively, however. Although a number of studies are concerned with evaluating productivity growth in state and local governments (see, e.g., Fisk [9]; Hulten [12]), little is known about the degree of technical efficiency involved in the provision of local public services[1]. This is somewhat surprising since technical efficiency is a crucial component of the overall performance of the local public sector. Although performance evaluation in principle requires the identification of all relevant objectives, it has been argued that technical efficiency is compatible with the realization of a variety of other goals that have explicitly or implicitly been attributed to the public sector[2]. A better understanding of the degree of technical efficiency and its determinants is therefore an important first step in global performance evaluation.

In this paper we study productive efficiency of municipal governments in Belgium. We thereby proceed in two steps. We first measure technical efficiency using a deterministic and non-parametric method based on the Free Disposal Hull (FDH) reference technology suggested by Deprins, Simar and Tulkens [5]. The FDH is based on minimal assumptions with respect to the production technology. Moreover, it has a strong intuitive appeal and requires a minor computational effort. In a second stage of the analysis we attempt to explain the variability in technical efficiency among municipalities in terms of their structural and political characteristics, taking into account the institutional framework of local government financing.

The paper is organized as follows. In the first section we present the FDH reference technology and discuss three alternative Farrell measures that will be used to evaluate technical efficiency. Application of the suggested methodology to all Belgian municipalities is reported in Section 2. We provide information on the distributions of the calculated efficiency measures for two different specifications of the vector of municipal outputs. In Section 3 we report on our attempt to explain the variability in productive efficiency within the framework of a censored regression model. Potential determinants of productive inefficiency are derived from the literature and from the Belgian institutional environment. The final section summarizes and suggests some conclusions.

2. The FDH-approach to technical efficiency

In this section we discuss the procedure used to measure technical inefficiency of Belgian municipalities. To fix ideas, note that the concept of productive or technical efficiency relates to the ability of a production unit to produce on the boundary of its production possibilities set. As a consequence, any methodology for the evaluation of technical efficiency must proceed in two steps. First, the set of production possibilities and its boundary must be completely specified. This defines the reference technology. Second, some concept of distance is required to relate the input and output vectors of observed production units to the postulated boundary of the production set. To characterize the approach used in this paper we therefore first specify its assumptions regarding the production set, and then present the efficiency measures calculated in the empirical analysis.

2.1. Definition of the FDH reference technology

With respect to the specification of the production set and its boundary a variety of methods have been suggested. At the risk of oversimplifying an impressive literature it is convenient to distinguish between parametric and non-parametric approaches. In the former case it is assumed that the boundary of the production possibilities set can be represented by a frontier of a known functional form with constant parameters[3]. The non-parametric approach on the other hand concentrates on the regularity assumptions of the production set and does not postulate a particular functional boundary. Imposing some plausible restrictions on the nature of the production process a piecewise linear reference technology or best practice frontier is directly constructed on the basis of observed input and output combinations[4].

In this paper we use the non-parametric FDH reference technology introduced by Deprins, Simar and Tulkens [5] and further popularized by Tulkens and his collaborators (for a review of recent applications see, e.g., Tulkens [25]). Compared to other non-parametric methods such as Data Envelopment Analysis (DEA) the FDH approach allows us to restrict the assumptions with respect to the production technology to a minimum. Apart from some standard regularity assumptions (e.g. boundedness and closedness of the production set[5]) our only additional assumptions are strong free disposability of inputs and outputs.

Strong free disposability of inputs or monotonicity rules out that an increase in inputs results in a decrease in outputs. Strong free disposability of outputs implies that any reduction in outputs remains producible with the same amount of inputs. Note that the latter assumption allows for variable returns to scale. The property of strong free disposal has a strong intuitive appeal. Given any particular combination of inputs and outputs a production unit must always be capable of producing less output with the same amount of inputs or producing the same output level with a larger amount of inputs.

A graphical illustration of the construction of the free disposal hull for the case of one input and one output is provided in Figure 1. Reflecting free disposability, each observed combination of inputs and outputs adds one orthant, positive in the inputs and negative in the outputs, to the production set. The free disposal hull FDH is then the boundary to the union of all orthants whose origin coincides with an observed vector. Note that the FDH approach results in a staircase shape of the best practice production frontier. Contrary to other non-parametric approaches, convexity is not imposed.

In practice two methods are available to reconstruct the FDH reference technology and to distinguish efficient from inefficient observations (see Tulkens [25] for details). First, it has been shown that FDH may be considered a special case of Data Envelopment Analysis and that the frontier can be obtained by solving an appropriately defined linear programming problem. Second, a highly convenient data classification algorithm can be used based on simple vector dominance reasoning. The algorithm, which we used in the empirical application to be discussed below, basically proceeds as follows. Each observation is sequentially compared to all other observations. An observation is declared inefficient if it is possible to find another observation which produces the same or more outputs with strictly less of at least one input, or which uses the same or less inputs to produce strictly more of at least one output. Observations for which no such other observation exists in the data set are 'undominated'. They are declared efficient. On the contrary, dominated observations are inefficient. Finally, observations which are efficient but which never dominate another observation are called efficient by default. Due to the partial ordering implied in the dominance reasoning the method is unable to make precise statements concerning their technical efficiency.

