Alexander Kalb

Public Sector Efficiency

Applications to Local Governments in Germany

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Preface

This book provides an empirical analysis of different aspects concerning the technical and cost efficiency of the public sector in Germany. More specifically, the studies in this book focus on the local level, namely on the local governments of the German state Baden-Württemberg. Apart from the efficiency analyses of the local governments, this book also provides a broad review of the methods which can be applied to calculate efficiency measures of decision-making units as well as an extensive review of the existing literature on public sector efficiency.

The work described in this doctoral thesis was carried out at the Centre for European Economic Research (ZEW) and has been made possible through the financial support of the German Research Foundation (DFG) within its Priority Programme "Institutional Design of Federal Systems: Theory and Empirical Evidence" and through different research projects at the ZEW.

First and foremost I am indebted to my supervisor Prof. Dr. Lars P. Feld for finding interest in my research topics and for giving me considerable freedom to write this doctoral thesis. I would also like to thank Prof. Dr. Timo Goeschl, who kindly consented to be my second supervisor. In addition, I am also very grateful to my colleagues at the ZEW from the research department "Corporate Taxation and Public Finance" for the pleasant and constructive working environment and for beneficial discussions. In particular, I would like to thank my co-authors Benny Geys and Friedrich Heinemann for great teamwork and fruitful discussions. Additionally, I would like to thank Daniel Becker, Tim Coelli, Eckhard Janeba, Sebastian Hauptmeier and Gerhard Kempkes for many valuable comments. I am also very grateful to the student assistants, notably to Julia Einsiedler, Martha Schell and Hela Hellerich, for literature research and editing this thesis. Finally, I would have never succeeded in finishing this doctoral thesis without the support of my girlfriend Franziska Gössel and my family.

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Chapter 1

Introduction: Theme, Objectives and Structure of the Book

1.1 Theme and Objectives of the Book

In recent years, public budgets in Germany have undergone a wave of consolidation. The current economic crisis, however, has put significant strain on government budgets - worldwide. Given the fact that in recent times, governments all around the world have spent huge amounts of money to alleviate the consequences of the economic crisis, the discussion about the sustainability of public finances will also be back on the agenda in Germany. The effects of the economic crisis, however, are unlikely to be limited to the national level. Indeed, the economic crisis will also put severe strain on the public finances of local governments. Usually, public budgets are consolidated either by cutting expenditures or by increasing income sources. But apart from the possibilities of cutting public spending by offering less public goods and services or by developing new sources of revenue (e.g. by levying new taxes or increasing current taxes), governments can also try to reduce public expenditures by operating more efficiently or, in other words, by producing a higher amount of public goods and services given a certain amount of (public) expenditures - provided that there is a potential to increase efficiency, of course.

Furthermore, the performance or efficiency of the public sector is also important with regard to the competition for mobile factors like (high-skilled) labour and capital (e.g. in local jurisdictions). Since local governments operating at a rather low efficiency level are not able to provide the same amount of public goods and services as local governments which operate at higher efficiency levels (for a given amount of costs), the former will not be able to attract as many mobile factors as the latter. The reason is simply that - for a certain amount of public spending - the latter governments can offer either a higher amount of public goods and services of the same quality or the same amount of public goods and services of higher quality, since they are using their means more efficiently (in comparison to the former governments). Thereby, inefficiencies in the public sector can be manifold: First, public administrations can be oversized, which, in turn, means that part of the (public) money spent provides no additional utility for the resident enterprises and households. In addition, it is possible that local governments do not choose the most competitive provider for certain tasks. Finally, a further potential source of inefficiency is the quality of public goods and services. Since the quality of public goods and services is sometimes hardly or even not all observable (by the citizens), the public sector can vary the quality substantially without sanction. An example on the local level would be the waste recycling. For a single citizen of a municipality it is very difficult to control whether the recycling of waste is of the same quality as in the neighbour municipality.

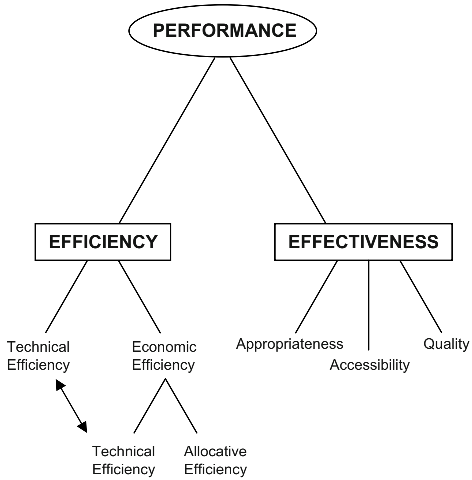
The above-mentioned examples demonstrate that the elimination of potential inefficiencies in the public sector could be used as a (concomitant) tool to consolidate public finances. In order to eliminate potential inefficiencies, however, we must first detect the main sources of these inefficiencies. Subsequently, this information can then be used by policy-makers to take action which, in turn, reduces potential inefficiencies. While there are numerous studies on the measurement of local governments' (in)efficiency (as a whole and for specific areas of public goods provision like schools, hospitals, etc.), the analysis of the main sources or drivers of this (in)efficiency has attracted far less attention in the literature.[1] Moreover, as will be shown in the literature review in chapter 3, there are only few studies on the efficiency of the German public sector. In fact, there exist only a couple of studies on the efficiency of specific areas of public goods provision (universities, hospitals, electricity distribution utilities and water supply utilities); efficiency studies on the (German local) public sector as a whole, however, do not exist at all. Therefore, the main focus of this book is on different aspects of the efficiency of the public sector in Germany; thereby, the object of investigation will be the local governments of the German state Baden-Württemberg.

1.1.1 Definitions

Since the performance of the public sector is the main topic of this book, it is necessary to first give detailed definitions of several concepts. First of all, the term "performance" can be divided into two components: (i) *efficiency* and (ii) *effectiveness* (see also Worthington and Dollery, 2000). While the former describes how well a decision-making unit (e.g. local government) employs resources in producing (public) goods and services, the latter describes the degree to which a decision-making unit achieves its programme and policy objectives. In turn, effectiveness can be decomposed into three components reflecting desired aspects of the programme outcome: (a) appropriateness (i.e. do the services match the needs of the clients?), (b) accessibility (i.e. can the clients afford the services?), and (c) quality (i.e. do the services meet the required standards?). In the present analysis, the focus is solely on the efficiency and not on the effectiveness of the provision of public goods and services. Closely related to the term "efficiency" is the concept of *productivity*, since - according to Fried et al. (2008a) - the

[1]For an extensive review on the literature of the efficiency of the public sector, see chapter 3.

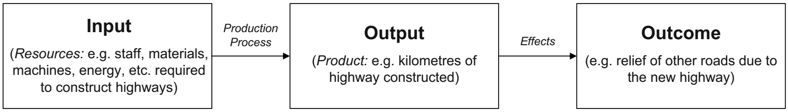
Figure 1.1: Relationship between performance, efficiency and effectiveness



productivity of a decision-making unit varies due to (i) differences in production technology, (ii) differences in the efficiency of the production process, and (iii) environmental differences; in other words, efficiency is one component of the productivity of a decision-making unit.

A further question is how the efficiency of a decision-making unit can be measured. Given a set of appropriate input and output indicators, a measure of the efficiency of a decision-making unit can be obtained by comparing the observed values with the optimal values of the respective inputs and outputs the decision-making unit faces. The comparison can thereby either take the form of the ratio of observed to maximum potential output - given a certain amount of input ("output-orientation"), or the ratio of minimum potential to observed input - given a certain amount of output ("input-orientation"). A further possibility to measure efficiency is to compare observed costs, revenues, profits, etc. with optimum costs, revenues, profits, etc. of the decision-making units - subject to appropriate constraints on quantities and prices. The difference between the two concepts is simply that in the former case, the optimum is defined in terms of production possibilities (=*technical* or *productive* efficiency; see also Debreu, 1951; Koopmans, 1951; Farrell, 1957) while in the latter case it is defined in terms of behavioural goals of the decision making unit (=*economic* efficiency; see also Fried et al., 2008a). The investigations on the efficiency of the local governments in Germany (in chapter 4) will be based on both concepts, the technical as well as the economic, or, more specifically, the cost efficiency. In addition, the economic efficiency can be further decomposed into two components: (i) the *(purely) technical efficiency*, and (ii) the *allocative efficiency*. While the definition of the former component was already given above, the allocative component refers

Figure 1.2: Relationship between input, output and outcome



to the ability to combine input(s) and output(s) in such a proportion that the input-price-mix is optimal. The relationship between the above-mentioned concepts is illustrated in figure 1.1.

Furthermore, in the context of efficiency measurement of decision-making units, it is also useful to differentiate between the following three concepts: (i) *inputs*, (ii) *outputs*, and (iii) *outcomes*. A graphical representation of the relationship between these three terms is given in figure 1.2 above. The inputs are the resources required to produce a certain amount of output. In the public sector, for example, the inputs to produce a highway would be the staff, materials, machines, energy, etc. required to construct the highway. In the production process these inputs are then transformed into the output. In the highway example, the kilometres of highway constructed would be the output. Finally, the outcomes describe the changes (in the utility of the target audience) and effects as a result of the (new) product. In case of the highways, an example for an outcome would be the relief of other roads due to the new highway. In order to carry out efficiency analyses, it is therefore first necessary to identify appropriate input and output indicators which approximate the real input(s) and output(s) of the decision-making units (e.g. local governments) as accurately as possible. However, as will be seen below, it is often very difficult to identify appropriate input and output indicators.

Before we close this subsection, it should be mentioned that the concepts of technical and economic efficiency are *relative* rather than *absolute* concepts. The efficiency of any decision-making unit (e.g. local governments) is always evaluated relative to the efficiency of the remaining decision-making units in the sample. This, however, implies that the decision-making unit(s) of the sample which is (are) deemed to be "most efficient" need not necessarily to be the "real" most efficient decision-making unit(s). In reality, the efficiency of the most efficient decision-making unit(s) could also be higher.

1.1.2 Public versus Private Sector

Since some characteristics of the public sector differ substantially from those of the private sector, it is further necessary to clarify the main differences between both sectors. This is also important with regard to the question as to why it is much more difficult to find appropriate input and output indicators for the public sector compared to the private one. Blank and Lovell (2000) give five characteristics which make the public sector so special: Firstly, the public sector is very large and still growing in most of the OECD countries.[2] However, large

[2] For more information on this issue, see Blank and Lovell (2000), p. 7.

public sector organisations are often said to be bureaucratic and cumbersome. Secondly, the ownership form of the public sector differs substantially from the ownership form of the private sector. While private enterprises are owned by their shareholders, public organisations usually belong to the general public. This, however, has the following implications: (i) The monitoring of the performance or efficiency of the managers of public organisations may be more difficult, since the apportionment of the property rights is (often) unclear and, as a result, property rights are not transferable among the owners of the public organsiations; this means that the principal-agent problem, which is also present in the private sector, is much more severe in the public than in the private sector. (ii) The salaries of civil servants are - compared to the salaries of managers in the private sector - usually lower. As argued by Blank and Lovell (2000), this "tends to deter the best and the brightest from entering public service" (p. 6) which, in turn, lowers the quality of the public sector management.

Thirdly, the objectives and constraints for managers in the public sector differ substantially from those of the public sector. While managers of private companies usually maximise profits or minimise costs subject to certain constraints, profit maximisation or cost minimisation is not an appropriate behavioural objective of managers in the public sector.[3] This is also due to the fact that there are no market prices for "genuine" public goods, that is the valuation of public goods (with market prices) is not possible. Moreover, for a number of public goods and services, we can only observe indicators which reflect the amount of one specific public good provided, for example, by a municipality (e.g. the number of kindergarten places); information about the quality of this specific public good, however, is hardly or even not at all available. The missing availability of indicators measuring the quality of the public goods and services provided is one of the biggest limitations to studies investigating the efficiency (of specific areas) of the public sector.

Fourthly, public enterprises often operate under monopolistic conditions (as opposed to private firms); without competition, however, managers can become unmotivated and inefficient, since fierce competition usually rewards good and punishes poor performance. A final characteristic distinguishing the public sector from the private sector concerns the difficulty of finding appropriate definitions of the goods and services provided by the public sector. In addition, even when there is an agreement on the definition, public goods and services are - as already mentioned above - frequently unpriced (due to the non-market nature of public goods and services). Therefore, it is much more difficult to find appropriate input and output indicators for public sector activities compared to private sector activities. Moreover, specifying appropriate input and output indicators raises the question of whether data are available which are good approximations of the input and output indicators. Unfortunately, this is often not the case.

[3] According to Rees (1984), public sector managers could pursue the following economic objectives: allocative, distributive, financial or macroeconomic objectives.

Taken together, these explanations show that it is much more difficult to measure the performance of specific areas of the public sector than the performance of e.g. private enterprises.

1.2 Structure of the Book

This book is organised as follows: Chapter 2 gives an overview of the methods which can be used to determine the technical efficiency of decision-making units. Basically, there are two different approaches to evaluating the performance of decision-making units: parametric approaches and non-parametric approaches, the former having been developed in economics and the latter in management science. Given data on decision-making units, both methods are based on the idea of comparing the performance of every decision-making unit with that of the best. Moreover, since one of the main objectives of this book is also concerned with the main sources of efficiency, chapter 2 also gives a brief overview of the different techniques of how exogenous influences (e.g. socio-economic or political variables) can be incorporated into efficiency analyses. Finally, at the end of chapter 2, a short overview of the software which can be used to carry out efficiency analyses is provided.

Chapter 3 presents an extensive review of the existing literature on public sector efficiency. Since researchers have shown interest in both the efficiency of specific areas of the public sector and the efficiency of the public sector as a whole (e.g. municipalities or countries; *global* approaches), this chapter first provides a detailed overview of the studies investigating specific areas of public goods provision. These include the cultural sector (e.g. libraries), the educational sector (e.g. schools or universities), the energy sector (e.g. electric utilities or nuclear power plants), the health care sector (e.g. hospitals or nursing homes), public facilities (e.g. water supply utilities, waste disposal companies, etc.), the security sector (e.g. police departments or prisons) and, finally, the transportation sector (e.g. railways or buses). Subsequently, a review of the global approaches is presented. As will be seen in this chapter, studies measuring the technical or cost efficiency of governments have so far mainly focused on specific areas of the public sector, whereas efficiency studies on the global performance of single local governments or whole countries have attracted far less attention in the past.

In chapter 4 the methods developed in chapter 2 will be used to investigate different aspects of the efficiency of local governments in Germany using data based on the local governments of the German state Baden-Württemberg. In order to clarify the context of local public decision-making in Germany, however, this chapter first provides an introduction of the institutional setting of the local governments in Baden-Württemberg. Subsequently, four applications to these local governments are presented. The first application (section 4.3) focuses on the cost efficiency of the municipalities of Baden-Württemberg and relates the results to the negative demographic change which will take place in the next decades in Germany. The results show that there is a substantial divergence in efficiency (among the municipalities) despite a homogenous institutional setting. In addition, a second major finding is that costs fall underproportionally with population size in smaller municipalities (with up to approximately 10,000 inhabitants). The second application (section 4.4) investigates the relationship between intergovernmental grants and (cost) efficiency. Using an extension of the seminal bureaucracy model of Niskanen (1975), it is examined how a higher degree of redistribution (or an increase in the amount of grants to local governments) influences the technical efficiency in the provision of public goods and services in this local jurisdiction. Afterwards, the results derived in the theoretical analysis are tested in an empirical framework using a panel of Baden-Württemberg's municipalities. Both the theoretical and empirical results support the existence of a negative incentive effect of fiscal equalisation on the cost efficiency of local governments.

The third application (section 4.5), by contrast, investigates the relationship between voter involvement (in political processes), fiscal autonomy and cost efficiency. While higher social and political involvement within the population is often argued to be beneficial for the performance of the public sector, it remains unclear from a theoretical point of view whether higher voter involvement necessarily results in a higher or lower performance of the incumbents. Using a panel of Baden-Württemberg's municipalities again, the empirical results show that higher voter involvement is, on the whole, associated with higher rather than with lower cost efficiency levels. In addition, the further results suggest that this efficiency-stimulating effect of voter involvement is significantly positively affected by local governments' fiscal autonomy. Finally, the fourth application (section 4.6) investigates the determinants of efficiency in a broader context and - in contrast to the preceding applications - for one specific area of public goods provision: the construction and maintenance of roads. Employing a panel of counties (rather than municipalities) of Baden-Württemberg, the results show that the disposable income of the counties' citizens, intergovernmental grants (for county roads), and the payments to the counties influence efficiency negatively. In addition, it is shown that (technical) efficiency declines with an increasing share of seats of left-wing parties in the county council; however, the hypothesis that (technical) efficiency decreases with the degree of political concentration in the county council could not be confirmed.

Finally, chapter 5 gives a short summary of the main results and derives some useful policy implications from the preceding applications.

Chapter 2

Methodology: Frontier Efficiency Measurement Techniques

2.1 Introduction

For the measurement of the technical or economic efficiency of decision-making units (DMUs; e.g. schools, hospitals, waste disposal companies, local governments, etc.) it is first necessary to define an appropriate set of input and output combinations. The inputs and outputs are then used to construct a *best practice frontier* - that is, a frontier which includes the most efficient decision-making units. Subsequently, the technical or economic efficiency of the other decision-making units lying below the best practice frontier can be determined by measuring the deviation from this frontier. Several problems, however, arise when one attempts to implement these two simple steps into real-world applications: Firstly, how the best practice frontier can be generated given a data set of DMUs, and secondly, after choosing an adequate method, identifying the extent to which deviations from the best practice frontier are attributable to either "real" inefficiencies or other influences such as measurement errors. These problems have been addressed in numerous different ways in the literature.