The method is illustrated in Figure 1. Observations 1 to 7 are efficient. Furthermore observations 1 and observations 5 to 7 are efficient but do not dominate any other observation. They are efficient by default. Observation 8 is dominated by observations 3 and 4 and itself dominates observation 9. Note finally the effect of not imposing convexity. The FDH approach results in observation 5 being efficient. However, had convexity been imposed this observation would have been dominated by a linear combination of observations 4 and 6. It therefore would have been labeled inefficient.

It is important to emphasize that the minimal technical and behavioral assumptions and the close enveloping of observed production units make the FDH reference technology particularly useful for analyzing public sector efficiency questions. Indeed, there is no generally accepted model of local governmental behavior that would justify the imposition of strong behavioral assumptions. Moreover, as illustrated above, the efficiency indices based on the FDH reference technology are conservative compared to those obtained by methods assuming convexity. Use of a conservative approach may be considered an advantage in an analysis of the public sector, where technical inefficiencies may give rise to intense discussions on the political platform. An observation labeled inefficient relative to the FDH would almost certainly have been characterized as inefficient relative to any of the other commonly used reference technologies. A final advantage of the FDH is that, contrary to some of the other methods, inefficiencies are calculated vis-à-vis actually observed input-output combinations.

Of course, the advantages of the method have to be traded off against at least one obvious shortcoming. The vector dominance reasoning implies a substantial sensitivity to the number of dimensions that are taken into account in the analysis. Increasing the number of inputs or outputs reduces the possibilities for an observation to be dominated, and therefore increases the probability of being declared efficient. Careful sensitivity analysis may throw some light on the empirical importance of this phenomenon.

2.2. Definition of the efficiency measures

Having described the construction of the best practice frontier we now turn to the problem of defining indices of inefficiency that somehow measure the distance of inefficient observations to the frontier. In applied work based on the non-parametric approach it has been common to confine the attention to Farrell measures of either input or output inefficiency (see, e.g. Färe, Grosskopf and Logan [7]). For example, in the case only input inefficiency is considered one typically searches for the maximum scalarwise reduction of all inputs yielding the same output. In terms of the textbook isoquant analysis, input efficiency is measured along a ray through the origin (see Farrell [8]). Note that a Farrell index of output inefficiency can be analogously defined by considering the maximal proportional increase in all outputs that is feasible for given inputs.

Although a case could be made in favour of non-radial efficiency measures, we limit our attention in this paper to indices of the Farrell type[6]. However, contrary to common practice in the literature, we do not restrict the analysis to separate input and output efficiency indices, but also calculate a global or graph efficiency index, taking into account all input and output dimensions simultaneously. This seems desirable, as restricting the indices to either the input or the output dimension implies that not all available information is used in the construction of the ranking of observations in terms of their productive efficiency. Therefore, in the empirical section of this paper we will report three Farrell efficiency indices referring to input, output, and global efficiency, respectively. The latter Farrell "graph measure" is described in Färe, Grosskopf and Lovell [6]. It is obtained by simultaneously considering the maximum proportional reduction of all inputs and increase of all outputs.

The different efficiency indices are illustrated in Figure 2 for the case of one input and one output. Consider the inefficient observation 8. The corresponding input and output efficiency indices are given by the ratios ab/ac and ec/ed, respectively. The global efficiency index is slightly more subtle to interpret graphically. Applying the maximum common input reduction and output increase to observation 8 results in point 5' on the FDH frontier. The global inefficiency index is then given by the ratio af/ac, which by definition equals the ratio ec/eg.

3. Technical efficiency in Belgian municipalities

In this section we apply the methodology previously outlined to study the efficiency of local public service provision by Belgian municipalities. We must admit at the outset that, mainly because of the quality of the data, the analysis is limited in scope. We initially worked with a data set comprising one input indicator and four output indicators for each of the 589 local governments[7]. Total municipal staff was the only input taken into account in the analysis. This is by far the most important, but obviously not the only input in the production of local public services. However, data on capital and material inputs were unavailable. The outputs used represent important aspects of local production in the field of education, transportation, and social and recreational services. Specifically, the outputs used were :

(i) the length of municipal roads;
(ii) the number of beneficiaries of minimal subsistence grants;
(iii) the number of students enrolled in local primary schools;
(iv) the surface of public recreational facilities[8].

Obviously, these output indicators do not cover the full range of services provided by municipal governments. From municipal accounts it can be verified that they typically capture between 30% and 75% of total municipal outlays. Hence the subsequent analysis should be carefully interpreted. For example, it is conceivable that municipalities spending a substantial fraction of their budget for the production of services not captured by our output indicators would be incorrectly assigned very low efficiency scores. To reduce the potential bias in our results on this account we also repeated the whole analysis using one input and five outputs, where the fifth 'output' was simply defined as total municipal outlays minus the outlays on the four outputs previously defined. In principle, this should largely eliminate the above-mentioned bias in the efficiency ranking of local governments[9].

As suggested in the previous section we applied the FDH-approach to calculate Farrell indices of input efficiency, output efficiency, and global efficiency[10]. Summary results are reported in Table 1. The figures presented in the left part of the table refer to the initial analysis using one input and four outputs. In the right part we give the corresponding results after the fifth output has been added.