Basically, best practice frontiers have been estimated using two different methods: *non-parametric* and *parametric* approaches. In addition, we can distinguish between two different ways of deviations from the best practice frontier: *deterministic* and *stochastic* (deviations). In the following subsections the several estimation approaches (non-parametric and parametric) - along with their main advantages and disadvantages - are briefly discussed.[1] However, the main focus lies on the estimation techniques, which will be used in chapter 4 (for the application to the German local governments). Because chapter 4 is also concerned with the main drivers of efficiency, the following subsections will also provide an overview of the different techniques of how exogenous influences have been incorporated into efficiency analyses in the past - separated by efficiency measures obtained by non-parametric approaches, on

[1] For more detailed introductions, see e.g. Fried et al. (2008b), Coelli et al. (2005) and Kumbhakar and Lovell (2000).

the one hand, and parametric approaches, on the other hand. Since researchers developed a variety of ways to incorporate exogenous influences, the advantages and disadvantages of the different procedures are briefly discussed as well. Finally, at the end of this chapter, a short overview of the software, which can be used to apply the methods described in this chapter, is presented.

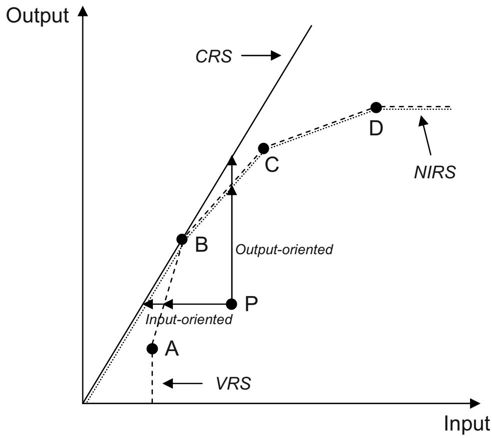
2.2 Non-Parametric Approaches: Mathematical Programming Models

2.2.1 Data Envelopment Analysis (DEA)

Among the non-parametric approaches, one of the most famous methodologies proposed to construct a best practice frontier is the *Data Envelopment Analysis*. Originally, this approach goes back to the work of Farrell (1957) and Charnes et al. (1978). DEA is based on the idea that the best practice frontier envelopes the data as tightly as possible; this envelopment is achieved by solving a sequence of linear programmes, one for each decision-making unit. There are several variants of DEA concerning (1) the behavioural objective of the decision-making units, and (2) the returns to scale. Looking first at the behavioural objectives of the DMUs, (technical) efficiency can either be identified as a proportional reduction in input usage, given a certain amount of output or, vice versa, as a proportional increase in output production, given a set of input(s). In the following, efficiency indices which are obtained by applying the former method are called *input-oriented* measures of technical efficiency, while the latter are termed *output-oriented* efficiency measures. Returns to scale, on the other hand, are concerned with the question of how output changes when all inputs increase proportionally. In principle, Data Envelopment Analysis can be based on one of the following three assumptions: (1) constant returns to scale (CRS), (2) variable returns to scale (VRS), or (3) non-increasing returns to scale (NIRS). The differences of the three DEA frontiers as well as the differences between input- and output-orientation are illustrated in figure 2.1 for the special case of one input and one output.

As can be seen from the figure, in the case of constant returns to scale only decision-making unit B is deemed to be efficient. If we assume non-increasing returns to scale, however, the best practice frontier runs through the points B, C, and D. The assumption of variable returns to scale, finally, also includes decision-making unit A as an efficient point. Only decision-making unit P is deemed to be inefficient in all three cases, since it always lies beneath the frontier. Figure 2.1 also shows the difference between the input-oriented measure of efficiency, on the one hand, and the output-oriented measure of efficiency, on the other hand. While the output-oriented measure is the same for the non-increasing returns to scale and the variable returns to scale technology, the input-oriented measure for the variable returns to scale technology is higher than the one for the non-increasing returns to scale technology. As a conclusion, the

Figure 2.1: Returns to scale as well as input- and output-orientation in the case of one input and one output



variable returns to scale technology "envelops" the data as tightly as possible, followed by the non-increasing returns to scale and constant returns to scale technology. In other words, DMUs which are deemed to be efficient under constant returns to scale are also efficient under the other two technologies, but not vice versa.

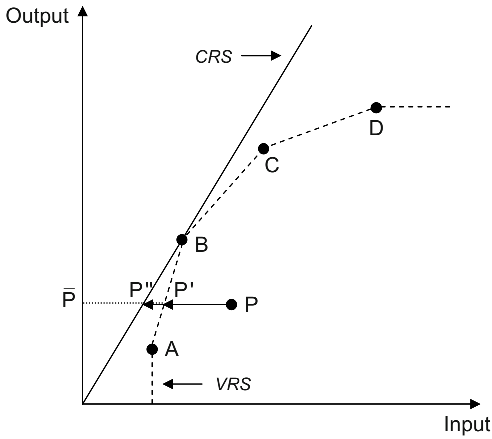
2.2.2 Input-Oriented DEA Model

In order to determine efficiency indices for the decision-making units, suppose now that DMU 0 employs the input level x_0 to produce the output level y_0. Then the input-oriented constant returns to scale DEA model (DEA-CRS; originally developed by Charnes et al., 1978) is specified by solving the following linear programming problem:

$$\begin{aligned} &\min_{\theta_0,\lambda_i} \ \theta_0 \\ &\text{s.t.} \ \theta_0 x_{k,0} - \sum_{i=1}^{n} \lambda_i x_{k,i} \geq 0 \quad \text{with } k = 1, ..., m \\ &\sum_{i=1}^{n} \lambda_i y_{r,i} \geq y_{r,0} \quad \text{with } r = 1, ..., s \\ &\lambda_i \geq 0, \ \ i = 1, ..., n, \end{aligned} \tag{2.1}$$

where x_i denotes the input level used by decision-making unit i to produce the output level y_i. Furthermore, k (r) equals the number of inputs (outputs) employed in the production

Figure 2.2: CRS and VRS input-oriented DEA-example with one input and one output



process, n represents the number of decision-making units and the λ_i's are weights given to those decisions-making units which are referred to by the comparison with decision-making unit 0. Solving the linear programming problem (2.1) n times generates the efficiency indices θ_1 to θ_n, one for each decision-making unit. Providers with efficiency scores of $\theta < 1$ are technically inefficient, since they are capable of reducing their input(s) without affecting the amount of output; on the other hand, efficient providers receive efficiency scores of $\theta = 1$.

Moreover, Banker et al. (1984) adjusted the constant returns to scale DEA model to account also for variable returns to scale (DEA-VRS). This is done by adding the *convexity constraint* (Banker et al., 1984, p. 1081) to the programming problem (2.1):

$$\sum_{i=1}^{n} \lambda_i = 0. \tag{2.2}$$

As already mentioned above, the best practice frontier then yields a closer envelopment of the data.

A graphical representation of the input-oriented DEA model with constant and variable returns to scale, respectively, is given in figure 2.2 again for the special case of one input and one output. As already mentioned above, the decision-making unit P is deemed to be inefficient in both cases (CRS and VRS), since it lies beneath the frontier. Now, the input-oriented technical inefficiency measure of point P is given by the ratio of the distances $\bar{P}P''$ and $\bar{P}P$ for the case of constant returns to scale:

$$\theta_P^{CRS} = \frac{\bar{P}P''}{\bar{P}P}, \ \ 0 < \theta_P^{CRS} < 1, \tag{2.3}$$

whereas the technical inefficiency measure for the case of variable returns to scale is represented by:

$$\theta_P^{VRS} = \frac{\bar{P}P'}{\bar{P}P}, \ \ 0 < \theta_P^{VRS} < 1. \tag{2.4}$$

Consequently, an efficiency index of say 0.71 (e.g. for DEA-CRS) means that the decision-making unit P should be able to attain the same level of output using only 71 percent of the inputs it is currently using. Or, in other words, DMU P employs approximately 40.8 percent ($=1/\theta_P^{CRS}$) resources more than the minimum required to provide the same amount of output. For the variable returns to scale case, the corresponding efficiency index would be a little bit higher. Finally, the figure reveals that the reference point(s) for the determination of the inefficiency of decision-making unit P is (are) given by B for the constant returns to scale case as well as by A and B for the variable returns to scale case.

2.2.3 Output-Oriented DEA Model

Turning now to the output-oriented version of the linear programming problem (2.1), an equivalent technical efficiency measure (for an output-oriented DEA model with constant returns to scale) can easily be obtained by dividing the constraints of (2.1) by θ_0:

$$\begin{aligned}
&\max_{\eta_0,\mu_i} \ \eta_0 \\
&\text{s.t.} \ \ x_{k,0} - \sum_{i=1}^{n} \mu_i x_{k,i} \geq 0 \quad \text{with } k = 1, ..., m \\
&\qquad \sum_{i=1}^{n} \mu_i y_{r,i} \geq \eta y_{r,0} \quad \text{with } r = 1, ..., s \\
&\qquad \mu_i \geq 0, \ \ i = 1, ..., n,
\end{aligned} \tag{2.5}$$

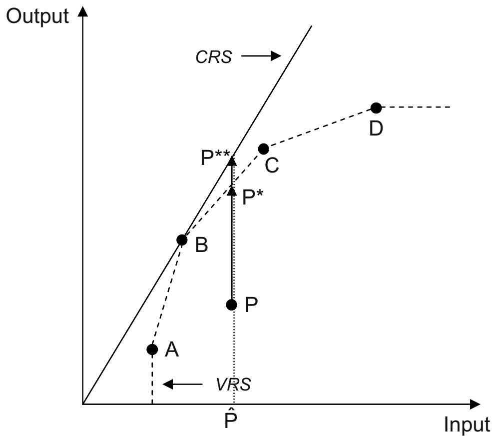
where all variables are defined as in the linear programming problem (2.1), $\mu_i = \frac{\lambda_i}{\theta_0}$, $\eta = \frac{1}{\theta_0}$, and η_0 is the output-oriented technical inefficiency measure for decision-making unit 0 (with $0 < \eta_0 \leq 1$). Analogous to the input-oriented case, the variable returns to scale version of the output-oriented DEA model is obtained by adding the constraint

$$\sum_{i=1}^{n} \mu_i = 0 \tag{2.6}$$

to the equation system (2.5).

Finally, the graphical representation of the output-oriented DEA model is provided in figure 2.3 - again for the special case of one input and one output. The corresponding technical

Figure 2.3: CRS and VRS output-oriented DEA-example with one input and one output



inefficiency measures of decision-making unit P (for the case of constant and variable returns to scale, respectively) are given by:

$$\eta_P^{CRS} = \frac{PP^{**}}{\hat{P}P^{**}}, \;\; 0 < \eta_P^{CRS} < 1 \quad \text{and} \tag{2.7}$$

$$\eta_P^{VRS} = \frac{PP^{*}}{\hat{P}P^{*}}, \;\; 0 < \eta_P^{VRS} < 1. \tag{2.8}$$

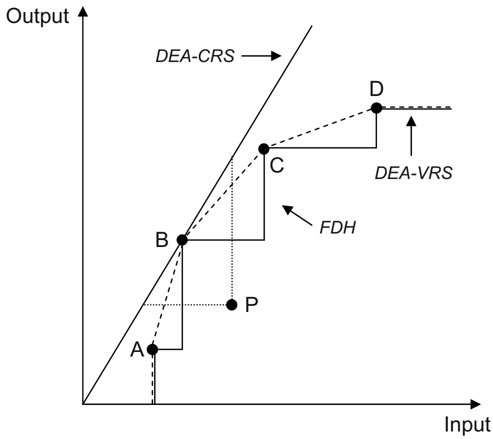
Here, an efficiency index of say 0.60 (e.g. for DEA-CRS) would mean that - given the current input level - the decision-making unit P only produces 60 percent of the output level that the most efficient DMU would produce with the same amount of input(s). Or, more intuitively, DMU P could increase its output by approximately 66.7 percent (=$1/\eta_P^{CRS}$) without increasing inputs.

2.2.4 Free Disposable Hull (FDH)

A further extension of the DEA model with variable returns to scale was proposed by Deprins et al. (1984). They relax the assumption of (strict) convexity of the output and input sets (underlying DEA) and construct a best practice frontier known as *Free Disposable Hull (FDH).* The FDH programming problem is identical to the linear programming problems (2.1) and (2.5) with variable returns to scale (i.e. $\sum_{i=1}^{n} \lambda_i = 0$ and $\sum_{i=1}^{n} \mu_i = 0$ holds, respectively), but it additionally includes the following constraints:

$$\lambda_i \in \{0,1\} \quad \text{and} \quad \mu_i \in \{0,1\}, \quad i = 1, ..., n \tag{2.9}$$

Figure 2.4: DEA-CRS, DEA-VRS and FDH in case of one input and one output



for the input- and output-oriented variant, respectively. This assumption along with the convexity constraints (2.2) and (2.6) assures that FDH identifies exactly one (efficient) DMU as a reference point for an inefficient DMU (in contrast to a combination of (efficient) DMUs in the case of DEA-VRS). Figure 2.4 graphically shows the difference between DEA-CRS, DEA-VRS and FDH (again for the one input and one output case). While the best practice frontier in the case of DEA-CRS and DEA-VRS is represented by a straight line and a curve, respectively, FDH generates a best practice frontier with a staircase shape. In addition, the reference points for the determination of the inefficiency of decision-making unit P are given by A and B, as well as by B and C, respectively, for DEA-VRS, whereas FDH only identifies decision-making unit B as a reference point. The figure also reveals that FDH efficiency estimates are generally higher than those produced by DEA-VRS or DEA-CRS.

Finally, it should be noted that in all three approaches the whole deviation of a given decision-making unit (e.g. DMU P in figure 2.4) from the best practice frontier is interpreted as technical inefficiency. Therefore, all of the above presented non-parametric approaches are *deterministic* in their set-up. This may be deemed problematic, since the observed levels of inputs and outputs that are used in the real-world applications may be subject to measurement errors or stochastic influences. To the extent that this is the case, it is not justifiable to denote the entire deviation from the best practice frontier as inefficiency. Therefore, researchers devoted much effort to developing a stochastic DEA model (SDEA; see e.g. Land et al., 1993; Olesen and Peterson, 1995). These approaches, however, have rarely been used and tested in the past, so that these models are rather unimportant. As will be seen in section 2.4, however, it is much more common to account for such stochastic influences in parametric approaches.

2.3 Incorporating Exogenous Influences on Efficiency into Non-Parametric Approaches

One crucial problem with the efficiency estimates derived from equation (2.1) or (2.5) is that they treat all decision-making units on the same footing. However, in some cases it may be advisable to take into account exogenous or non-discretionary variables, which may influence the performance of the decision-making units. Basically, two types of such influences can be distinguished:

1. Characteristics of decision-making units which affect their individual production possibilities and which describe the production environment. If the decision-making unit is represented by a local government, for example, one such an external constraint would be the geographical location of the local government: A municipality in a hilly region may need to spend more money on a given road infrastructure than a municipality located on the plain.

2. Determinants of technical or cost efficiency such as the socio-economic characteristics of the population or the political orientation of the local council which affect the level of technical efficiency of the decision-making units (e.g. local governments) but not the shape of the best practice frontier.

Researchers proposed a number of ways in which such exogenous or non-discre-tionary variables can be incorporated into non-parametric efficiency analyses. In the following, two of the most popular approaches will be presented.[2]

2.3.1 Incorporation into the Programming Problem

One of the earlier approaches which investigated the technical efficiency of decision-making units when some of the inputs or outputs are exogenously fixed and beyond the control of the DMU was proposed by Banker and Morey (1986). This extended DEA model reduces (expands) only the inputs (outputs) over which the decision-making unit has discretionary control - given the non-discretionary inputs (outputs) and outputs (inputs). Consider, for example, the case of variable returns to scale, input-orientation, and both the presence of discretionary (D) and non-discretionary (ND) inputs. Then, the DEA model (2.1) can be rewritten as follows:[3]

[2] For a detailed overview, see e.g. Coelli et al. (2005) and Thanassoulis et al. (2008).
[3] The output-oriented DEA model (2.5) can be rewritten in a similar way.

$$\begin{aligned}
&\min_{\theta_0,\lambda_i} \ \theta_0 \\
&\text{s.t.} \ \theta_0 x_{k,0} - \sum_{i=1}^{n} \lambda_i x_{k,i} \geq 0 \quad k \in \text{D} \\
&\quad x_{k,0} - \sum_{i=1}^{n} \lambda_i x_{k,i} \geq 0 \quad k \in \text{ND} \\
&\quad \sum_{i=1}^{n} \lambda_i y_{r,i} \geq y_{r,0} \quad \text{with } r = 1, ..., s \\
&\quad \sum_{i=1}^{n} \lambda_i = 0 \\
&\quad \lambda_i \geq 0, \ i = 1, ..., n.
\end{aligned} \tag{2.10}$$

As can be seen from the above equation system, the efficiency parameter θ_0 is only associated with the discretionary inputs (D). Therefore, the linear programming problem (2.10) only seeks radial reduction in this subset of the inputs.

Obviously, this approach has a number of drawbacks. First of all, we must decide whether an exogenous variable is to be classified as a non-discretionary input or output variable. On reconsidering, for example, the case where the decision-making unit is represented by a local government, it is very difficult to decide whether the geographical location of the local government is rather a non-discretionary input or output. Another disadvantage of the above mentioned approach is that the exogenous variables must be continuous, that is, categorical variables cannot be used. Finally, one of the main drawbacks of this method is that no inference about the (quantitative) impact of the exogenous variables on technical efficiency is possible.[4] But since one of the main objectives in chapter 4 is to investigate the determinants of local governments' technical or cost efficiency, this approach seems to be inappropriate.