The results clearly illustrate the importance of the choice of the dimensions on which the efficiency measure is calculated. Not surprisingly, the alternative Farrell measures lead to substantial differences in calculated inefficiencies. In the initial analysis based on four outputs mean input efficiency amounts to 0.77, indicating that, on average, municipalities could produce their observed output levels with approximately 23% fewer inputs. Mean output and global (graph) efficiency are calculated to be 0.81 and 0.88, respectively. The latter suggests that, on average, local governments could have produced somewhat less than 12% more output with 12% less input. Also note that the different measures have a quite different range and standard deviation. The input and output measures are substantially more dispersed. Finally, observe that quite similar remarks apply for the analysis based on five outputs.

The results in Table 1 also illustrate the consequences of using a conservative reference technology. In the four output case almost 40% of all municipalities is classified as efficient. As increasing the number of inputs and outputs in the data set decreases the possibility of being dominated by other observations, the analysis based on five outputs yields an even larger number of efficient municipalities (50%). Finally note that, depending on the number of outputs considered, 3% to 10% of all observations are declared efficient by default.

The choice of dimensions not only affects the location and shape of the distribution, it also alters the implied rankings of technical efficiency. In Table 2 we compare the correlation coefficients between different efficiency measures. The correlation between the output and input measure is relatively small. If one calculates the correlation coefficients on the inefficient observations only the relevant figure is as low as 0.56 in the four output case. The correlation between input and graph measures and between output and graph measures is substantially larger, ranging between 0.74 and 0.79.

To conclude this section, Figures 3 and 4 present the distribution of the efficiency measures for the cases of four and five outputs, respectively. These distributions are obviously bimodal due to the concentration of efficient municipalities at unity. They are somewhat skewed to the right even if one ignores the efficient observations.

4. Explaining technical inefficiencies of Belgian municipalities

In this section we report on our attempt to explain differences in the calculated technical inefficiencies of Belgian municipalities. We consecutively present the estimation method, suggest a number of potential determinants of variations in efficiency, and discuss the empirical results.

An appropriate model to explain efficiency differences as revealed by the FDH approach should take account of the characteristics of the distribution of the efficiency measure. Following Martin and Page [15] and Rhodes and Southwick [21] we used the Tobit censored regression model to accommodate the mass of efficiency scores at unity. This seems warranted because the true variability in efficiency among the municipalities having an efficiency score equal to one is unobserved. Moreover, as indicated before, the FDH method implies that nothing can be said about the relative efficiency of those municipalities declared 'efficient by default'. Consistent with this observation, they were deleted from the sample in the explanatory analysis that follows.

For our purpose the standard Tobit model can be defined in the following way :

$$
\begin{aligned}
&y_i^* = x_i'\beta + u_i, \quad i = 1, \ldots, n \\
&y_i = y_i^* \quad if\ y_i^* < 1 \\
&y_i = 1 \quad if\ y_i^* \geq 1
\end{aligned}
$$

where u_i are assumed to be i.i.d. drawings from $N(0,\sigma^2)$. The latent variable y^*_i is not directly observable. Its observed counterpart is the efficiency index y_i which is censored at the limit level of 1 thus masking the true value of y^*_i. For y^*_i less than 1 both y_i and x_i are observed while for $y^*_i \geq 1$ the x_i are observed and the y_i equal the limit value of 1. It is well-known that the Tobit estimates are sensitive to any violation in the underlying assumptions. However, in this stage of the analysis we did not use any of the available diagnostic tests, but confined ourselves to residual checking.

Many studies dealing with estimating inefficiencies in the public sector simply do not attempt to explain the estimated differences in a systematic way (see, e.g., Levitt and Joyce [13]). However, recently a number of exceptions have appeared in the literature (Bartel and Schneider [2]; Boardman and Vining [3]; Lovell, Walters and Wood [14]). Although these studies did not measure efficiency using non-parametric techniques or were not specifically concerned with local governments, they do provide useful suggestions with respect to the potential determinants of inefficiency. Moreover, the literature on productivity growth in the local public sector and the public choice literature each provide additional determinants. Finally, our search for explanatory factors of municipal inefficiencies has been guided by our understanding of the Belgian institutional framework.

A first source of inefficiencies may be related to a poor adjustment of municipalities' size to the optimal scale of providing local public services (see, e.g., Spann [24]). For example, the size of the municipality may inhibit exploiting economies of scale in some or all of the production processes. Although strictly speaking technical efficiency and scale efficiency are distinct concepts, our methodology to measure inefficiencies implies that empirically scale inefficiencies may show up as technical efficiency. To analyze the relation between scale and efficiency two variables have been experimented with, viz. the municipality's population (POP) and its surface (SURFACE). To capture possible nonlinearities in the impact of the population being served, quadratic terms for this variable have been added.

Second, when appropriately applied to the public sector both the theory of property rights and, more recently, principal-agent models suggest the possibility that politicians and public managers may pursue goals independent from the constituency they represent and from the organization in which they operate. A number of reasons have been suggested as to why they may lack appropriate incentives to effectively audit and control expenditures. The public choice literature suggests that the process of political decisionmaking itself may impede the effective control of the public sector (Mueller [17]; Borcherding, Pommerehne and Schneider [4]; Bartel and Schneider [2]). Politicians' emphasis on political rather than economic rationality is likely to contribute to inefficiency. For example, top bureaucrats may be appointed according to party affiliation and not because of their managerial skills. In addition, political rationality may imply the use of explicit or implicit (e.g. logrolling) 'side payments' in the decision-making process. In this respect, the size of political coalitions may affect technical inefficiency because arbitrage in the bargaining process may require more such payments. To approximate the above ideas, two sets of variables were constructed. First, we introduced the number of parties in a municipal coalition (CPAR). Second, to test whether inefficiencies might be party-related we used dummy variables indicating the presence of a particular political family in the ruling coalition (CLIB and CSOC for the liberal and socialist parties, respectively).