2.3.2 Two-Stage Approach

The most common approach of incorporating exogenous or non-discretionary variables into non-parametric efficiency analyses is the so-called two-stage approach: In a first-stage analysis the linear programming problem (2.1) or (2.5) is solved (alternatively with variable returns to scale), and afterwards, in a second stage, the efficiency scores derived from the first stage are regressed on the exogenous variables:

$$\widehat{EI}_i = \alpha_0 + \beta_1 \sum_{j=1}^{J} C_{i,j} + \beta_2 \sum_{l=1}^{L} D_{i,l} + \varepsilon_i, \quad i = 1, ..., n, \tag{2.11}$$

[4]For further criticisms of the Banker and Morey (1986) model and numerous extensions to this model, see Thanassoulis et al. (2008), p. 346 et seqq.

where $\widehat{EI}_i$ presents the efficiency index of DMU i obtained by DEA, C_i the J characteristics of DMU i, and D_i the L determinants of technical efficiency. Since the efficiency scores are usually bounded between zero and one or one and infinity, most researchers used censored regression techniques (Tobit) instead of a simple OLS regression to estimate the influence of exogenous variables on technical efficiency.[5]

The two-stage approach, however, has been criticised in several ways (see Simar and Wilson, 2007): Firstly, the dependent variable in equation (2.11) is unobserved and must be replaced by the estimate of the linear programming problem (2.1) or (2.5), $\widehat{EI}_i$. The estimated DEA efficiency indices, however, are serially correlated (in finite samples), since perturbations of observations that are lying on the best practice frontier will in many cases cause changes in the efficiency scores of other (inefficient) observations. This, however, means that the error term ε_i in equation (2.11) is serially correlated as well. Secondly, since the exogenous or non-discretionary variables are correlated with the inputs as well as the outputs (otherwise there would be no need for a second-stage regression), the exogenous variables must also be correlated with the error term of the second-stage (Tobit) regression. Indeed, both correlations disappear asymptotically, but only at a slow rate.

To avoid these inconsistencies, Simar and Wilson (2007) propose an alternative inference procedure based on bootstrap methods. Moreover, the authors argue that the second-stage regression should be conducted by a truncated instead of a censored (Tobit) regression, since the efficiency scores are truncated (at one) by construction and not by censoring. The procedure ("algorithm 1") proposed by Simar and Wilson (2007) involves the following steps:

[1] Compute the efficiency scores $\hat{\eta}_i$, $i = 1, .., n$ by solving the linear programming problem (2.5) and calculate $\hat{\delta}_i = 1/\hat{\eta}_i$.[6]

[2] Estimate the following truncated regression by maximum likelihood: $\hat{\delta}_i = z_i\beta + \varepsilon_i$, $i = 1, .., n$, where z_i is a vector of exogenous variables and β is a vector of parameters to be estimated - using the $m < n$ observations where $\hat{\delta}_i > 1$ - and obtain an estimate $\hat{\beta}$ of β and $\hat{\sigma}_\varepsilon$ of σ_ε.

[3] Compute L bootstrap estimates of β and σ_ε as follows: For each $i = 1, ..., m$, draw ε_i from the $N(0, \hat{\sigma}_\varepsilon^2)$-distribution with left-truncation at $(1 - z_i\hat{\beta})$ and compute $\delta_i^* = z_i\hat{\beta} + \varepsilon_i$ (again for each $i = 1, ..., m$). Use the maximum likelihood method to estimate the truncated regression of δ_i^* on z_i, yielding bootstrap estimates $(\hat{\beta}^*, \hat{\sigma}_\varepsilon^*)$.

[5] For a review of two-stage approaches employed for different areas of the public sector, see table C.1 of Appendix C; for a general review, see Simar and Wilson (2007).

[6] In the original procedure, Simar and Wilson (2007) employ output-oriented efficiency estimates which are left-truncated.

The bootstrap estimates $(\hat{\beta}^*, \hat{\sigma}^*_\varepsilon)$ and the original estimates $(\hat{\beta}, \hat{\sigma}_\varepsilon)$ can then be used to construct confidence intervals for β and σ_ε and to test hypotheses,[7] whereas Simar and Wilson (2007) propose $L = 2000$ bootstrap replications. Finally, Simar and Wilson (2007) further show that the estimate $\widehat{EI}_i$ of the "true" efficiency estimate (obtained in the linear programming problem (2.1) or (2.5) in the first stage) is biased towards one in small samples. Therefore, the authors also propose a second bootstrap procedure ("algorithm 2") to correct for this bias in the first stage:

[1] See algorithm 1.
[2] See algorithm 1.
[3] Compute L_1 bootstrap estimates for each δ_i as follows: For each $i = 1, ..., m$, draw ε_i from the $N(0, \hat{\sigma}^2_\varepsilon)$-distribution with left-truncation at $(1 - z_i\hat{\beta})$ and compute $\delta^*_i = z_i\hat{\beta} + \varepsilon_i$; set $x^*_i = x_i$, $y^*_i = y_i \frac{\hat{\delta}_i}{\delta^*_i}$ and compute $\hat{\delta}^*_i$ by solving the linear programming problem (2.5), whereas y_i on the left-hand side of the second constraint is replaced by y^*_i.
[4] For each $i = 1, ..., n$, compute the bias-corrected efficiency estimator $\tilde{\delta}_i = 2 \cdot \hat{\delta}_i - \bar{\delta}^*_i$, where $\bar{\delta}^*_i = \frac{1}{L_1} \sum_{l=1}^{L_1} \hat{\delta}^*_{l,i}$; Simar and Wilson (2007) propose $L_1 = 100$ bootstrap replications.
[5] Continue with algorithm 1 from step [2] upwards by replacing $\hat{\delta}_i$ with $\tilde{\delta}_i$.

In chapter 4, where - among other things - the determinants of local governments' technical and cost efficiency are investigated, both two-stage approaches, the Tobit regression and the procedure(s) proposed by Simar and Wilson (2007), are applied to further test the robustness of the obtained results.

2.4 Parametric Approaches: Econometric Models

In contrast to the non-parametric estimation techniques, parametric approaches determine the best practice frontier on the basis of a specific functional form using econometric techniques. Since the applications to the German local governments in chapter 4 will be based on cost functions (rather than production functions) - meaning that the (single) input is approximated by the cost of the governments - the following explanations are based on cost rather than production frontier models.[8]

Suppose that the cost frontier can be expressed as:

$$C_i \geq c(y_i, w_i; \beta), \quad i = 1, ..., n, \tag{2.12}$$

[7] For a detailed description of the construction of confidence intervals, see Simar and Wilson (2007), p. 43.

[8] This subsection is mainly based on Kumbhakar and Lovell (2000). For a detailed derivation of parametric production (rather than cost) frontier models, see e.g. Kumbhakar and Lovell (2000), p.64 et seqq.

where C_i represents the actual costs of DMU i (e.g. the total expenditure of a municipality or county), y_i denotes a vector of outputs produced by DMU i, w_i is a vector of input prices DMU i faces, β is a vector of parameters to be estimated and, finally, $c(y_i, w_i; \beta)$ represents the cost frontier (=best practice frontier) all decision-making units face. Then, the cost efficiency, CE_i, of decision-making unit i is given by:

$$CE_i = \frac{c(y_i, w_i; \beta)}{C_i}, \tag{2.13}$$

that is, cost efficiency is defined as the ratio of minimum feasible to actual costs. Moreover, from equation (2.12) it follows that $CE_i \leq 1$. As in the case of non-parametric efficiency scores, decision-making units with $CE_i < 1$ are cost inefficient, since they are capable of producing the same output with lower cost. Decision-making units which lie on the best practice or cost frontier, in contrast, receive efficiency scores of $CE_i = 1$. In addition, cost efficiency scores which are based on equation (2.12) are deterministic (like the non-parametric estimation approaches presented in section 2.2), since they interpret the whole deviation of a decision-making unit from the best practice frontier as (cost) inefficiency. As already mentioned above, such approaches ignore the fact that real-world applications could be subject to stochastic influences. In the case of the cost function (2.12), one could imagine, for example, that expenditures are influenced by random shocks which are not controlled by the decision-making units. To account for such stochastic influences, equation (2.12) can be rewritten as:

$$C_i \geq c(y_i, w_i; \beta) \cdot \exp\{v_i\}. \quad i = 1, ..., n, \tag{2.14}$$

where the deterministic part of the right hand side of equation (2.12) is extended by the stochastic part $\exp\{v_i\}$, which captures the effects of random shocks, measurement errors, etc. The cost efficiency measure subsequently changes to:

$$CE_i = \frac{c(y_i, w_i; \beta) \cdot \exp\{v_i\}}{C_i}. \tag{2.15}$$

The estimation of the cost efficiency measures, CE_i, $i = 1, ..., n$, can now be based on either equation (2.12) (*deterministic approaches*) or (2.14) (*stochastic approaches*). In the following, the different estimation procedures for both approaches will be presented.

2.4.1 Deterministic Approaches

Deterministic approaches can be seen as a preliminary stage to the stochastic frontier models presented in the next subsection. Since they completely ignore stochastic influences, they do not yield - in comparison to the stochastic frontier models - completely satisfactory results. Therefore, these approaches will not be used in chapter 4 and are only covered briefly here.

Assume that the deterministic cost frontier (2.12) takes a log-linear Cobb-Douglas functional form. Then equation (2.12) can be rewritten in the following way:

$$\begin{aligned} \ln C_i &\geq \beta_0 + \sum_r \beta_r \ln y_{r,i} + \sum_p \alpha_p \ln w_{p,i} \\ &= \beta_0 + \sum_r \beta_r \ln y_{r,i} + \sum_p \alpha_p \ln w_{p,i} + u_i, \end{aligned} \tag{2.16}$$

where the cost (in)efficiency $CE_i = \exp\{-u_i\}$. Since it is required that $CE_i \leq 1$ (see above), it follows that $u_i \geq 0$. This condition guarantees that inequality (2.12), $C_i \geq c(y_i, w_i; \beta)$, is satisfied. Now, the objective is to obtain estimates of the parameter vectors β and α as well as the (in)efficiency component u_i. The estimates of u_i, in turn, can then be used to obtain estimates of the cost (in)efficiency by means of the equation $CE_i = \exp\{-u_i\}$. In the past, researchers proposed several methods to obtain estimates of the (in)efficiency component u_i. In the following, three of the most common methods are presented:

Corrected Ordinary Least Squares (COLS)

The method of “correcting” ordinary least squares estimates to obtain estimates of u_i originally goes back to Winsten (1957). The idea of COLS is to estimate the parameter vectors β and α of (2.16) by ordinary least squares in a first step and, afterwards, to correct the upward bias in the estimated OLS intercept by shifting it down until all corrected residuals are non-negative and at least one is zero, which is - by definition - the residual of the decision-making unit lying on the best practice frontier. More formally, the COLS intercept is estimated by:

$$\hat{\beta}_0^{COLS} = \hat{\beta}_0 + \min_i\{\hat{u}_i\}, \tag{2.17}$$

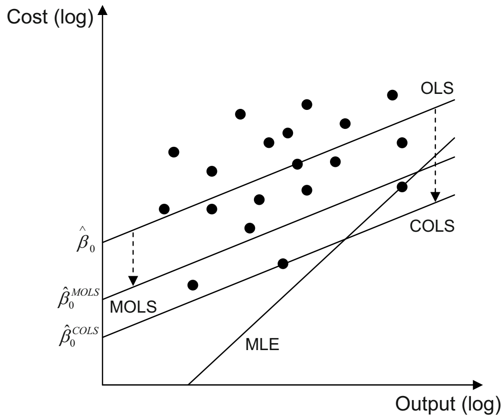
where $\hat{\beta}_0$ and $\hat{u}_i$ are the intercept and residuals of the OLS regression, respectively. In addition, the COLS residuals are obtained by the following correction:

$$\hat{u}_i^{COLS} = \hat{u}_i - \min_i\{\hat{u}_i\}. \tag{2.18}$$

A graphical illustration of the COLS estimator for the one output case is also given in figure 2.5.

One of the main disadvantages of the above described method - apart from its deterministic nature - is that only the OLS intercept is corrected. This, however, implies that the best practice frontier has the same structure as the OLS curve. As a consequence, this structural similarity rules out the possibility that decision-making units are more efficient than other ones, since they exploit possible economies of scale, for example. In addition, it should be mentioned that COLS make no assumptions about the functional form of u_i.

Figure 2.5: COLS, MOLS, and MLE deterministic cost frontiers



Modified Ordinary Least Squares (MOLS)
A further "correction" of ordinary least squares, which is very closely related to COLS, was proposed by Afriat (1972) and Richmond (1974). In a first stage, they also estimate the parameter vectors β and α by means of OLS, but in contrast to COLS, the authors make an assumption about the functional form of the efficiency term u_i. It is explicitly assumed that u_i follows a one-sided distribution, such as the exponential or half-normal distribution. In a second step, the estimated OLS intercept is shifted down by the estimated mean of u_i:

$$\hat{\beta}_0^{MOLS} = \hat{\beta}_0 - E(\hat{u}_i), \tag{2.19}$$

whereas the OLS residuals are modified in the opposite direction:

$$\hat{u}_i^{MOLS} = \hat{u}_i + E(\hat{u}_i). \tag{2.20}$$

The difference between the MOLS and COLS estimator is also graphically illustrated in figure 2.5. As can be seen from the figure, the MOLS estimation technique does not guarantee that the estimated intercept will be shifted far enough to cover all observations. If a decision-making unit has a sufficiently large OLS residual, it is therefore possible for u_i to be smaller than zero, generating a cost efficiency score of $CE_i > 1$ (as shown in the graph). On the other hand, it is also possible that the shift of the intercept is so large that none of the decision-making units is deemed to be efficient. Finally, the MOLS estimator also produces a best practice frontier which is parallel to the original OLS curve. Therefore, the MOLS estimator can be criticised in the same way as the COLS estimator.

Maximum Likelihood Estimation (MLE)
Just like the previous approach, Greene (1980) also proposed to assume a functional form for the non-negative efficiency component u_i. But in contrast to MOLS, he assumes that u_i follows a gamma distribution:

$$f(u_i) = \frac{\theta^P}{\Gamma(P)} u_i^{P-1} e^{\theta u_i}, \quad u_i > 0, \ \theta > 0, \ P > 2. \tag{2.21}$$

Now, simultaneous estimation of the parameter vectors β and α as well as the parameters of the distribution of u_i by maximum likelihood yields a best practice frontier that envelops all observations. Again, the best practice frontier generated by MLE is shown in figure 2.5. The figure reveals that, in contrast to the other two approaches, the best practice frontier generated by MLE has a different structure than the OLS curve. This is a crucial advantage in comparison to the other two approaches. The deterministic nature of the frontier, however, remains.

2.4.2 Stochastic Approaches

Cross-Sectional Models

As already mentioned in the beginning of this section, stochastic frontier models (Aigner et al., 1977; Meeusen and Van den Broeck, 1977) decompose the deviation from the best practice frontier into two components: an inefficiency part and a part arising from stochastic influences or measurement errors. Therefore, stochastic frontier models are more precise - compared to deterministic models (including also the non-parametric methods presented in section 2.2) - with regard to the definition of the deviation from the best practice frontier.

Assuming again that the deterministic kernel $c(y_i, w_i; \beta)$ of the cost frontier takes a log-linear Cobb-Douglas functional form, the stochastic cost frontier model given in equation (2.14) can be rewritten in the following way:

$$\begin{aligned} \ln C_i &\geq \beta_0 + \sum_r \beta_r \ln y_{r,i} + \sum_p \alpha_p \ln w_{p,i} + v_i \\ &= \beta_0 + \sum_r \beta_r \ln y_{r,i} + \sum_p \alpha_p \ln w_{p,i} + \underbrace{v_i + u_i}_{=\varepsilon_i}, \end{aligned} \tag{2.22}$$

where the (asymmetric) error term ε_i in the last equation now consists of two components: (1) the non-negative cost efficiency component, $u_i \geq 0$, and (2) the two-sided random-noise component, v_i, which is usually assumed to be independently and identically normally distributed $N(0, \sigma_v^2)$. In addition, both error terms, u_i and v_i, are assumed to be independent. Usually, equation (2.22) is estimated using maximum likelihood estimation techniques, although OLS also provides consistent estimates of the β- and α-parameters - except of the intercept β_0. Therefore, sometimes a two-step procedure is employed where, in a first step, the slope parameters of the β- and α-vector are estimated and, in a second step, maximum likelihood estimation is used to obtain estimates of the intercept, β_0, and the variances of the two error components. When maximum likelihood estimation is used, distributional assumptions about the one-sided error component, u_i, are needed. In the past, different distributional assumptions about u_i were made: the half-normal, truncated normal, exponential, or gamma distribution.[9]

The next question is how the (in)efficiency component, u_i, can be extracted from the composed error term, ε_i, since the estimation of equation (2.22) only produces estimates for ε_i, and not for every single component of the composed error term. Jondrow et al. (1982) and Bauer (1987) showed for production and cost functions, respectively, that the conditional distribution of u_i given ε_i contains all necessary information about the efficiency component, u_i. As a consequence, this information can be used to generate point estimates for the efficiency components of every decision-making unit, whereas either the mean or the mode of this distribution can serve as a point estimator for u_i. In case u_i is half-normal distributed, for example, the conditional distributions are given by:

$$E(u_i|\varepsilon_i) = \sigma^* \left[\frac{\phi(\varepsilon_i \lambda/\sigma)}{1 - \Phi(-\varepsilon_i \lambda/\sigma)} + \left(\frac{\varepsilon_i \lambda}{\sigma} \right) \right], \tag{2.23}$$

where $\sigma = \sqrt{\sigma_u^2 + \sigma_v^2}$, $\lambda = \frac{\sigma_u}{\sigma_v}$, $\sigma^* = \frac{\sigma_u^2 \sigma_u^2}{\sigma}$, and $\Phi(.)$ as well as $\phi(.)$ are the standard normal cumulative distribution and density functions, respectively, and

$$M(u_i|\varepsilon_i) = \begin{cases} \varepsilon_i \left(\frac{\sigma_u^2}{\sigma^2} \right), & \text{if } \varepsilon_i \geq 0, \\ 0, & \text{otherwise.} \end{cases} \tag{2.24}$$

For the other distributions (truncated normal, exponential and gamma distribution) similar conditional moments can be derived. Finally, with the point estimates of u_i, cost efficiency estimates for each decision-making unit can be obtained via the equation $CE_i = \exp\{-u_i\}$.

Obviously, one drawback of the parametric estimation techniques (deterministic as well as stochastic) - in comparison to the non-parametric ones - is that one has to specify a functional form and make assumptions about the distribution of the inefficiency term. When the true functional form of the cost structure is unknown, this problem can be mitigated by using the more flexible translogarithmic function (Christensen et al., 1973) instead of the "simple" Cobb-Douglas function. The translogarithmic cost function extends the Cobb-Douglas function by also including the quadratic- and cross-product terms of the right hand side (output and input price) variables of the cost frontier (2.22):

[9] For a detailed discussion of the different distributional assumptions in the context of production frontiers, see e.g. Kumbhakar and Lovell (2000), p.74 et seqq.

$$\begin{aligned}\ln C_i &= \beta_0 + \sum_r \beta_r \ln y_{r,i} + \sum_p \alpha_p \ln w_{p,i} + \frac{1}{2}\sum_r\sum_q \beta_{r,q} \ln y_{r,i} \ln y_{q,i} \\ &+ \frac{1}{2}\sum_p\sum_m \alpha_{p,m} \ln w_{p,i} \ln w_{m,i} + \frac{1}{2}\sum_r\sum_p \gamma_{r,p} \ln y_{r,i} \ln w_{p,i} \\ &+ v_i + u_i. \end{aligned} \tag{2.25}$$

In order to obtain estimates of the (in)efficiency component for the translogarithmic cost frontier, u_i, the deterministic kernel in equation (2.14) just has to be replaced by the translogarithmic functional form. Since translogarithmic cost functions apparently have a number of advantages over the Cobb-Douglas specification, and since there is only very limited information about the functional form of local governments' cost functions available, the translogarithmic specification (instead of the Cobb-Douglas specification) is used in chapter 4.

Finally, a graphical representation of the stochastic frontier model is given in figure 2.6 (again for the special case of one output). Since parametric approaches employ regression techniques, the best practice frontier - in contrast to the non-parametric approaches - is a smooth curve. In addition, the deviation of the (inefficient) decision-making unit P from the best practice frontier (PP') is now decomposed into the inefficiency component u_P and the (symmetric) component v_P, capturing the effects of other sources of random noise. All deterministic approaches (the parametric ones described in the last subsection as well as the non-parametric ones) would interpret the whole deviation as inefficiency. Moreover, the figure reveals that it is also possible for the influence of random noise to dominate the influence of inefficiency for some decision-making units. In this case, the decision-making unit ends up above and not beneath the best practice frontier (e.g. DMU B).

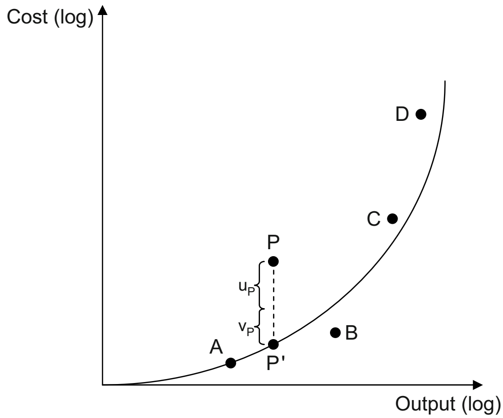
Panel Data Models

So far, only cross-sectional models have been considered. Equations (2.22) and (2.25), however, can also be extended to account for panel data. Basically, researchers proposed two different types of panel frontier models: (1) Models, in which cost efficiency varies across the decision-making units, but is assumed to be constant over time for each DMU, and (2) models, in which cost efficiency varies across decision-making units and time for each DMU. Starting with the first case, a Cobb-Douglas cost frontier[10] with time-invariant cost efficiency can be written as:

$$\ln C_{i,t} = \beta_0 + \sum_r \beta_r \ln y_{r,i,t} + \sum_p \alpha_p \ln w_{p,i,t} + v_{i,t} + u_i, \;\; i = 1, ..., n, \tag{2.26}$$

[10]In the following, only Cobb-Douglas cost frontiers are considered. The extension to the translogarithmic case, however, is straightforward.

Figure 2.6: Example of a stochastic cost frontier with one output



where $t = 1, ..., T$ is the time subscript, $v_{i,t}$ is an independently and identically normally distributed $N(0, \sigma_v^2)$-random variable, and u_i represents the time-invariant cost (in)efficiency component. All other variables are as defined in equation (2.22). Now, the parameters of the model as well es the time-invariant (in)efficiency component, u_i, can basically be estimated in three different ways:

1. *The Fixed-Effects Model:* If we assume that $v_{i,t}$ is uncorrelated with the regressors, but allow u_i to be correlated with the regressors as well as with $v_{i,t}$, and if no assumptions about the distribution of the inefficiency component, u_i, are made, a fixed-effects model can be estimated. After the estimation, the cost efficiency estimates can be obtained in a similar manner as in the COLS model of subsection 2.4.1 (see e.g. Schmidt and Sickles, 1984).

2. *The Random-Effects Model:* If, instead, we assume that both $v_{i,t}$ and u_i are mutually uncorrelated and uncorrelated with the regressors, and u_i is a randomly distributed (rather than a fixed) variable, a random-effects model can be estimated by employing a standard two-step generalised least squares (GLS) method (see e.g. Schmidt and Sickles, 1984).

3. *Maximum Likelihood Estimation:* If, on the other hand, both $v_{i,t}$ and u_i are independently and identically distributed (of each other and of the regressors), and if a distributional assumption about the (in)efficiency component, u_i, is made (e.g. half-normal distribution), the maximum likelihood estimation technique can be employed.

As a result, the procedure to obtain estimates of u_i is structurally similar to the one derived for cross-sectional models (see e.g. Pitt and Lee, 1981).

However, the assumption that cost efficiency is time-invariant is relatively unrealistic, especially in (very) long panels. Therefore, researchers developed models which also allow for time variation in the (in)efficiency component. Equation (2.26) then changes to:

$$\begin{aligned} \ln C_{i,t} &= \beta_{0,t} + \sum_r \beta_r \ln y_{r,i,t} + \sum_p \alpha_p \ln w_{p,i,t} + v_{i,t} + u_{i,t} \\ &= \beta_{i,t} + \sum_r \beta_r \ln y_{r,i,t} + \sum_p \alpha_p \ln w_{p,i,t} + v_{i,t}, \end{aligned} \quad (2.27)$$

where $\beta_{0,t}$ is the intercept of all decision-making units in period t, and $\beta_{i,t} = \beta_{0,t} + u_{i,t}$ is the intercept of DMU i in period t. Again, equation (2.27) can be estimated by using fixed-effects- and random-effects estimation techniques (see e.g. Cornwell et al., 1990) or maximum likelihood estimation techniques (see e.g. Kumbhakar, 1990; Battese and Coelli, 1992).

Furthermore, all of the above mentioned models interpret the term, which is specific to every single decision-making unit (u_i in equation (2.26) or $u_{i,t}$ in equation (2.27)), as "inefficiency". This, however, means that any unmeasured time variant or invariant heterogeneity of the decision-making units is interpreted as inefficiency as well. As a consequence, the above mentioned models possibly underestimate the cost efficiency of the decision-making units, since they mix (in)efficiency and DMU-specific heterogeneity. For this reason, Greene (2005) extended the above mentioned models by adding a stochastic term for DMU-specific unobserved heterogeneity. Assuming time-varying efficiency, and making no distributional assumptions about the DMU-specific term, equation (2.27) can then be rewritten in the following way (*'true' fixed-effects model*):

$$\ln C_{i,t} = \gamma_i + \sum_r \beta_r \ln y_{r,i,t} + \sum_p \alpha_p \ln w_{p,i,t} + v_{i,t} + u_{i,t}, \quad (2.28)$$

where γ_i represents the DMU-specific unobserved heterogeneity, $v_{i,t}$ is again an independently and identically normally distributed $N(0, \sigma_v^2)$-random variable, and the (in)efficiency component, $u_{i,t}$, is assumed to follow a half-normal distribution $N^+(0, \sigma_u^2)$. Moreover, equation (2.28) can be estimated using maximum likelihood estimation techniques.[11] The *'true' random-effects model*, in contrast, can be written as:

$$\ln C_{i,t} = \beta_0 + \gamma_i + \sum_r \beta_r \ln y_{r,i,t} + \sum_p \alpha_p \ln w_{p,i,t} + v_{i,t} + u_{i,t}, \quad (2.29)$$

where γ_i now represents the random DMU-specific effect. According to Greene (2005), equation (2.29) can be estimated using simulated maximum likelihood methods.[12]

[11] For more details, see Greene (2005), p. 278 and 279.
[12] For more details, see Greene (2005), p. 285.

Table 2.3: Summary of the stochastic panel frontier models

Model	Author	Inefficiency Component u: *Time-Invariant*	*Time-Variant*	DMU-specific Component γ
Fixed-Effects Model	Schmidt and Sickles (1984)	x	-	-
	Cornwell et al. (1990)	-	x	-
Random-Effects Model	Schmidt and Sickles (1984)	x	-	-
	Cornwell et al. (1990)	-	x	-
Maximum Likelihood Estimation	Pitt and Lee (1981)	x	-	-
	Kumbhakar (1990) and Battese and Coelli (1992)	-	x	-
True Fixed-Effects Model	Greene (2005)	-	x	x
True Random-Effects Model	Greene (2005)	-	x	x

The models proposed by Greene (2005), however, also have some drawbacks. The 'true' fixed-effects model, for example, produces biased coefficient and inefficiency estimates when the time period, T, is small ($T \leq 5$). Secondly, in both models, the 'true' fixed-effects as well as the 'true' random-effects model, there is a tendency to overestimate cost efficiency, since the DMU-specific factors (γ_i) might partially be related to inefficiency. If this is the case, part of the inefficiency is completely absorbed by the DMU-specific term and is thus not reported as "inefficiency".

Finally, table 2.3 provides a short summary of the above described stochastic panel frontier models - in terms of the inefficiency and DMU-specific components.

2.5 Incorporating Exogenous Influences on Efficiency into Parametric Approaches

As with the non-parametric approaches presented in section 2.2, exogenous or non-discretionary variables have been incorporated into stochastic frontier analyses by means of two-stage methods. Thus, in a first stage, efficiency estimates were obtained by employing one of the models introduced in the preceding section and afterwards, the efficiency scores were regressed on the exogenous or non-discretionary variables in an OLS regression (see e.g. Pitt and Lee, 1981; Vitaliano, 1997). However, as pointed out by Kumbhakar and Lovell (2000), there are serious econometric problems connected to this two-stage approach. Firstly, it must be assumed that the exogenous variables are uncorrelated with the elements of the output vector, y_i.[13] If this is not the case, the maximum likelihood estimates of the parameters of the model are biased. If the set of inputs, outputs, and exogenous variables is very large, this assumption is very likely to be violated. Secondly, since it is assumed in the first stage that the efficiency scores are independently and identically distributed, the assumption that the efficiency scores have a functional relationship with the exogenous variables in the second stage regression is falsified.

[13] In case of production frontiers, it must be assumed that the exogenous variables are uncorrelated with the elements of the input vector, x_i.

To avoid the latter of the above-mentioned problems (the former problem can only be avoided by checking the correlations between the exogenous and the output variables), researchers developed *one-step procedures* in which the parameters of the stochastic frontier as well as the parameters of the exogenous variables are estimated simultaneously by maximum likelihood estimation techniques. Kumbhakar et al. (1991) were one of the first to specify such a one-step procedure for cross-sectional data (for production frontiers). Using again a Cobb-Douglas functional form, an equivalent stochastic cost frontier model can be written as:[14]

$$\ln C_i = \beta_0 + \sum_r \beta_r \ln y_{r,i} + \sum_p \alpha_p \ln w_{p,i} + v_i + u_i \tag{2.30}$$

$$u_i = \delta_0 + \sum_j \delta_j z_{j,i} + w_i, \quad i = 1, ..., n, \tag{2.31}$$

where z_i represents the vector of exogenous or non-discretionary variables, $v_i \sim$ iid $N(0, \sigma_v^2)$, and $u_i \sim N(\delta_0 + \sum_j \delta_j z_{j,i}, \sigma_u^2)$. In addition, v_i and u_i are assumed to be independently distributed; for the error term w_i no distributional assumptions are made. Now, maximum likelihood estimation techniques can be used to obtain estimates of the parameter vectors β, α, and δ as well as the variances σ_v^2 and σ_u^2. These parameter estimates can then be used to obtain (adjusted) estimates of the (in)efficiency component, u_i, again using the decomposition proposed by Jondrow et al. (1982) (see also subsection 2.4.2).

Moreover, Battese and Coelli (1995) extended the above model to also account for panel data. The basic equation system then changes to:

$$\ln C_{i,t} = \beta_0 + \sum_r \beta_r \ln y_{r,i,t} + \sum_p \alpha_p \ln w_{p,i,t} + v_{i,t} + u_{i,t} \tag{2.32}$$

$$u_{i,t} = \delta_0 + \sum_j \delta_j z_{j,i,t} + w_{i,t}, \tag{2.33}$$

where t is the (additional) time subscript. Unlike Kumbhakar et al. (1991), however, Battese and Coelli (1995) make a distributional assumption about the error term of the inefficiency equation (2.33), $w_{i,t}$. Since it is required that the (in)efficiency component $u_{i,t} \geq 0$, it follows that $u_{i,t} = \delta_0 + \sum_j \delta_j z_{j,i,t} \geq 0$. This assumption is modeled by defining $w_{i,t}$ as the truncation of the normal distribution with zero mean and variance σ_w^2. Again, the parameters (along with the variances) of the model can be estimated using maximum likelihood methods.[15] Afterwards, the (adjusted) cost efficiency estimates of decision-making unit i can be obtained by means of the equation $CE_i = \exp\{-u_{i,t}\} = \exp\{-\delta_0 - \sum_j \delta_j z_{j,i,t} - w_{i,t}\}$.

[14] For slightly different approaches with regard to the specification of the relationship between the (in)efficiency component, u_i, and the vector of exogenous variables, z_i, in equation (2.31), see Reifschneider and Stevenson (1991) and Huang and Liu (1994).

[15] For more details, see Coelli (1996b).

In chapter 4, where the cost efficiency of German local governments - along with its determinants - is investigated, mainly the one-step procedure (in a panel context) is employed, since, in contrast to the two-step approaches mentioned at the beginning of this subsection, it yields unbiased estimators.

2.6 Software Issues

Finally, the question remains of how the above derived models can be implemented with real data. Therefore, this subsection provides a brief overview of the software packages which are available for the estimation of non-parametric and parametric frontier models. Starting with the non-parametric ones, Scheel (2000) provides a programme (*EMS: Efficiency Measurement System*) which computes - among other things - Data Envelopment Analysis (and Free Disposable Hull) efficiency estimates. The programme is based on Microsoft Excel and is able to compute all the models described in section 2.2 - including the model of Banker and Morey (1986) (introduced in subsection 2.3.1) which allows for the incorporation of non-discretionary (input or output) variables into the linear programming problem. A further software package which can be used to calculate DEA efficiency estimates is provided by Coelli (1996a): *Data Envelopment Analysis Program (DEAP).* With this programme, however, it is not possible to calculate FDH-based efficiency indices. In addition, Wilson (2009) provides the software library *FEAR (Frontier Efficiency Analysis with R)* which can be linked to the statistical package *R*. Besides the calculation of simple DEA and FDH efficiency estimates, FEAR also provides commands for bootstrap routines that can be employed to correct for the bias arising in simple DEA analyses (see also subsection 2.3.2).

In contrast, parametric frontier models can be estimated using the software package *Stata*. Stata provides commands for the cross-sectional as well as some of the panel models described in subsection 2.4.2. In addition, Stata enables us to assume different distributional assumptions for the (in)efficiency component, u_i, in the cross-sectional case; in the panel model, the inefficiency term is assumed to follow a truncated-normal distribution (in the time-variant as well as time-invariant frontier model). The frontier models of Greene (2005) and the one-step approach proposed by Battese and Coelli (1995), however, have so far not been implemented in Stata. The latter approach can be implemented by the software package *FRONTIER* (Coelli, 1996b). This programme also makes it possible to calculate almost all of the other cross-sectional and panel frontier models described in subsection 2.4.2. Finally, the only software package that provides tools for both stochastic frontier analysis and DEA is the most recent version of the software package *LIMDEP* (version 9.0). With LIMDEP it is possible to implement (almost) all of the stochastic frontier models described in sections 2.4 and 2.5.

Before we conclude this chapter, it should be mentioned that the efficiency analysis in chapter 4, in which some of the estimation approaches described in the previous sections are applied to German local governments, is implemented by using the programmes FRONTIER, Stata, and EMS.

Chapter 3

Literature Review on Efficiency Studies in the Public Sector

3.1 Introduction

In this chapter, an extensive review of the literature on public sector efficiency is provided. As will be seen in the following subsections, studies measuring the technical or cost efficiency of governments have so far mainly focused on particular areas of the public sector; efficiency studies which examine the global performance of single local governments or whole countries have, in contrast, attracted far less attention in the past. Despite the wide-ranging interest in investigating the technical or cost efficiency of the public sector, researchers have also been interested in the main drivers of this efficiency, since information about the sources of technical or cost efficiency of governments can provide helpful information for policy-makers or politicians.

This chapter is structured as follows: Firstly, a detailed overview of the efficiency studies on the different areas of public goods provision is given.[1] These include the cultural sector (e.g. libraries), the educational sector (e.g. schools or universities), the energy sector (e.g. electric utilities or nuclear power plants), the health care sector (e.g. hospitals or nursing homes), public facilities (such as water supply utilities, waste disposal companies, etc.), the security sector (e.g. police departments or prisons), and finally, the transportation sector (e.g. railways or buses). Subsequently, the studies on the (technical or cost) efficiency of administrative units (local governments and countries) are presented. Finally, at the end of this chapter, a short conclusion is drawn.

The review on the efficiency literature is also summarised in table C.1 of Appendix C; the table is structured in the same manner as the main text: Firstly, the studies on particular areas of the public sector are provided (in the order mentioned above), followed by the studies on

[1]Since there exists a huge amount of studies for some areas (e.g. educational and health care sector), only a selection of studies (for these sectors) is presented here. For further reviews of studies on public sector efficiency, see e.g. Blank (2000) and Worthington and Dollery (2000).

government efficiency (as a whole). Note that the studies in table C.1 are listed alphabetically within each category.