It is conceivable that the incomes and wealth of citizens affects the incentives of both politicians and taxpayers to effectively control expenditures. First, these factors largely determine the fiscal capacity of municipalities. Higher fiscal revenue capacity may increase the on-the-job leisure of politicians and public managers and affect the possibilities to operate inefficiently. Second, citizens of high-income municipalities may be less motivated to effectively monitor expenditures, for example due to the higher time cost involved. To proxy for the above influences two variables have been defined. The first one is average personal income (INCOME). Alternatively, a direct measure of fiscal revenue capacity was defined as the tax revenues generated by levying a 1% tax rate on the existing tax base (TAXREC).

The financing of local public services may be important for several reasons. First, it has been argued (see, e.g., Spann [24]) that high tax prices associated with a given level of service provision increases voters' monitoring of public expenditures, especially if cost comparisons between municipalities are easy. We therefore investigated to what extent high local tax rates encourage efficiency. In Belgium the two main municipal taxes are a local income tax and the property tax. In the regressions reported below, only the latter tax rate (HTAX) was included, as the former yielded consistently poor results. Second, on average, slightly more than 20% of local government operations are funded by block grants. These are often believed to induce a 'flypaper' effect in that they result in a larger increase in local government expenditures than an equivalent change in residential incomes (see, e.g., Hamilton [11]). Although this is not implied by the flypaper effect, it could be hypothesized in addition that large grants increase the potential for technical inefficiency. In the regressions we therefore added the size of the block grant (GRANT) as an explanatory variable.

Finally, three additional influences were accounted for. First, Spann [24] suggests that citizens' mobility between alternative municipalities may stimulate politicians to more closely control public production. We used net immigration as a proxy for mobility (NETMIG). Second, in addition to mobility the performance of the municipality may also be enhanced by the political participation of citizens. Hypothesizing that home owners are more deeply involved in community life we added the percentage of home owners in the population (PCTOWN). Third, we allowed for the possibility of regional differences in efficiency by introducing dummy variables for the Walloon (REG1) and the Brussels (REG2) region. We simply interpret these as reflecting regional effects of socio-economic and political characteristics not captured by the other variables.

Note that we do not claim that this list of included explanatory variables is complete. As in most empirical work some potential explanatory variables could not be explored due to data limitations. On the one hand, for example, it has been argued that the degree of unionization of municipal personnel, the possibility to obtain certain publicly provided goods from private suppliers, and the opportunity to contract out services may increase technical efficiency (see Spann [24]; Bartel and Schneider [2]; Boardman and Vining [3]). On the other hand, several models explain the public sector's tendency towards an excessively large bureaucracy encouraging technical inefficiency (see, e.g., Niskanen [18]). Unfortunately, we did not have any information concerning these potential determinants, except for some poor proxy variables, and therefore could not assess their explanatory power.

Tobit regression results are presented in Table 3. Note that in order to save some space, we only report the results of the explanatory analysis based on the global (graph) efficiency measure. Moreover, we only give a relatively small subset of alternative specifications. For ease of comparison we present the same specifications for the four and five output cases. The majority of explanatory variables is common to all specifications.

The scale variable (POP) has a significant positive effect, while population squared (POPSQ) has a significant negative impact[11]. Hence productive efficiency appears to be a concave function of the population being served. This indicates that despite the giant fusion operation of Belgian municipalities in the seventies, on average the scale of public good provision may be suboptimal. The tax price (HTAX) has a positive albeit insignificant impact while the block grant variable (GRANT) yields a negative coefficient. Interpreting this result literally suggests that grants may not only encourage local service provision, but that they also lead to some additional technical inefficiency. Combined with the insignificance of the local tax rate, the impact of block grants may point at the presence of some fiscal illusion. The income variable (INCOME) yields a significantly negative coefficient, consistent with the interpretation of this variable as affecting both politicians' and taxpayers' incentives to monitor local expenditures. The results indicate the negative impact of the number of coalition partners (CPAR), providing some support for the hypothesis formulated above. Finally, the dummy variables for the Walloon (REG1) and the Brussels (REG2) region indicate an overall lower performance compared to the Flemish region.

The purpose of the second and third regression is to test the impact of two other potential determinants and to find out how sensitive the coefficients of the first regression are to changes in the specification. We incorporated the ownership rate previously defined (PCTOWN) as well as the mobility proxy (NETMIG). Consistent with a priori expectations the results suggest that political participation increases technical efficiency. The mobility of citizens seems to encourage efficiency, which may suggest that households at least partially choose location on the basis of the characteristics of local service provision.

Changing the specification does not seem to affect the coefficients of the most important variables in a dramatic way. Not surprisingly, the magnitude of the insignificant coefficients of the grant and the tax price are somewhat affected, but qualitatively the results remain unchanged.