3.2 Culture

Studies investigating the (technical) efficiency of the cultural sector have so far focused exclusively on (public) libraries. Vitaliano (1997, 1998), for example, considers the technical efficiency (by means of a stochastic frontier analysis and DEA, respectively) and its determinants of public libraries in New York State, USA. While Vitaliano (1997) employs total costs as an input indicator, and the total circulation of books, serials and non-book items, weekly hours of operation, the number of books added during the year, and total holdings (of books, serials, etc.) as output indicators, Vitaliano (1998) approximates input by total holdings, hours of operation, new books purchased as well as total serial subscriptions and output by the internal and external circulation of books. Both studies reveal substantial inefficiencies among the libraries. Moreover, using a second-stage Tobit regression, Vitaliano (1998) shows that the main source of inefficiency are exceedingly long opening hours of the libraries. Vitaliano (1997), on the other hand, finds evidence that gifts given to libraries and a higher proportion of funds derived from local taxation are associated with less inefficiency. In addition, one key result of the latter study is that public (municipal) libraries are less efficient than (private) non-profit libraries. Hemmeter (2006), in contrast, comes to the opposite conclusion (also using a sample of US libraries and similar input and output indicators): Non-profit libraries are found to be more inefficient than public libraries. Similar to Vitaliano (1997), he also uses stochastic frontier analysis and investigates the determinants of efficiency by means of a second-stage Tobit regression. Another interesting result of the study of Hemmeter (2006) is that competition (e.g. in terms of other libraries) has no significant influence on the efficiency of libraries. According to the author this could be due to the fact that competition leads to a decrease in monitoring of public services. In a further study, Sharma et al. (1999) investigate the efficiency of public libraries in Hawaii, whereas the authors also detect substantial inefficiencies among the libraries.

In a cross-sectional analysis, Stevens (2005) compares the resulting efficiency scores of one parametric and one non-parametric estimation approach for a sample of English local public libraries. Using similar input and output indicators as Vitaliano (1997), he shows that the efficiency scores are very sensitive to the estimation approach and specification used. In a further step, the author shows that the share of population aged below 16 as well as the share of population older than 65 are associated with higher efficiency, whereas efficiency decreases with the percentage of the population that is income-deprived. Chen (1997) and Worthington (1999), on the other hand, investigate the (technical) efficiency of libraries in Taiwan and Australia, respectively. The results of Chen (1997) suggest that 11 of the 23 libraries under investigation do not operate at the best practice frontier. In contrast, by means of a second-stage Tobit regression on DEA efficiency indices for 168 libraries in New South Wales, Worthington (1999) shows that libraries which are located in non-metropolitan, costal and rural areas are comparatively more efficient. A further result of the study of Worthington (1999) is that the technical efficiency of libraries decreases with population size. Finally, Silkman and Young (1982) show for a sample of US libraries (of different states) that the technical efficiency of libraries is negatively influenced if the county where the libraries are located is more dependent on grants.

3.3 Education

One of the areas which attracted much attention in the literature about the public sector efficiency during the last decades is the educational sector. There, researchers analysed both the technical or cost efficiency of educational institutions (i.e. schools and universities) for numerous countries and the main drivers of this inefficiency. Also striking is the fact that most of the studies focus on the educational institutions of the United States and the United Kingdom.

The studies of Banker et al. (2004) and Grosskopf et al. (1997, 1999, 2001), for example, focus on the technical, allocative and cost efficiency of school counties in Texas. Using operating expenditures as an input indicator and total school enrolment in elementary, middle and high schools as an output indicator, Banker et al. (2004) show by means of a DEA based estimation method for a sample of 585 Texas school counties for the years 1993 to 1999 that the technical inefficiency increased over this six year period, whereas the allocative inefficiency remained relatively stable. Grosskopf et al. (1997, 1999), on the other hand, use cost-indirect output distance functions and DEA-type linear programming techniques, respectively, to simulate some of the consequences of various school finance reforms in Texas. Their results suggest that reforms could result in significant cost savings. In addition, Grosskopf et al. (2001) show (by means of a Shepard input distance function) that technical efficiency is lower in school counties with higher proportions of homeowners, highly educated individuals and households with school-age children. Moreover, the results indicate that increased competition for enrolment could enhance the allocative efficiency.

In further studies, Bessent et al. (1982) and Färe et al. (1989b) investigate in a cross-sectional analysis the efficiency of educational institutions in Houston and Missouri, respectively, using non-parametric estimation approaches. While the authors of the first study find substantial inefficiencies among the educational institutions (elementary schools), one of the striking results of the latter study is that more than half of the observations are operating at an efficient level. In contrast, the studies of Ray (1991), Ray and Mukherjee (1998), Duncombe et al. (1997) and Ruggiero (1996) investigate the determinants of technical efficiency for the school counties of the states Connecticut and New York. All studies use non-parametric estimation techniques to estimate efficiency indices for the school counties. In addition, the first three studies analyse the main drivers of efficiency by means of second-stage regressions; Ruggiero (1996), on the other hand, proposes an estimation method which integrates the exogenous variables in the DEA programming model. All studies hint at the fact that technical efficiency varies systematically with socio-economic as well as environmental characteristics of the counties. These results are confirmed by Deller and Rudnicki (1992) and Cooper and Cohn (1997), who analyse the technical efficiency of schools (along with its determinants) in the states Maine and South Carolina. Unlike the studies mentioned above, Deller and Rudnicki (1992) and Cooper and Cohn (1997) use parametric approaches (stochastic frontier analysis) to determine the technical efficiency of the schools. Moreover, the impact of the exogenous variables on the efficiency is not analysed by means of a second-stage regression; the exogenous variables are included in the cost and production frontier, respectively.

Investigations on the efficiency of educational institutions in the United Kingdom are provided by Glass et al. (1998) and Johnes (2006), both of which use DEA to detect potential inefficiencies. Glass et al. (1998) show for a sample of 54 publicly-funded universities that the overall efficiency of the university system in the United Kingdom has increased by approximately three percent from 1989 to 1992. In order to do so, they employ several types of academic staff, net assets and income from research grants as input indicators and research as well as postgraduate and undergraduate teaching as output indicators. These results are in line with those of Johnes (2006) who comes to the conclusion that the general efficiency among the English universities is very high. In a further study, Bates (1993) applies and compares DEA and OLS for a sample of 96 Local Education Authorities (LEAs) in England. Using teaching as well as non-teaching expenditures as input indicators and examination results as output indicators, the author shows that the results obtained by the two different methods are very similar: The top seven LEAs which obtain the highest efficiency scores by the OLS regression are also deemed to be efficient in the Data Envelopment Analysis.

Besides the numerous efficiency studies on the United States and the United Kingdom, there are also several studies measuring the efficiency of educational institutions (along with its determinants) of other countries. Bonesrønning and Rattsø (1994), Kirjavainen and Loikkanen (1998), Avkiran (2001), and Mancebon and Muniz (2008), for example, investigate the technical or cost efficiency of Norwegian (high schools), Finnish (senior secondary schools), Australian (universities), and Spanish (high schools) educational institutions by means of DEA. In general, the results of all these analyses show that the (mean) efficiency scores vary substantially depending on the model specification used. In addition, Bonesrønning and Rattsø (1994) also find evidence that school size and efficiency are positively related. Moreover, one key result of Mancebon and Muniz (2008) is that the efficiency scores of private schools are generally higher than those of public schools. The authors argue that this is not the consequence of comparatively more effective management (in private schools) but rather of having pupils with a more favourable educational background. The latter result is also consistent with the findings of Mizala et al. (2002) who investigate the technical efficiency of 2,000 schools in Chile - using and comparing DEA and stochastic frontier analysis. Their findings also suggest that private fee-paying schools are more efficient than private subsidized and public schools. Oliveira and Santos (2005), on the other hand, use the FDH reference technology and a two-stage approach to estimate the level of efficiency and to identify the main drivers of efficiency for 42 Portuguese secondary schools. In order to avoid the bias arising in typical two-stage approaches the authors use the bootstrapping correction method proposed by Simar and Wilson (2007). The results show that a high percentage of secondary schools in Portugal are inefficient and that the health care influences efficiency positively, whereas the unemployment rate has a negative impact on school performance.

Furthermore, Fandel (2007) and Kempkes and Pohl (2008, 2009) concentrate on the (technical) efficiency of German universities. While Fandel (2007) employs the number of students and personnel as well as outside funding as input indicators and the number of graduates and doctorates as output indicators, the last two studies approximate input by total costs (without third-party funds), financial means and the number of technical as well as research personnel, and output by the number of graduates and research grants. By means of DEA, Fandel (2007) calculates mean efficiency scores for the universities of the German state North Rhine-Westphalia (for the year 1997) of 0.92 (Natural Science) and 0.97 (Engineering). The studies by Kempkes and Pohl (2008, 2009), in contrast, focus on the institutional setting of the universities for the whole of Germany. Their results suggest that more liberal state regulation has a positive impact on efficiency, whereas a restrictive framework is associated rather with lower efficiency levels. Another interesting result is that Eastern German universities seem to be less efficient than the ones in Western Germany. In further studies, Ouellette and Vierstraete (2005) and McMillan and Chan (2006) are concerned with the efficiency and its determinants of educational institutions (school boards and universities, respectively) in Canada. While McMillan and Chan (2006) use and compare DEA and stochastic frontier analysis, Ouellette and Vierstraete (2005) only use DEA to detect potential inefficiencies. Both studies come to the conclusion that the efficiency among Canada's educational institutions is relatively high: While McMillan and Chan (2006) estimate mean efficiency scores of 0.90 (SFA) and 0.98 (DEA), the efficiency scores of Ouellette and Vierstraete (2005) range from 0.91 to 0.94 depending on the specification used. Moreover, the latter study also confirms the findings mentioned above that inefficiencies are (highly) related to socio-economic characteristics of the surrounding location of the school boards.

Finally, Afonso and St. Aubyn (2005, 2006) compare the efficiency of the educational systems (secondary education) of selected OECD countries for the years 2000 and 2003, respectively. While Afonso and St. Aubyn (2005) apply two non-parametric approaches (DEA and FDH), the second study uses the semi-parametric approach proposed by Simar and Wilson (2007). The results of both studies suggest that there are substantial differences in the efficiency levels of the countries - employing the number of teachers per student and the time the 12- to 14-year-old pupils spend at school as input indicators and the PISA results of 15-year-old pupils (in mathematics, reading, and science) as output indicators. Moreover, the analysis of Afonso and St. Aubyn (2006) shows that a wealthier and more cultivated environment is an important factor for a better performance of the students.

3.4 Energy Supply

The efficiency of the energy sector has also attracted a lot of attention over the past decades. But in contrast to the educational sector, efficiency studies of the energy sector mainly focus on the technical, allocative or scale efficiency of energy supply utilities (e.g. electric utilities or nuclear power plants); the main drivers of this efficiency, however, have attracted far less attention in the literature. As in the case of the educational sector, the bulk of studies concentrate on the efficiency of energy supply utilities in the United States. As will be seen in the following discussion, however, there are also numerous studies on other countries.

One early study by Kopp and Smith (1980) compares the results of three different deterministic and stochastic (parametric) frontier estimation approaches using a sample of steam electric generating plants in the United States for the period 1969-1973. Employing the coal consumed and capital (in installed nameplate capacity) as input indicators and the (net) electric generation of a plant as an output indicator, the authors come to the conclusion that both the functional form (Cobb-Douglas or translogarithmic) and the different frontier estimation techniques have an impact on the estimated efficiency indices. In contrast, the studies of Färe et al. (1983, 1985, 1986, 1989a) use non-parametric estimation techniques and slightly different input and output indicators to analyse the efficiency of electric utilities in the United States. Using an unbalanced panel of regulated electric utilities in Illinois, the first study shows that only 24 of the 86 observations are (purely) technically efficient and only 14 are scale efficient. Therefore, the authors conclude that regulation does not necessarily result in efficient operation of electric utilities. The purpose of the second study is to compare the relative performance of publicly- and privately-owned electric utilities. Based on several non-parametric tests, the authors find that the publicly- and privately-owned utilities are not significantly different in terms of overall technical efficiency measures. The focus of the last two studies, in contrast, lies on the influence of environmental factors on (technical) efficiency. The key results of these studies are that plant size affects efficiency and that the installation of precipitators has little impact on the efficiency of the electric utilities in the sample. Finally, Sickles and Streitwieser (1992) and Yaisawarng and Klein (1994) investigate the efficiency of natural gas transmission companies between 1977 and 1991 and coal-fired electric generating plants in the late 1980s in the United States, respectively. While the findings of Sickles and Streitwieser (1992) hint at the fact that the efficiency of the gas transmission companies has declined during the considered time period, the results of Yaisawarng and Klein (1994) suggest that the (productive) efficiency of the electric generating plants remained relatively stable.

Furthermore, Sueyoshi (1999), Sueyoshi and Goto (2001) and Nemoto and Goto (2006) investigate the efficiency of electric utilities in Japan. While Sueyoshi (1999) and Nemoto and Goto (2006) apply traditional non-parametric (DEA) and parametric (stochastic frontier analysis) estimation approaches to detect potential inefficiencies, Sueyoshi and Goto (2001) use a slack-adjusted Data Envelopment Analysis model, which explicitly accounts for the influence of slacks. All three studies point to substantial inefficiencies among the electric power companies in Japan. Moreover, one important result of Sueyoshi (1999) is that the overall efficiency of large electric power companies is higher than the overall efficiency of smaller ones. The results of the investigations mentioned above are also in line with the study of Hattori et al. (2005), who compare the performance of Japanese and UK electricity distribution utilities - using total (operational) expenditures as an input indicator and the number of customers as well as electricity units delivered as output indicators - and come to the conclusion that efficiency scores are generally higher for UK utilities. Price and Weyman-Jones (1996), on the other hand, estimate Malmquist productivity indices for a sample of natural gas utilities in the United Kingdom from 1977 to 1991 in order to investigate whether the privatisation of the gas industry - which occurred within this period - has led to an increase or decrease of productivity. While the authors approximate input by the number of employees and the length of the gas mains transmission and distribution system, output is proxied by the number of customers served, gas using appliances sold and domestic, industrial as well as commercial gas sales. The results of the study point to the fact that the privatisation has increased the productivity of the gas industry in the UK.

Farsi and Filippini (2004b) and Farsi et al. (2006a) estimate a cost frontier for a panel (1988-1996) of 59 Swiss electricity distribution utilities using total annual costs (per kWh output) as the left hand side (input) variable and the total number of kWh delivered as the right hand side (output) variable. In addition, the input prices are approximated by the average annual salary of the firm's employees (labour) as well as the ratio of capital expenses to the total installed capacity of the utilities' transformers (capital). Using and comparing different (parametric) deterministic and stochastic cost frontiers, the authors calculate mean efficiency scores ranging from 0.74 to 0.96. Therefore, one key result of both studies is that researchers should perform sensitivity analyses to identify the limitations of different models and to test the robustness of the results. Moreover, the studies of Bagdadioglu et al. (1996), Hjalmarsson and Veiderpass (1992), Hu and Wang (2006), Miliotis (1992), Von Hirschhausen et al. (2006) and Whiteman (1999) examine the efficiency of the energy sector in Turkey, Sweden, China, Greece, Germany, and Australia, respectively; all of the studies mentioned above focus on different aspects of (technical) efficiency. The study by Von Hirschhausen et al. (2006), for example, investigates the differences between East and West German electricity distribution utilities; the results of the authors suggest that electricity distribution utilities in East Germany operate more efficiently than their West German counterparts. Moreover, both studies by Hjalmarsson and Veiderpass (1992) and by Miliotis (1992) come to the conclusion that energy supply utilities are more efficient in urban than in rural regions.

Finally, researchers have also been interested in the comparison of efficiency levels of different countries. Chien and Hu (2007), for example, examine the technical efficiency in the production of renewable energy for 45 countries by means of DEA. Their findings point to higher efficiency scores of OECD countries compared to those of non-OECD countries. Pollitt (1996), on the other hand, estimates and compares efficiency indices along with their determinants of nuclear power plants in the United States, the United Kingdom, Canada, Japan, and South Africa. One of the key results of this analysis is that there are few differences in the performance of public and private nuclear power plants among the countries of the sample. In addition, the studies of Yunos and Hawdon (1997) and Zhang and Bartels (1998) compare the performance of electricity producers in Malaysia, Thailand, and the United Kingdom on the one hand, and Australia, New Zealand, and Sweden on the other hand. The latter study highlights the consequences of different sample sizes (of the countries). In a simulation study the authors show that an increasing sample size generally leads to a decrease in the estimated mean technical efficiency indices.

3.5 Health Care

In the literature on public sector efficiency, the health sector has attracted most of the attention over the previous decades. There is a huge amount of studies investigating the technical or cost efficiency (along with its determinants) of health care institutions (e.g. hospitals, nursing homes, etc.) in different countries. Again, the bulk of studies focuses on the health care institutions of the United States.

Early studies in this field are the studies by Banker et al. (1986), Wilson and Jadlow (1982), Grosskopf and Valdmanis (1987), Nyman and Bricker (1989) and Valdmanis (1992). All of these studies use linear programming techniques to investigate different aspects concerning the technical efficiency of hospitals and nursing homes in the United States. The latter four studies, for example, investigate the influence of the type of ownership of the hospitals and nursing homes, respectively, on (technical) efficiency. While Grosskopf and Valdmanis (1987) and Valdmanis (1992) find evidence that public hospitals have (slightly) higher average efficiency rates than (private) not-for-profit hospitals, the results of Wilson and Jadlow (1982) suggest that proprietary hospitals tend to operate closer to the best practice frontier than non-profit hospitals. The latter result is also in line with Nyman and Bricker (1989) who investigate the technical efficiency of 184 nursing homes in Wisconsin, USA. Vitaliano and Toren (1994), on the other hand, suggest that inefficiency is not related to the profit status of the institutions - using stochastic frontier analysis for a sample of 164 nursing and 443 skilled and health related facilities in New York State. In addition, several other studies examine the differences in (technical) efficiency regarding ownership types of health care institutions (see e.g. Burgess and Wilson (1996) and Fizel and Nunnikhoven (1993) for the United States; Farsi and Filippini (2004a) for Switzerland; Hsu and Hu (2007) for Taiwan, and Mobley and Magnussen (1998) for an international comparison).

Steinmann and Zweifel (2003), in contrast, focus on the relationship between the size of health care institutions (e.g. in terms of the number of beds in hospitals) and (technical) efficiency. Using inpatient days, non-labour expenses, academic, nursing as well as administrative staff as input indicators and medical, pediatric, surgical, gynaecological as well as intensive care discharges as output indicators, the authors find evidence for a sample of 89 Swiss hospitals that the smallest and largest hospitals (in terms of beds) are more efficient than the medium-sized hospitals. Moreover, using a sample of 160 German hospitals (for the year 1994), the results of Staat (2006) suggest that local hospitals are, on average, less efficient than hospitals with facilities which are of regional importance - employing the per diem rate of the hospitals and the number of beds as input indicators, and the number of cases per year as well as the length of patients' stay (reciprocal) as output indicators. Both studies analyse the efficiency of the hospitals by means of Data Envelopment Analysis. Finally, using and comparing DEA and stochastic frontier analysis, Dismuke and Sena (1999) show for a panel of Portuguese hospitals (1992-1994) that central hospitals (which are partly also teaching hospitals) are less productive than county hospitals.

Apart from the ownership structure and size, researchers were also interested in other determinants of hospitals' technical or cost efficiency. Brown (2003), Deily and McKay (2006) and Zuckerman et al. (1994), for example, investigate the (technical) efficiency of hospitals - along with its main drivers - for several states of the United States using stochastic frontier analysis. By estimating a cost frontier with total expenses of hospitals as left hand side (input) variable and total admissions, total outpatient visits (outputs), average annual salary per full-time equivalent employee (price of labour), depreciation and interest expenses per bed (capital price) as well as non-patient care and non-capital expenses per bed (price of support and service) as right hand side variables, the two latter studies find evidence for substantial inefficiencies among the hospitals. Moreover, Zuckerman et al. (1994) incorporate several output characteristics in the cost frontier and estimates different specifications. Their results, however, show that the inefficiency measures are not very sensitive to the different model specifications. Brown (2003), in contrast, uses the one-step approach proposed by Battese and Coelli (1995) to demonstrate that the technical efficiency of hospitals increases with managed care insurance (such as health maintenance organisations). Parkin and Hollingsworth (1997), Maniadakis and Thanassoulis (2000) and Ferrari (2006), on the other hand, focus on the (technical) efficiency of hospitals in Scotland (UK). The aim of the two latter papers is to analyse the effectiveness of the introduction of the internal market in the National Health Service in the United Kingdom in 1991. Using non-parametric and parametric approaches, respectively, the results of Maniadakis and Thanassoulis (2000) suggest that the efficiency levels of the hospitals increased from 1991 to 1996. In contrast, Ferrari (2006) detects no significant improvement in efficiency over the same time period (using a slightly different set of input and output indicators). Moreover, investigations on different aspects of the (technical) efficiency of hospitals in Canada, England, Finland, Greece, Northern Ireland, Spain, Thailand, and Turkey are included in Ouellette and Vierstraete (2004), Street and Jacobs (2002), Linna (1998), Giokas (2001), McCallion et al. (2000), Prior (1996), Puenpatom and Rosenman (2008) as well as Sahin and Ozcan (2000). Again, the studies use non-parametric and parametric estimation approaches to detect potential inefficiencies in the respective countries.

In contrast to studies focusing on hospitals, Kooreman (1994) and Farsi et al. (2005b) investigate the (technical) efficiency of nursing homes. Using the nursing home staff as an input indicator and the number of full and day care patients as output indicators for a sample of 320 Dutch nursing homes, Kooreman (1994) shows (by means of DEA) that the efficiency scores of the homes, on average, range from 0.80 to 0.94 depending on the specification used. Moreover, the author shows by means of second-stage Probit and Tobit regressions that quality is negatively related to efficiency indicating that higher quality requires more labour resources. Farsi et al. (2005b), on the other hand, compare different stochastic frontier estimation techniques for a panel of 36 Swiss nursing homes. Their results suggest that the estimated efficiency scores are largely dependent upon how the unobserved heterogeneity among the nursing homes is accounted for.

The (technical) efficiency of physicians is subject to investigation in the studies of Chilingerian (1995) and Defelice and Bradford (1997). While Chilingerian (1995) approximates input by the total length of each patient's stay as well as total charges for all ancillary services and output by the number of (patient) cases, Defelice and Bradford (1997) employ weekly visits per physician as an input indicator, and the number of hours the physician spent in the doctor's practice, hours of nursing time, clerical worker time as well as the percentage of visits the physician utilises laboratory tests or orders x-rays as output indicators. The first study examines a sample of 36 physicians of one single hospital, and shows that 24 of these physicians do not operate at the best practice frontier. In addition, a second-stage Tobit regression on the efficiency scores (obtained by DEA) reveals that physicians belonging to a health maintenance organisation operate more efficiently. The main focus of Defelice and Bradford (1997), in contrast, is on the differences between solo and group practice physicians. For a sample of 924 primary care physicians in the United States, the authors use stochastic frontier analysis to show that there are no significant differences in the efficiency of solo practice physicians on the one hand and group practice physicians on the other hand. Moreover, the focus of Thanassoulis et al. (1995), Giuffrida and Gravelle (2001) Luoma et al. (1996), and Bradford et al. (2001) lies on different aspects of (technical) efficiency of health authorities providing perinatal care and primary care in England (the first two studies), health care centres in Finland, and patients who are treated for cardiac revascularization in the United States, respectively.

Finally, Afonso and St. Aubyn (2005) compare the efficiency of hospitals of selected OECD countries for the years 2000 and 2003, respectively - using two non-parametric approaches (DEA and FDH). Employing the number of doctors, nurses and inpatient beds as input indicators, and life expectancy as well as an index for the infant survival rate as output indicators, the authors calculate mean efficiency scores for the countries ranging from 0.82 (DEA) to 0.98 (FDH); Korea, Japan and Sweden were found to be the most efficient among these countries. Another study which also aims at estimating efficiency scores of health care institutions on the country level is the study by Grosskopf et al. (2006). Using DEA and a slightly different set of input and output indicators, the authors estimate efficiency scores for the health care sector of 143 countries (which are also used in the World Health Report). They come to the conclusion that developed countries typically have higher efficiency scores than less developed countries. Moreover, the comparison of the performance of the countries over time (1977-1990) shows that efficiency improvements also vary according to the level of development of the countries.

3.6 Public Facilities

In this section the focus lies on studies which investigate the efficiency of public facilities such as water supply utilities, waste disposal companies, post offices, employment offices, social insurance offices, and public day care centres. Since there are relatively few studies on these topics, all of these public services are summarised here under the heading “public facilities”.

Starting with the water supply utilities, one early study in this area is Fox and Hofler (1986), in which the authors focus on differences in the efficiency of private and public water supply utilities. By estimating a dual output stochastic frontier for a sample of 176 water supply utilities in the United States, they find no evidence for differences in the pure technical efficiency of private and public utilities. Using similar input and output indicators but a non-parametric estimation approach (DEA), Garcia-Sanchez (2006) comes to the same conclusion - employing a sample of 24 Spanish water supply utilities. Woodbury and Dollery (2004) and Haug (2008), on the other hand, analyse the efficiency of water supply utilities along with its main drivers for Australia and (Eastern) Germany. While the first study approximates input by total costs (for water supply) and output by the number of assessments, annual water consumption and an index reflecting the quality of the water as well as the service, the second study uses the total number of employees, the book value of property, plant and equipment as well as total expenses for materials and purchased services as input indicators and the volume of billed water as an output indicator. Employing a second-stage Tobit regression on efficiency scores obtained by DEA, the results of both studies suggest that the exogenous variables have (mostly) no significant impact on efficiency. Finally, Aida et al. (1998), Cubbin and Tzanidakis (1998) and Garcia-Valinas and Muniz (2007) examine the technical efficiency of water supply utilities in Japan, the United Kingdom and Spain. Using similar input and output indicators as in the studies of Woodbury and Dollery (2004) and Haug (2008), the authors of all three studies find evidence for substantial inefficiencies among the water supply utilities in the different countries.

Studies in the area of waste collection include Hirsch (1965), Stevens (1978) and Domberger et al. (1986). All of these studies investigate different aspects of waste collection in the United States (two former studies) and in the United Kingdom (latter study). Basically, the authors estimate cost functions with total expenditure of waste collection as the left hand side (input) variable and the number of pickup points, total quantity of waste collected, the frequency as well as the method of collection as right hand side (output) variables. In addition, several control (exogenous) variables are included to the estimation equation to test different hypotheses. While the study of Hirsch (1965) finds no evidence for significant economies of scale in the provision of waste collection, the results of Stevens (1978) show that, for cities (of the sample) with more than 50,000 inhabitants, total expenditure of waste collection is significantly less when service is provided by a private monopolist rather than a public monopolist. The findings of Domberger et al. (1986), in contrast, show that where services have been tendered, costs are approximately 20% lower than where they have not been tendered. In a further study, Callan and Thomas (2001) find evidence for significant economies of scope in the provision of recycling services for a sample of 110 cities and towns in Massachusetts (USA) using a similar cost function approach. Bosch et al. (2000), on the other hand, compare two non-parametric (DEA, FDH) and two parametric (COLS, SFA) estimation approaches to investigate the (technical) efficiency of waste collection companies in 75 Spanish municipalities. Using the number of containers, vehicles, and workers as input indicators and the tons of organic waste collected as output indicator, the results of the authors suggest that the inefficiency estimates obtained by the different estimation approaches are very sensitive to the adopted specification: The mean efficiency scores range from 0.55 (COLS) to 0.96 (FDH).

Deprins et al. (1984), Doble (1995) and Borenstein et al. (2004) are concerned with the (technical) efficiency of post offices in Belgium, the United Kingdom, and Brazil, respectively. While the authors of the former study compare two non-parametric approaches and one parametric estimation method to detect potential inefficiencies in postal services, the latter two investigations only apply DEA. Although all studies employ different input and output indicators, they all find evidence for substantial inefficiencies among the post offices in the three countries. Althin and Behrenz (2004), in contrast, investigate the technical efficiency of Swedish employment offices for the year 1993. Using DEA, the authors show that the efficiency scores of the offices range from 0.28 to 1 with a mean value of approximately 0.70. In addition, a second-stage Tobit regression on the DEA efficiency scores reveals that efficiency increases with the number of unemployed and vacancies. Moreover, in two further studies, Bjurek et al. (1990) and Kumbhakar and Hjalmarsson (1995) examine the efficiency of Swedish social insurance offices for the period 1974 to 1984 using the number of working days as an input indicator and the income evaluation assessments, sickness reports and controls, minor reimbursements of personal outlays for travel expenses as well as the evaluation of pension and social insurance payments as output indicators. While the former study is based on different non-parametric and parametric deterministic frontiers, the authors of the latter study estimate different stochastic frontier models. Both studies detect substantial inefficiencies among the offices; yet an additional interesting result of Bjurek et al. (1990) is that the differences between the approaches are surprisingly small. Finally, high levels of (technical) inefficiency are also found by Bjurek et al. (1992) for a sample of public day care centres in Gothenburg (Sweden).

3.7 Security

The efficiency of public facilities in the security sector (like police departments or prisons) has also been an area of great interest for many researchers in the past. In contrast to most of the previous sectors, however, the bulk of studies concentrates on the efficiency of institutions in the United Kingdom (and not in the United States).

One of the earlier studies in this field is Thanassoulis (1995). Using the number of police officers employed and the number of violent crimes, burglary and other crimes recorded as input indicators as well as the corresponding clear-up rates (of the three last input indicators) as output indicators, the author uses a sample of 41 English and Welsh police forces to show by means of DEA that only 13 out of the 41 police forces operate at the best practice frontier. More recent studies on the technical, scale and allocative efficiency of English and Welsh police forces include Drake and Simper (2000, 2001, 2002, 2003, 2004, 2005a). With minor exceptions almost all of these studies use the total cost of the employed staff, premise-related and transport related expenses, and capital cost as input indicators, while the number of traffic offences, breathalyser tests as well as the clear-up rates are used as output indicators. In addition, the bulk of the studies mentioned above applies DEA; only Drake and Simper (2002, 2003) use and compare different parametric and non-parametric estimation techniques. The main results of these investigations are that smaller and larger police forces tend to produce higher pure technical efficiency scores than intermediate ones (Drake and Simper, 2000), but larger police forces also display significant diseconomies of scale and scale inefficiencies (Drake and Simper, 2001). Further results point to a statistically significant negative relationship between size and pure technical efficiency of the police forces (Drake and Simper, 2002). Finally, Drake and Simper (2005a) come to the conclusion that it is extremely important to adequately incorporate the impact of environmental variables. In a further study Drake and Simper (2005b) analyse the efficiency of 293 English and Welsh Basic Command Units (BCUs) which are subunits of the police forces - using and comparing DEA and stochastic frontier analysis. Their results point to substantial divergence in efficiency levels, both across police forces as a whole, and across BCUs within the same police force. Ganley and Cubbin (1987), on the other hand, compute performance indicators for 25 prisons in England for the year 1984/1985. Using man hours, materials and energy consumption as input indicators, and prisoner days and the number of punished offences committed by inmates as output indicators, the authors show (by means of DEA) that 15 out of the 25 prisons operate efficiently.

In contrast, Davis and Hayes (1993) and Grosskopf et al. (1995) investigate the efficiency of police departments in Illinois and Texas (Dallas) in the United States, respectively. While Davis and Hayes (1993) estimate a stochastic cost frontier - using the sum of operating and capital expenditures as input variables, and the (inverse of the) per capita crime rate as an output indicator - Grosskopf et al. (1995) estimate Shepard-type distance functions and explicitly distinguish between variable inputs (number of police officers, sergeants and civilians) and fixed inputs (number of reported auto thefts and murders) to detect potential inefficiencies among the police departments. The results of the latter study suggest that the Dallas police department performed quite well in the considered period (1977-1987). By means of a second-stage OLS regression on the efficiency scores obtained in the first stage, Davis and Hayes (1993) show that the tax rates (city size) influence the performance of the police departments positively (negatively). Grosskopf and Yaisawarng (1990), on the other hand, concentrate on the measurement of economies of scope for 49 municipalities in California (USA) for the year 1982. For this purpose, they apply DEA using the aggregate (or variable) total cost to approximate input, and full time equivalent employment in police and fire services to approximate output. For the case of total cost as an input indicator, the authors do indeed find evidence of economies of scope in the provision of police and fire services.

Finally, the studies of Carrington et al. (1997), Barros and Alves (2005), Diez-Ticio and Mancebon (2002) and Sun (2002) investigate the technical efficiency of police services in Australia (police patrols), Portugal (police precincts), Spain (police forces) and Taiwan (police precincts), respectively, applying non-parametric and parametric estimation techniques. The input and output indicators used in these studies are very similar to the ones in the above-mentioned studies. With the exception of Barros and Alves (2005), all studies also analyse the influence of exogenous or environmental variables on the efficiency scores by means of second-stage Tobit- and OLS regressions. Surprisingly, none of the authors finds a significant relationship between the efficiency scores (obtained in the first stage) and the exogenous or environmental variables.

3.8 Transportation

There is also a large amount of studies which focuses on the efficiency of public transportation (like railways or buses) and related issues (like the construction or maintenance of roads). Starting with railways, one of the earlier studies in this field is Caves and Christensen (1980). The authors compare the efficiency of public and private railway companies in Canada using freight-ton-miles and passenger-miles as output indicators, and labour, structures, equipment, material and fuel as input indicators. They calculate an index of total factor productivity and show that public railway companies are not inherently less efficient than private ones. Using similar output and input indicators, Gathon and Perelman (1992), Gathon and Pestieau (1995) and Oum and Yu (1994) investigate the relationship between managerial or institutional autonomy of the railway companies and technical efficiency for a panel of railway companies in Europe (first two studies) and OECD-countries (latter study). Although all three studies use different estimation techniques, all come to the conclusion that (technical) efficiency increases with managerial or institutional autonomy. Moreover, Oum and Yu (1994) find evidence that (technical) efficiency decreases with the dependence (of the railway companies) on subsidies. The studies of Perelman and Pestieau (1988), Coelli and Perelman (1999), Farsi et al. (2005a) and Cowie and Riddington (1996), in contrast, concentrate on methodological issues also using samples of railway companies. While the first study highlights the fact that the inclusion of exogenous or environmental variables (in the production frontier) changes the ranking of the efficiency scores, the authors of the second study find evidence for high correlations among efficiency scores obtained by different (parametric and non-parametric) estimation approaches and conclude that "researchers can safely select one of these methods without too much concern for their choice having a large influence upon results" (p. 338). In contrast, Farsi et al. (2005a) show that the inefficiency estimates obtained by different stochastic frontier techniques are very sensitive to the adopted specification. Similar results are also obtained by Cowie and Riddington (1996), who apply and compare parametric and non-parametric estimation approaches.

Similar to the case of railways, Jorgensen et al. (1997), Chang and Kao (1992) and Cowie and Asenova (1999) investigate the relationship between the ownership type of bus companies and (technical) efficiency. Estimating a stochastic frontier with total costs per vehicle kilometre as an input indicator, and the number of vehicle kilometres, passengers boarding the buses and the average bus size as output indicators, Jorgensen et al. (1997) find, for a sample of 170 Norwegian bus companies, no significant differences between private and public bus companies. This stands in sharp contrast to the other two studies, which come to the conclusion that public bus companies are less efficient than private ones - using DEA. Both studies, however, use a sample of several bus firms in Taiwan and the United Kingdom, respectively, and slightly different input and output indicators. Moreover, Farsi et al. (2006b) analyse the cost efficiency of bus companies in Switzerland using and comparing different stochastic frontier models. As in their study on the efficiency of railways (see above), the authors show that the results are very sensitive to the estimation method; more specifically, they find evidence that models which do not distinguish between unobserved network effects and inefficiency are likely to overestimate the inefficiency level.