Comparing the estimates for the efficiency measures based on four and five outputs does reveal some quantitatively large differences in coefficients (see, e.g., the coefficients of population and the regional dummys). This is not surprising, given the difference in expenditures captured by the outputs in the two cases. This finding illustrates the importance of a careful and complete coverage of inputs and outputs.

Although these parameter estimates are not reported, qualitatively very similar results were obtained using the fiscal capacity measure (TAXREC) instead of income (INCOME). Furthermore, replacing the number of coalition partners (CPAR) by dummy variables indicating the presence of a political family in the coalition suggest that the presence of the liberals (CLIB) tends to decrease technical efficiency, while the socialist party (CSOC) seems to have no effect. Finally, adding the municipality's surface (SURFACE) as a proxy for scale yields a positive significant coefficient. But as it may be correlated with two of the outputs (viz. the length of municipal roads and the surface of public recreational facilities), its interpretation is dubious.

To conclude this section, one final remark is in order. Our results were obtained in a single equation context, which implicitly assumes exogeneity of all independent variables. This may not be entirely appropriate. For example, local tax rates and even the grants allocated to individual municipalities may be dynamically related to inefficiencies. It could be argued that a more thorough explanation of the degree of technical inefficiency requires a simultaneous modelling of all decision variables of the municipal authorities. Such a comprehensive analysis was outside the scope of this paper, however.

5. Conclusion

The purpose of this paper was twofold. First, based on the free disposal hull (FDH) reference technology we calculated various measures of productive efficiency for a data set of all 589 Belgian local governments. Second, within the framework of a censored regression model we attempted to explain in a systematic way the resulting distribution of the efficiency measures.

The FDH methodology was indicated to make minimal assumptions with respect to the production technology and to be relatively easy to implement. It was used to calculate input, output and global Farrell measures of productive efficiency. Mean technical efficiency of Belgian municipalities was found to range between 0.77 to 0.93, depending on the specification of outputs and the particular efficiency measure used. Given the relatively low correlation between the input and output efficiency indices we argued in favor of the global Farrell 'graph' measure.

Variations in efficiency among local governments were explained in terms of the structural and political characteristics of municipalities, taking into account the institutional environment in which they operate. Some evidence was found that the scale and the fiscal revenue capacity of municipalities are important determinants of efficiency. Moreover, the financing mechanism of local public service provision and the political characteristics of municipal governments were estimated to affect inefficiencies. Finally, net migration provided an additional element of explanation. Importantly, however, the results were indicated not to be entirely robust to changes in the empirical specification, suggesting the need for further analysis.

When judging the empirical results obtained in this paper, it is useful to keep in mind that the combination of a Farrell graph efficiency measure with the FDH reference technology may make the explanation of technical efficiency a difficult exercise. As noted earlier the FDH reference technology automatically yields conservative efficiency measures. Moreover, the Farrell graph measure results in a relatively limited range over the sample, since it is always larger than either the input or output efficiency measures. Although this problem can easily be remedied by working with other technical efficiency measures, in this paper we did not want to depart from the tradition of using radial measures.

Notes

1. One recent study is Vanden Eeckaut, Tulkens and Jamar [26].

2. See e.g. Pestieau and Tulkens [19].

3. For an early survey, see Førsund, Lovell and Schmidt [10].

4. For a recent review of these reference technologies, see Seiford and Thrall [23].

5. For details and interpretation we refer to Färe, Grosskopf, and Lovell [6], p.24-25.

6. A number of non-radial measures have been proposed in the theoretical literature. For a detailed discussion, see Färe, Grosskopf and Lovell [6], Russell [22] and Zieschang [27].

7. Vanden Eeckaut, Tulkens and Jamar [26] have also reported results for the Belgian local authorities using FDH. This paper differs from their study in several respects. First, their sample is restricted to the 262 municipalities in the Walloon region. Second, they use different inputs and outputs. Third, they do not explain the variability in the calculated efficiency measures.

8. This includes the municipalities' surface of parks, and of sports and various other recreational facilities.

9. A much more complete sensitivity analysis was carried out to investigate the sensitivity of the results with respect to sample size, definition of inputs and outputs, and the number of input and output indicators used. Reporting the corresponding results is outside the scope of this paper, however.

10. To perform the calculations an algorithm was written in Turbo-Pascal. Apart from Farrell efficiency indices the program also provides a wealth of additional information (the set of dominating observations, the excess in inputs and shortage in outputs, non-radial efficiency measures, etc.).

11. Note that the estimated coefficients cannot directly be interpreted as partial effects. The appropriate correction factor is discussed in McDonald and Moffitt [16] and Pudney [20]. As an example the first regression in the five output case implies that a population increase of 10000 people results in an increase in efficiency with 0.21.

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Figure 1 : FDH graph reference technology

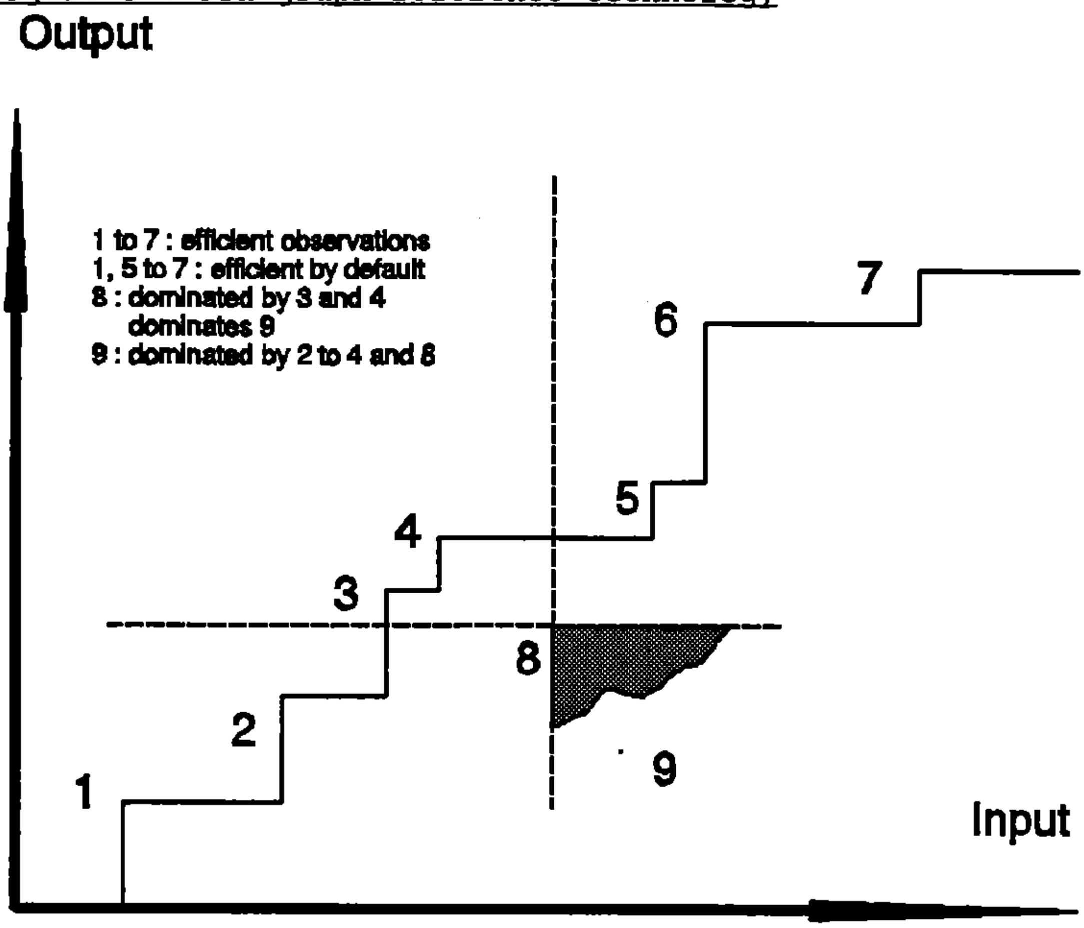

Figure 2 : Farrell efficiency measures

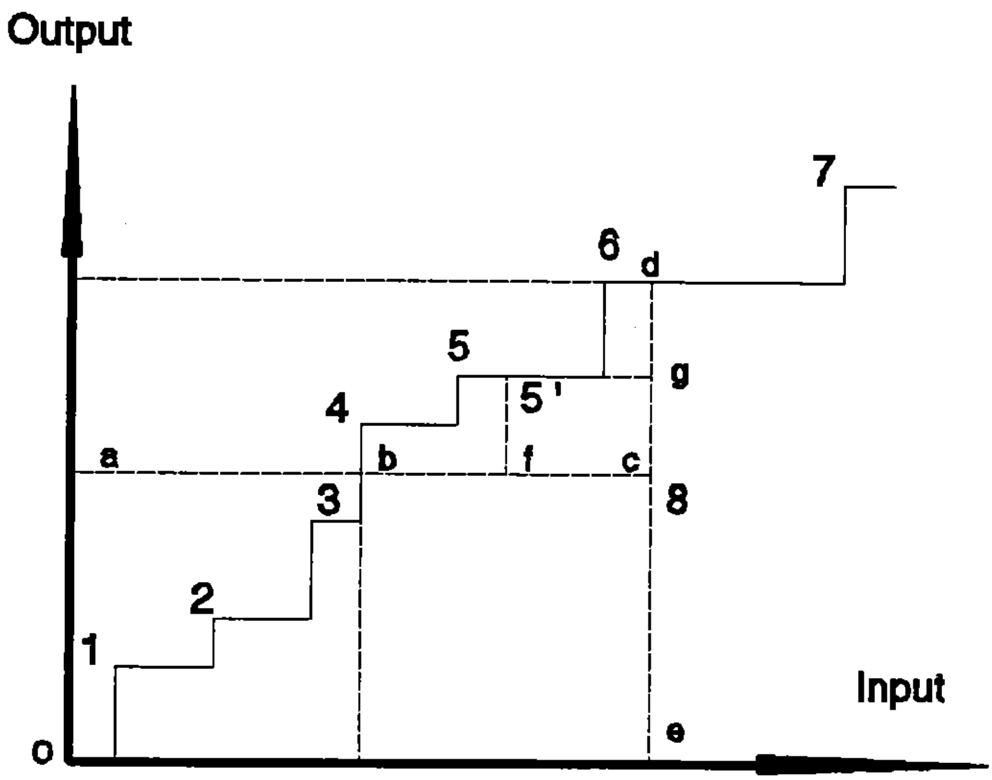

Table 1 : Descriptive statistics of Farrell efficiency measures

	4 outputs			5 outputs		
	Farrell global	Farrell input	Farrell output	Farrell global	Farrell input	Farrell output
Mean	.877	.773	.808	.927	.861	.878
Median	.938	.846	.881	1.000	1.000	.999
Minimum	.438	.128	.167	.490	.235	.268
Std Dev	.147	.247	.216	.105	.189	.167
Kurtosis	2.960	2.181	2.404	4.732	3.245	3.582
Skewness	-1.012	-.681	-.805	-1.492	-1.162	-1.152
# Most dom. observations	78(13%)	88(15%)	87(15%)	74(13%)	72(12%)	80(14%)
# Ineffic	358(61%)			297(50%)		
# Efficient by default	20(3%)			59(10%)		