Furthermore, Chu et al. (1992) deal with the technical efficiency of bus transit agencies in the United States. By means of DEA the authors show that there are substantial inefficiencies among the transit agencies. High levels of (technical) inefficiency are also found by Thiry and

Tulkens (1992) for a sample of urban transit firms in Belgium. The study of Viton (1992), on the other hand, focuses on the measurement of economies of scope for a whole bundle of transit firms (motor-buses, railways, streetcars and trolley buses) for the United States. By estimating a stochastic frontier, evidence is found for economies of scope for all types of transit firms except for motor-buses. In a further study, Silkman and Young (1982) investigate the relationship between (technical) efficiency and grant-dependence - focusing on school bus transportation in the United States. One of their main results is that school bus transportation is more efficient in those counties which are less grant-dependent. Finally, Førsund (1992) investigates the (technical) efficiency of Norwegian ferry companies for the period from 1961 to 1988. Using wages, fuel as well as maintenance and repair cost as input indicators, and an index reflecting the capacity as well as the length run of the ferries as an output indicator, the author calculates a potential of input saving of approximately 30 percent (for the period considered).

In the past, researchers were not only interested in the measurement of the efficiency of public transportation, but also in the provision of infrastructure like the construction and maintenance of roads. Deller et al. (1988) and Chicoine et al. (1989), for example, examine the size efficiency in the production of rural roads for several US states by estimating cost functions - approximating input by total road cost and output by miles of paved and loose aggregated surfaced roads as well as miles of roads with bituminous surface. As approximations for input prices, the authors use the hourly wage rate paid to employees, prices for materials and operations required to maintain roads, and the replacement costs for road graders and single-axle trucks. Both studies find evidence for substantial size inefficiencies in the production of rural roads. Deller and Nelson (1991), Deller et al. (1992), Deller (1992), and Deller and Halstead (1994), on the other hand, investigate the (overall) technical efficiency of rural road maintenance (also for several states in in the United States). Using similar input and output indicators but different estimation techniques (stochastic frontier analysis with cost or production function approaches and non-parametric techniques), the results of the studies suggest that road maintenance costs are 14 to 50 percent higher than necessary due to production inefficiencies. In addition, Deller and Nelson (1991), and Deller (1992) find evidence that larger townships are more efficient in the production of rural road maintenance than smaller ones. Substantial inefficiencies in road maintenance are also found by Rouse et al. (1997) for a sample of 73 local authorities in New Zealand.

Finally, Hjalmarsson and Odeck (1996), and Cook et al. (1991) are concerned with the (technical) efficiency of trucks used in road construction in Norway and highway maintenance patrols in Ontario (Canada), respectively. Using driver's wage, fuel, rubber accessories and maintenance costs as input indicators, and the total transport distance as well as the effective hours in production as output indicators, the authors of the first study show by means of DEA that the mean efficiency scores of the trucks range from 0.76 to 0.88 depending on the specification used. In addition, the results suggest that neither the brand nor the age of the trucks influence efficiency. Cook et al. (1991), on the other hand, focus on the impact of privatisation on efficiency. The authors, who also use the DEA method, show that the privatisation of the highway maintenance patrols in Ontario basically did not influence (technical) efficiency.

3.9 Administrative Units

Apart from the studies which focus on the efficiency of special areas of public good provision, researchers were also interested in measuring the global performance (along with its determinants) of administrative units like municipalities or entire countries. The idea behind such *global* approaches is that restricting ones attention to one specific public good precludes a more general view on government performance. As will be seen in the following two subsections, however, such global approaches have attracted far less attention in the literature on public sector efficiency. This is mainly due to the fact that it is much more difficult to find appropriate input and output indicators for single (local) governments than for specific areas of the public sector.

3.9.1 Local Governments

The existing global approaches focusing on the performance of local governments are restricted to a rather small sample of countries. The studies of De Borger and Kerstens (1996a,b), De Borger et al. (1994), Vanden Eeckaut et al. (1993), Geys and Moesen (2009a,b), and Geys (2006), for example, investigate different aspects of technical and cost efficiency of the Belgian municipalities. With the exception of De Borger et al. (1994), all of these studies employ total expenditures of the local governments as an input indicator, and variables reflecting the (most important) responsibilities of the local governments - like the number of beneficiaries of minimal subsistence grants, the number of students enlisted in local primary schools, the surface area of public recreational facilities and municipal roads, total population, the fraction of population older than 65 or the share of municipal waste collected - as output indicators. Using a sample of 589 municipalities (for the year 1985), the first three studies show that the mean efficiency scores of the local governments in Belgium range from 0.57 (COLS) to 0.97 (FDH) depending on the estimation approach used. Therefore, De Borger and Kerstens (1996a) conclude that “focusing on just one reference technology, as most previous studies of local government efficiency have done, may be misleading” (p. 166). Moreover, the authors show by means of second-stage (Tobit) regressions that local tax rates and the level of education influence efficiency positively, whereas (average) income and (block) grants are associated with lower efficiency levels. The latter result stands in sharp contrast to Geys and Moesen (2009a), who find evidence (for a cross-section of only the Flemish municipalities) that grants from higher level governments affect efficiency positively. According to the authors this (surprising) result could be due to the fact that grants from higher level governments in Flanders are linked to strict supervision on expenditures. Moreover, Vanden Eeckaut et al.

(1993) show, for a sample of 235 municipalities of Wallonia, that political majorities are an explanatory factor for the observed inefficiencies. By decomposing the efficiency scores obtained by a FDH- and DEA-analysis into different (political) categories, the authors show that local governments run by nationwide parties are more efficient than local councils where other majorities are in power. Furthermore, local governments with multiple-party coalitions are more efficient than municipalities governed by a single party. In contrast, Geys (2006) investigates whether the efficiency indices for a sample of Flemish municipalities - obtained in a first stage by stochastic frontier analysis - form a spatial pattern across the municipalities. Using a Maximum Likelihood spatial lag model, the author confirms the existence of such neighbourhood effects in local government policies. In addition, further results show that the presence of this spatial pattern is only weakly related to the political situation in the municipalities.

Moreover, in a cross-sectional analysis, Gimenez and Prior (2007) and Balaguer-Coll et al. (2007) explore the sources of (technical) efficiency for Spanish municipalities. While Gimenez and Prior (2007) explain the efficiency scores obtained in the first stage by means of a Tobit regression, Balaguer-Coll et al. (2007) employ non-parametric smoothing techniques in the second stage. Both analyses support the findings of the above-mentioned studies: Fiscal, political and educational variables are (significantly) related to local governments' performance. Borge et al. (2008), on the other hand, examine how efficiency is related to political and budgetary institutions, fiscal capacity, and democratic participation - for a panel of Norwegian local governments. By regressing an efficiency measure defined as the ratio of an aggregate output indicator and local government revenue on a set of explanatory variables, the authors show that (technical) efficiency decreases with fiscal capacity and the degree of party fragmentation, whereas democratic participation influences efficiency positively. Moreover, the authors find evidence that a centralised top-down budgetary procedure is associated with low efficiency. Further studies which concentrate on different aspects concerning the determinants of local governments' technical or cost efficiency are provided by Worthington (2000), Loikkanen and Susiluoto (2005), Athanassopoulos and Triantis (1998), Sung (2007), Afonso and Fernandes (2008) and Grossman et al. (1999) for Australia, Finland, Greece, Korea, Portugal and the United States, respectively. With the exception of Loikkanen and Susiluoto (2005) and Grossman et al. (1999), all of these studies investigate the main drivers of efficiency by means of second-stage Tobit regressions. The other two studies either include the exogenous variables in the production frontier (Grossman et al., 1999) or use a second-stage OLS regression (Loikkanen and Susiluoto, 2005).

Investigations focusing solely on the measurement of the technical or cost efficiency of local governments are provided by Afonso and Fernandes (2006) and Grosskopf and Hayes (1993) for Portugal and the United States. While Afonso and Fernandes (2006) use DEA, the study by Grosskopf and Hayes (1993) applies Shepard-type distance functions to detect potential inefficiencies. Both studies find evidence for substantial inefficiencies among the municipalities. Finally, Sampaio De Sousa and Ramos (1999) and Sampaio De Sousa and Stosic (2005) examine the technical efficiency of Brazilian local governments for the years 1991 and 2001, respectively - employing similar input and output indicators as in the studies on Belgium. Both studies use non-parametric estimation techniques (DEA and FDH); Sampaio De Sousa and Stosic (2005) additionally apply a "Jackstrap" model (which is a combination of bootstrap and jackknife resampling methods) to reduce the effect of outliers and possible errors in the sample. The main findings of both studies are that smaller cities in Brazil tend to be less efficient than larger ones.

3.9.2 Countries

Since it is very difficult to compare the global performance of whole countries, there are only few papers which focus on the (technical) efficiency of whole countries. This is mainly due to the fact that, besides the difficulty to find appropriate input and output indicators, global approaches comparing the performance of whole countries also suffer from the heterogeneity of the public services (also with regard to the quality) provided in the different countries. The studies by Afonso et al. (2005, 2008), for example, investigate and compare the efficiency of industrialised countries and emerging markets, respectively. To approximate the output of the countries, they construct an aggregated indicator consisting of several sub-indicators which reflect important responsibilities of the countries. The input, in contrast, is approximated by the total public spending of the countries (as a percentage of GDP). Using FDH and DEA, respectively, the first study shows that small governments tend to be more efficient than large governments; one key result of the second study is that Singapore, Thailand, Cyprus, Korea, and Ireland operate very close to the best practice frontier. Moreover, by means of a second-stage Tobit regression, the authors show that efficiency increases with per capita income, education, the competence of the incumbents and the security of property rights.

Lovell (1995), Lovell et al. (1995), Brockett et al. (1999), and Henderson and Zelenyuk (2007), on the other hand, focus more on the macroeconomic performance of different countries. They all use GDP or the growth rate of GDP as an output indicator of the countries and proxies for labour and (human) capital as input indicators. Using non-parametric estimation approaches (DEA and FDH), the first two studies use a panel of OECD and Asian countries to show that the macroeconomic performance of Taiwan and Japan are best, while the Philippines and Australia are at the end of the ranking. Another important insight from the second study is that the results strongly depend on the specification used (e.g. whether environmental variables are included or not). Moreover, using a sample of 17 OECD countries from the period 1979-1988, the results of Brockett et al. (1999) point to a steady increase in the productivity growth of Japan and Finland (over this period), while the productivity growth of Ireland almost consistently decreased. The results of Henderson and Zelenyuk (2007), in contrast, suggest that developed countries are more efficient than developing countries. In both studies non-parametric estimation approaches are applied. Finally, Maudos et al. (2003)

investigate the role of human capital in productivity gains by breaking down the productivity gains into technical change and efficiency gains - using non-parametric approaches and stochastic frontier analysis for a panel of 23 OECD countries. Their results point to a positive relationship between the growth rates of the OECD countries and human capital.

3.10 Conclusion

To sum up, while the technical or cost efficiency of public goods provision attracted much attention in the last decades, the bulk of studies focuses on the efficiency of the health care sector (in particular hospitals). Apart from the health care sector, there are also numerous studies on the efficiency of educational institutions, energy supply companies, and public transportation. Another striking fact is that in the above-mentioned sectors (with the exception of public transportation) the authors mostly concentrated on the United States. In contrast, the remaining areas (culture, public facilities, security) attracted far less attention. In addition, investigations on the global performance of local governments or countries are, compared to the studies on specific areas of public good provision, relatively rare. As already mentioned at the beginning of this chapter, this is mainly due to the fact that it is more difficult to find adequate input and output indicators for (whole) governments than for specific sectors of the governments.

Moreover, the literature review shows that researchers investigated the technical or cost efficiency of governments or public institutions and companies mostly by means of non-parametric and parametric estimation approaches. The bulk of studies, however, employs the non-parametric Data Envelopment Analysis to detect potential inefficiencies of public goods provision. Here, researchers also suggested numerous variants and extensions (e.g. the incorporation of non-discretionary inputs and outputs in the linear programming model) to minimise potential measurement errors. Of all the parametric estimation approaches, the majority of researchers chose to apply the stochastic frontier analysis. Concerning the main drivers of technical or cost efficiency of public goods provision, researchers mostly employed the “traditional” two-step procedures. This means that, in a first stage, they calculate efficiency scores by means of a non-parametric or parametric estimation technique and, afterwards, they regress the efficiency scores on the potential determinants via a Tobit- or OLS regression. The one-step approach (in the stochastic frontier analysis) proposed by Battese and Coelli (1995) or the truncated regression along with the bootstrapping correction (in the Data Envelopment Analysis) proposed by Simar and Wilson (2007), however, have only been used in a few analyses so far.

Finally, the literature review reveals that there are only few studies on the efficiency of the German public sector. In fact, there are merely three studies on the efficiency of German universities (Fandel, 2007; Kempkes and Pohl, 2008, 2009), and one study on the efficiency of electricity distribution utilities (Von Hirschhausen et al., 2006), hospitals (Staat, 2006) as well as water supply utilities (Haug, 2008), respectively. Therefore, in the next chapter, some of the estimation techniques explained in chapter 2 are applied to investigate different aspects of German local governments' technical and cost efficiency. The focus will thereby lie on the local governments as a whole as well as on one specific area of public good provision: the construction and maintenance of (county) roads.

Chapter 4

Applications to German Local Governments

4.1 Introduction

In this chapter some of the methods derived in chapter 2 will be employed to investigate different aspects of the (cost) efficiency of local governments in Germany. More specifically, section 4.3 focuses on the cost efficiency of German municipalities and relates the results to the negative demographic change which will take place within the next decades in Germany. In section 4.4 and 4.5, in contrast, the relationship between intergovernmental grants and cost efficiency, on the one hand, as well as voter involvement (in political processes), fiscal autonomy and cost efficiency, on the other hand, is analysed. In both sections the focus lies again on German municipalities. Finally, section 4.6 focuses on the main drivers of efficiency of one specific area of public good provision: the construction and maintenance of county roads in Germany.

All sections share the common feature that they use the local governments (either the municipalities or counties) of the German state *Baden-Württemberg* as data base (mostly in a panel context).[1] Moreover, all applications employ the (parametric) one-step approach proposed by Battese and Coelli (1995) (see also section 2.5), whereas the total expenditures of the municipalities and the expenditures for the county roads are used as input indicators. This, in turn, implies that the applications are based on stochastic cost rather than production frontiers. The determinants of efficiency in the construction and maintenance of county roads in section 4.6 are additionally examined by using the two-stage procedure proposed by Simar and Wilson (2007) (see also section 2.3).

However, before presenting the results along with the underlying data sets and estimation equations, the institutional setting of the German local governments in Baden-Württemberg will be provided. This is necessary in order to clarify the context of local public decision making in Germany.

[1]For more information on the sources of the data, see Appendix A.

4.2 Institutional Setting of the Local Governments in Germany

Germany is characterised by a federal structure consisting of a federal state (*Bund*), states (*Länder*) and local governments (*Kreise und Gemeinden*). The state considered here, Baden-Württemberg, lies in the southwest of Germany (bordering France and Switzerland) and is the third largest of the 16 states - both in terms of its surface area (circa 35.8 square kilometres) and its number of inhabitants (currently circa 10.7 million). The local governments, in turn, can basically be divided into two administrative units: counties and municipalities, whereas the counties constitute the higher administrative level. More specifically, we can distinguish between rural (*Landkreise*) and urban (*Stadtkreise*) counties. The former are associations of a fixed number of municipalities, the latter consist of only one municipality (city), and therefore are county and municipality at the same time. Baden-Württemberg consists of 35 rural and 9 urban counties as well as 1102 municipalities (including the nine urban counties).[2] According to the (German) Basic Law (*Grundgesetz*) both administrative units (counties and municipalities) are guaranteed the right to local self-government (art. 28, para. 2).[3] Therefore, counties as well as municipalities exhibit considerable autonomy on the revenue as well as the expenditure side.

4.2.1 Political System

The institutional setting of the local governments is the same in all municipalities and counties of Baden-Württemberg.[4] Starting with the municipalities (including the urban counties), the local governments of each of these municipalities basically are composed of two (municipal) political institutions: (1) The municipal council (*Gemeinderat*) which is elected every five years and constitutes the main decision-making body of the municipalties, and (2) the mayor (*Bürgermeister*) who is directly elected (by the citizens of the municipalities) for an eight-year term. The election of the mayor is held in two ballots, whereas in the first ballot the absolute and in the second ballot the relative majority is needed. Moreover, the mayor acts as the chairman of the municipal council and has also significant agenda-setting powers. Both institutions, council and mayor, are independent of each other and have their own statutory responsibilities.

The institutional setting on the county level is basically very similar to the one described above. The rural counties are governed by a county council (*Kreistag*) (elected by the citizens of the counties for five years), and a "county administrator" (*Landrat*) who, again, acts as the

[2]From 1975 to 2005 Baden-Württemberg consisted of 1111 municipalities. In 2006, 2007 and 2009, however, several municipalities merged and the number of municipalities decreased to 1102.

[3]For more information on the statutory details, see e.g. Gern (2005).

[4]The statutory base of the institutional setting of the municipalities and rural counties constitutes the local codes (of Baden-Württemberg) of the municipalities (*Gemeindeordnung*) as well as the rural counties (*Landkreisordnung*), respectively.

chairman of the county council. In contrast to the mayor, however, the county administrator is not directly elected by the citizens, but by the members of the county council (for an eight-year term). Moreover, the successful candidate has to win an absolute majority in both ballots, the first and the second one; in the event of a tied vote, the election will be decided by drawing lots. As above, both institutions, council and county administrator, are independent of each other and have their own statutory responsibilities. Finally, it should be mentioned that, contrary to the state or federal level, the formation of governing majorities within the local councils (municipal or county councils) is not institutionalised in the local codes of Baden-Württemberg. Nevertheless, their existence is uncontested. These inter-party cooperations are used to facilitate and, to a certain extend, control the formation of opinions and decision-making.[5]

Turning now to the election results, it should first be noted that Baden-Württemberg - at the state level - is a traditional stronghold of the Christian Democrats (CDU). Since the state's inception in 1952, the state government has generally been led by CDU prime ministers, often as one-party governments (the sole exception is the 1952-1953 government under the liberal prime-minister Reinhold Maier). On the municipal as well as county level, the CDU has been almost equally dominant - as can be seen from table 4.1 which shows the results of the local council elections in Baden-Württemberg of the last decades. Still, unlike state or federal elections, local elections in Baden-Württemberg are also characterised by the increasing importance of so-called "free voters' unions" (*Freie Wählervereinigungen*). The latter can be seen as an indicator of local voter involvement. The reason is that they are a grassroots type of organisation that is the result of local initiatives. They are not linked to one of the traditional political ideologies and even explicitly reject the idea of constituting a political party. Furthermore, there is no national organisation of free voters that initiates the foundation of free voter unions at the local level. While in some cases they do form networks at the state level, these local groups are independent (and tend to focus on specific affairs within their municipality or county).[6]

4.2.2 Financial System

Though the local governments constitute the lowest level of government in Germany, they have considerable autonomy in raising revenue (especially the municipalities). Indeed, the local governments are able to pursue any politics that benefit the interest of the inhabitants (art. 28, para. 2, Basic Law). This autonomy (or self-administration) is also reflected in the revenue structure of the local governments. Figures 4.1 and 4.2 show the structure of

[5]For more details on the institutional setting of the municipalities and counties, see e.g. Bock (2004) and Neser (2004), respectively.