Table 2 : Correlations between Farrell efficiency measures

	4 outputs			5 outputs		
All observations	Farrell global	Farrell input	Farrell output	Farrell global	Farrell input	Farrell output
Farrell global	1.000			1.000		
Farrell input	.868	1.000		.890	1.000	
Farrell output	.888	.792	1.000	.890	.811	1.000
Inefficient observations	Farrell global	Farrell input	Farrell output	Farrell global	Farrell input	Farrell output
Farrell global	1.000			1.000		
Farrell input	.743	1.000		.780	1.000	
Farrell output	.786	.560	1.000	.782	.594	1.000

Figure 3 : Histogram : Farrell efficiency measures (4 outputs)

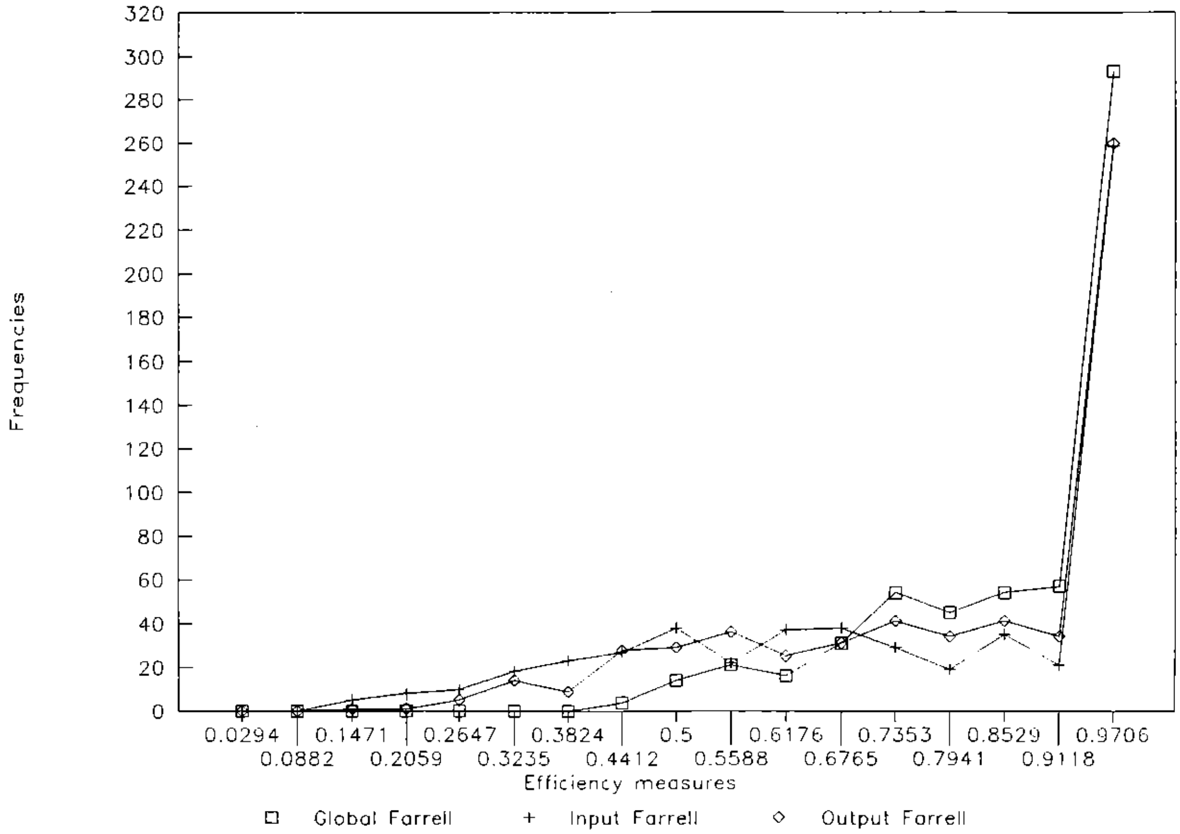

Figure 4 : Histogram : Farrell efficiency measures (5 outputs)

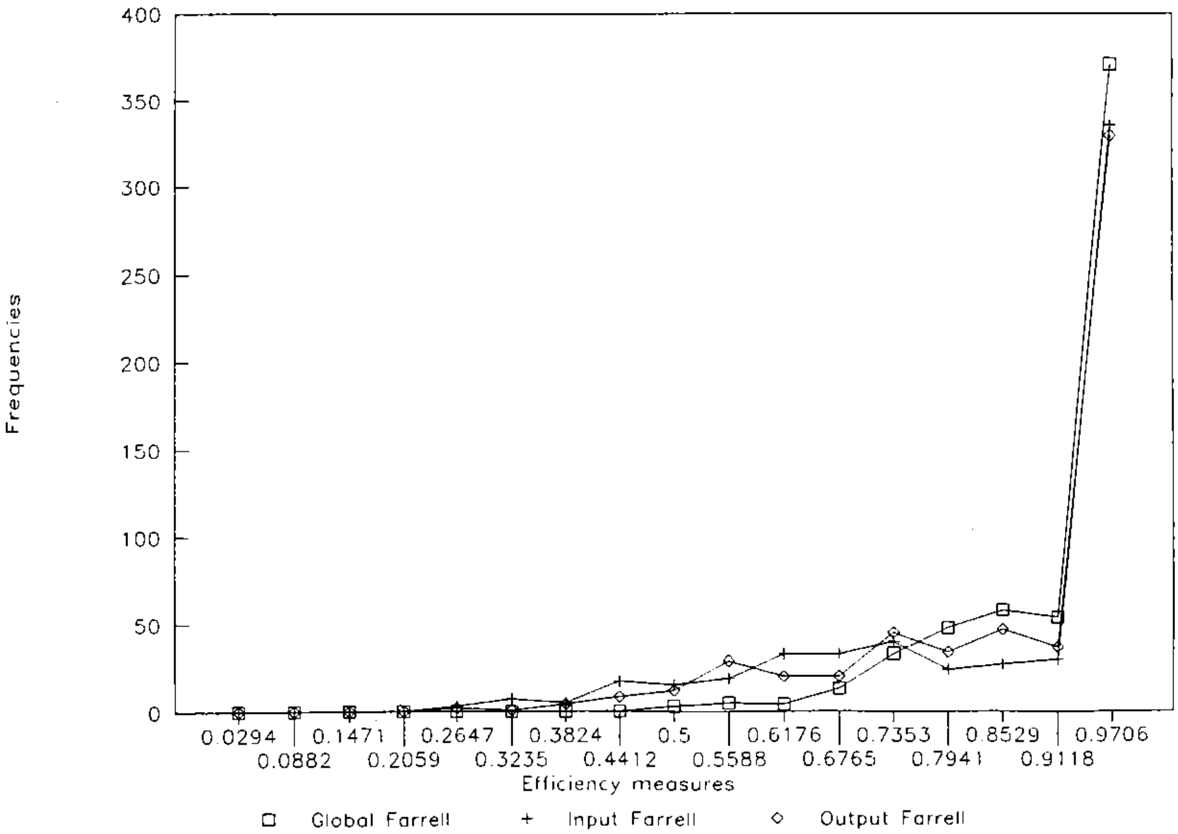

Table 3 : Determinants of technical efficiency : Tobit results (standard errors between brackets)

	Dataset 4 outputs			Dataset 5 outputs		
INTERCEPT	1.302	1.146	1.167	1.249	1.100	1.111
	(.087)*	(.137)*	(.136)*	(.075)*	(.119)*	(.119)*
POP	0.77E-02	0.84E-02	0.88E-02	0.12E-01	0.13E-01	0.13E-01
	(.12E-02)*	(.13E-02)*	(.13E-02)*	(.20E-02)*	(.21E-02)*	(.21E-02)*
POPSQ	-0.17E-04	-0.20E-04	-0.20E-04	-0.80E-04	-0.88E-04	-0.89E-04
	(.13E-04)	(.13E-04)	(.13E-04)*	(.23E-04)*	(.23E-04)*	(.23E-04)*
CPAR	-0.73E-02	-0.82E-02	-0.74E-02	-0.18E-01	-0.19E-01	-0.19E-01
	(.13E-01)	(.13E-01)	(.13E-01)	(.11E-01)	(.12E-01)*	(.12E-01)*
HTAX	0.46E-06	0.31E-05	0.85E-05	0.89E-06	0.25E-05	0.55E-05
	(.20E-04)	(.20E-04)	(.20E-04)	(.18E-04)	(.18E-04)	(.18E-04)
INCOME	-0.24E-02	-0.23E-02	-0.25E-02	-0.19E-02	-0.18E-02	-0.19E-02
	(.40E-03)*	(.41E-03)*	(.41E-03)*	(.36E-03)*	(.36E-03)*	(.36E-03)*
GRANT	-0.10E-03	-0.90E-04	-0.12E-03	-0.27E-03	-0.22E-03	-0.17E-03
	(.10E-03)	(.10E-03)	(.10E-03)	(.18E-03)	(.19E-03)	(.19E-03)
REGION1	-0.022	-0.017	-0.014	-0.036	-0.031	-0.032
	(.019)	(.019)	(.019)	(.018)*	(.018)*	(.018)*
REGION2	-0.300	-0.257	-0.233	-0.195	-0.149	-0.131
	(.057)*	(.064)*	(.065)*	(.050)*	(.057)*	(.058)*
PCTOWN		0.16E-02	0.16E-02		0.16E-02	0.16E-02
		(.11E-02)	(.11E-02)		(.10E-02)	(.10E-02)
NETMIGR			0.19E-03			0.12E-03
			(.84E-04)*			(.75E-04)*
Ln L	-96.8	-95.8	-93.3	-46.7	-45.5	-44.1

* Significance at the 90% confidence level

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