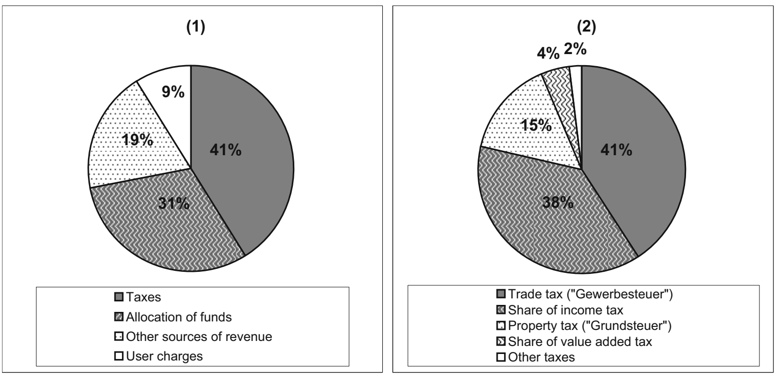
[6]Free voters' unions can also be seen as a response to bad polities of the past. But even then, these initiatives can be regarded as an indicator of higher voter involvement since dissatisfied citizens now actively participate in politics and get involved in political process in order to change something. This issue, however, will be discussed in section 4.5 in more details.

Table 4.1: Results of the local council elections in Baden-Württemberg from 1975 to 2004 (as a percentage of valid votes)

Party	**Election Year**						
	1975[a]	1980[a]	1984	1989	1994	1999	2004
	Municipal Level						
CDU (Christian Democrats)	38.9	39.6	37.9	32.6	31.6	36	33.2
SPD (Social Democrats)	29.2	30.2	26.3	25.6	24.1	21.7	19.9
FDP/DVP (Liberals)	5.5	5.3	3.9	4.6	3.5	3	3.7
GRÜNE (Greens)	-	1.7	6.3	5.9	7.7	5.2	8.2
Wählervereinigungen (Voters' unions)	19.9	18.3	21.6	23.6	26.6	27.5	29.4
Other	6.5	4.9	4	7.7	6.5	6.6	5.6
	County Level						
CDU (Christian Democrats)	44.9	44.8	41.2	36.6	34.6	39.6	37.6
SPD (Social Democrats)	28.1	29.6	24.9	24.8	23.7	21.6	19.4
FDP/DVP (Liberals)	5.7	5.2	4.5	4.8	4	4	5.5
GRÜNE (Greens)	-	0.7	9.6	9.1	11	7.8	10.3
Wählervereinigungen (Voters' unions)	14.8	13.5	16	19.1	20.1	22.1	22.9
Other	6.5	6.2	3.8	5.6	6.6	4.9	4.3

Source: Statistical Office of Baden-Württemberg
[a] The elections on the county level were held in 1973 and 1979, respectively.

Figure 4.1: Structure of the total revenue (1) and composition of the tax revenue (2) of the municipalities in Baden-Württemberg in 2004



Source: Ministry of Finance of Baden-Württemberg (2006)
Note: Other sources of income include administrative income, shares in profits, concession levy, reimbursement of costs and capital gains. Payments between the municipalities and imputed costs are not included.

Table 4.2: Intergovernmental grants of Baden-Württemberg's municipalities in 2004

Type of grant	**Mio. €**	**Per capita**
Key grants	2110.04	197.47
Grants for current expenditures	1372.82	128.48
Grants for investments and investment assistance	649.14	60.75
Grants for municipalities with special financial requirements	1.09	0.10
Other general grants	454.19	42.15
Sum	4587.28	429.31

Source: Statistical Office of Baden-Württemberg, own calculations

the main income sources of the municipalities and counties, respectively. Starting with the municipalities, figure 4.1 (1) reveals that revenues basically derive from three main sources: tax revenue (41% of total revenue in 2004), allocation of funds (through, for example, fiscal equalisation schemes; 31%), and revenue from user charges (for services like the disposal of waste; 9%). Among the tax revenues, however, a substantial part (i.e. 42%) originates from shared taxes (i.e. income and value added tax; see figure 4.1 (2)) decided upon by the federal and state-level governments. More specifically, the municipalities receive 15% of the income tax revenue and 12% of the revenue from the tax on capital income generated in Baden-Württemberg as well as 2.2% of the value added tax revenue. Apart from the shared taxes, the municipalities can independently decide on five types of taxes: trade tax (*Gewerbesteuer*), property tax (*Grundsteuer*), tax on keeping dogs, second residence tax and entertainment tax, whereas the last three taxes are not raised by all municipalities. Figure 4.1 (2) shows that only the first two of these taxes yield significant revenues (41% and 15% of total tax revenue, respectively).[7]

With respect to the allocation of funds, the German municipal system of fiscal equalisation incorporates both vertical and horizontal elements, whereas all transfers within this equalisation system are regulated by law (*Finanzausgleichsgesetz - FAG*).[8] The vertical equalisation is concerned with the financial relationships between the state (of Baden-Württemberg) and its local authorities (municipalities and counties); the state has to ensure that the local authorities are able to perform their tasks. In contrast, the horizontal equalisation serves to balance differences in the fiscal capacity (*Finanzkraft*) among the local authorities. This is necessary since the revenue of the municipalities (especially from the trade tax) and counties can vary substantially among each other. The most important element of the fiscal equalisation system, however, constitutes the so-called fiscal equalisation mass (*Finanzausgleichsmasse*) which is financed by both, the state as well as the municipalities and counties. Within a formula based system this fiscal equalisation mass is distributed to the local governments, whereas jurisdictions with lower fiscal capacity receive more grants from the fiscal equalisation mass.

[7]Nevertheless, the most important autonomous tax source - the trade tax - is not paid by the citizens of the municipalities in general, but only by larger local firms (smaller firms are tax-exempt due to tax thresholds).

[8]The following explanations are mainly based on Ministry of Finance of Baden-Württemberg (2006).

Table 4.3: Baden-Württemberg's municipalities according to their fiscal capacity in 2004

Type of municipality	**Number**	**% of all municipalities**
Abundant	104	9.36
Financially weak	737	66.34
Financially very weak	270	24.30
Total	1111	

Source: Statistical Office of Baden-Württemberg, own calculations

The different types of grants received by the municipalities of Baden-Württemberg in the fiscal year 2004 are shown in table 4.2. As can be seen from this table, roughly 50% of the fiscal equalisation mass are distributed via so-called key grants (*Schlüsselzuweisungen*) which are lump-sum transfers established according to a predetermined formula ("key").

One basic idea of the key grants is to equate the differences in revenue (among the local authorities) by comparing fiscal capacity and fiscal needs (*Finanzbedarf*) of the local governments.[9] On the basis of this comparison, three different types of municipalities can be distinguished: (1) If fiscal capacity exceeds fiscal needs, the jurisdiction is said to be "abundant" and obtains no key grants, (2) in case fiscal capacity lies between 60% and 100% of fiscal needs, the municipality is called "financially weak", and (3) municipalities with a fiscal capacity of less than 60% of fiscal needs are said to be "financially very weak". Of course the (key) grants are highest for the last category.[10] The distribution of the municipalities' financial power in 2004 is depicted in table 4.3 above. There it is shown that most municipalities fall under the category "financially weak" whereas only a small fraction is "abundant".

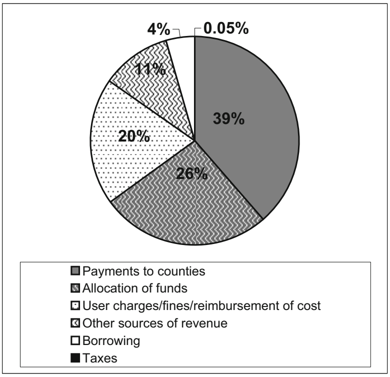
To sum up, it can be stated that revenues from fiscal equalisation schemes and shared taxes constitute about half of the municipal revenue. Hence, though some leeway exists for generating own revenues, the extensive tax sharing and fiscal equalisation payments limit the budgetary autonomy and responsibility of the municipalities.

Turning now to the counties, figure 4.2 reveals that - in contrast to the municipalities (including the urban counties) - rural counties have no significant income from autonomously raised taxes. The only tax levied by the rural counties is a tax on hunting; in addition, the counties (both rural and urban) receive 55.5% of the land transfer tax (*Grunderwerbsteuer*)

[9]In case of the municipalities, the fiscal capacity is calculated by adding the municipalities' different tax revenues and the key grants received two years ago, whereas fiscal needs are established by the product of a predetermined per capita sum (*Kopfbetrag*) and the number of inhabitants (of each municipality). For the counties, the procedure is very similar.

[10]In section 4.5, this distinction will be used to create an indicator of the fiscal autonomy of the municipalities. More specifically, it is distinguished between abundant municipalities, which obtain no key grants and non-abundant municipalities, which obtain key grants (including financially weak and very weak municipalities). It should be noted, however, that the classification of a municipality as abundant and non-abundant can change due to parameter changes of the fiscal equalisation scheme. If, for example, the predetermined per capita sum is increased, some of the abundant municipalities can become non-abundant. On the other hand, an increase in the state-wide uniform collections rates (*Anrechnungshebesätze*) (which are used to determine the fiscal capacity of a municipality) would make some of the non-abundant municipalities abundant. The choice of abundant and non-abundant municipalities as indicators for the degree of fiscal autonomy is therefore rather a relative than an absolute concept.

Figure 4.2: Structure of the total revenue of the rural counties in Baden-Württemberg in 2004



Source: Statistical Office of Baden-Württemberg, own calculation
Note: Other sources of income include income from interest, shares in profits, concession levy, capital gains and cost-accounting depreciation.

levied by the state. As can be seen from figure 4.2, however, both taxes yield only 0.05% of total revenue and are therefore negligibly small. The main income source of the counties rather derives from the so-called "payments to the counties" (*Kreisumlage*; 39% of total revenue in 2004). The rural counties are able to levy theses contributions from their municipalities if the other revenues (user charges, allocations of funds,...) are not sufficient to cover costs. More specifically, the size of the payments to the counties is based on a predetermined collection rate (*Hebesatz*) on the sum of the different (tax) revenues of the municipalities belonging to the rural county.[11] Therefore, the payments to the counties can be interpreted as a kind of "tax" on the revenues of the municipalities.[12] Finally, as in the case of the municipalities, a major part of the budget also derives from allocation of funds through fiscal equalisation schemes (as described above; 26%) and from user charges, fines, and reimbursement of costs (20%).

4.2.3 Tasks of the Local Governments

Basically, the revenue obtained by the municipalities as well as the counties serves to finance three types of tasks.[13] Firstly, the local governments face *voluntary tasks*, which can be

[11]Note that the collection rates can differ from county to county. While the average collection rates amounted to approximately 20% in the 1970s and 1980s, they steadily increased in the 1990s. In 2004, the average collection rate was 33.62%. Therefore, the payments to the counties are a further financial burden for the municipalities. For more details on this issue, see Neser (2004).

[12]The difference between the payments to the counties and "usual" taxes is that the payments to the counties are not paid by the citizens (of the jurisdictions) themselves but by the municipal governments belonging to the rural counties.

[13]A more detailed classification and description of these tasks is given e.g. in Gern (2005) and Neser (2004).

performed by the local governments; they are, however, not obliged to perform these tasks. Examples are cultural affairs (e.g. library, museum), social affairs (e.g. residential home for the elderly), sport facilities (e.g. public swimming pools), recreational facilities (e.g. parks, hiking trails), traffic facilities (e.g. bus, tram, cycle paths), adult education centres, school exchange, local business development, etc. The second type of tasks can be labelled as *duties without instruction*. These have to be performed by the local governments, but do not involve detailed prescriptions imposed by a higher-level government (e.g. the state) as to how to perform these tasks. Examples for tasks in this category are the lighting and cleaning of (municipal and county) roads, playgrounds, fire service, public transportation, the construction and maintenance of municipal and county roads, and so on. Finally, there are *duties with instruction*. While local governments are obliged to perform these tasks, the state imposes detailed regulations on how municipalities and counties should perform them. In other words, the implementation of these tasks is predetermined by the state. On the municipal level, the management of local police authorities would be an example for duties with instruction, while the payment of housing benefits represents an example on the county level.

Table 4.4 provides a detailed overview of the money spent on the different types of tasks by the municipalities and counties, respectively, for the year 2004 - using the classification of functions as given in Baden-Württemberg's administrative regulation on the local authorities' budgets (*Verwaltungsvorschrift über die Gliederung und Gruppierung der Haushalte der Kommunen*). It is clear, that general financial management which includes, among other things, interest and amortization repayments, accounts for the bulk of total expenditures, whereas the share is on the municipal level much higher than on the county level (circa 35% compared to 26%). Moreover, it is striking that the counties spend almost one third of their money on social security. In contrast, social security accounts for only approximately 11% of the municipalities' total expenditures. Major parts of the budget are also spent on public facilities and business development (approximately 11%, respectively), schools (counties; approximately 11%), and architecture, housing and traffic (municipalities; approximately 10%). The remaining posts on the budget are somewhat smaller, whereas public safety as well as science, research and culture constitute the smallest parts of the budget on the municipal level (approximately 3%, respectively), and science, research and culture as well as commercial companies and real and separate estates on the county level (circa 0.5% respectively).

Table 4.4: Total expenditures of the local governments - per capita and as a percentage of total expenditure - for selected areas of public goods provision in 2004

Class. Number	**Scope of functions**	**Expenditure (in € per capita)**	**Share of total expenditure (in %)**
	Municipal Level		
0	General Administration	191.85	7.85
1	Public Safety	75.99	3.11
2	Schools	161.90	6.61
3	Science, Research, Culture	89.66	3.67
4	Social Security	280.76	11.49
5	Health, Sport, Recovery	127.28	5.20
6	Architecture, Housing, Traffic	241.45	9.89
7	Public Facilities, Business Development	277.95	11.36
8	Commercial Companies, Real and Separate Estate	153.48	6.28
9	General Financial Management	844.14	34.55
	County Level		
0	General Administration	42.45	7.73
1	Public Safety	23.72	4.32
2	Schools	57.81	10.53
3	Science, Research, Culture	3.88	0.71
4	Social Security	174.80	31.83
5	Health, Sport, Recovery	17.14	3.12
6	Architecture, Housing, Traffic	22.31	4.06
7	Public Facilities, Business Development	62.62	11.40
8	Commercial Companies, Real and Separate Estate	1.59	0.29
9	General Financial Management	142.89	26.02

Source: Statistical Office of Baden-Württemberg, own calculations

4.3 Demographic Change, Economies of Scale and Efficiency

4.3.1 Introduction

Even when immigration is taken into account, the German population has been in decline since 2003 (Federal Statistical Office of Germany, 2006b). Moreover, this trend is expected to continue in the upcoming decades. In fact, depending on the specific assumptions made concerning migration, fertility, and mortality, the German population is predicted to tumble from the current 82 million inhabitants to roughly 69-74 million in 2050 (Federal Statistical Office of Germany, 2006a). This negative population trend is not restricted to Germany. Within the EU27, several other - mainly central and eastern European - countries are expected to see their population decrease between now and 2050. Regarding the period between 2025 and 2050, this trend is even more prevalent. Indeed, in that time period, all but 8 countries in the EU27 (i.e. Belgium, France, Ireland, Cyprus, Luxemburg, Malta, Sweden and UK) are expected to witness population reductions (Eurostat, 2006).

Such - often drastic - falls in population size are unlikely to leave public finances unaffected. Indeed, fiscal revenues are likely to be negatively affected - if only because there are simply less residents to pay taxes. Furthermore, to the extent that the population decline in most Western countries is accompanied by increased population aging (putting upward pressure on public expenditures), a significant strain on government budgets is probable. In line with this, "many Europeans view population decline and aging as threats to national influence and the welfare state" (Van de Kaa, 1987, p. 1).

Interestingly, most studies thus far focus on the effects of demographic change in terms of population aging rather than population decline (e.g. Jackson and Felmingham, 2002; Bloom and Canning, 2004; Seitz et al., 2007). Moreover, the majority of studies on demographic change concentrate on the effects at the country - or even global - level (e.g. Bloom and Canning, 2004; Batini et al., 2006). However, as mentioned above, demographic change is not limited to changes in the age distribution (e.g. increasing share of individuals over 65), but can also refer to variations in population size. Furthermore, the effects of demographic change (whether in terms of aging or decline) are unlikely to be constrained to the national level. Indeed, regional and local governments are also susceptible to its implications since "the lived experience of population ageing [and decline] will be played out at the level of local rather than national government" (Jackson, 2004, p. 101). Hence, an exclusive focus on the national level is unwarranted and, moreover, fails to notice possible differences across regions within a country (see Jackson and Felmingham, 2002). The following analysis attempts to address both these elements. That is, the focus is on (i) the local level of government and (ii) population decline rather than aging. While the policy relevance of such research is evident, it has to date received only limited attention. In fact, only one study has thus far attempted to assess the impact of population decline on local government operations (Felmingham et al., 2002).

The analysis proceeds in two steps - using data on 1022 municipalities of Baden-Württemberg. Firstly, the efficiency of the local governments in the year 2001 is examined; this part of the analysis builds on the idea that one can expect more efficient governments to be better able to adequately address adverse economic, fiscal or demographic shocks. Still, currently inefficient governments may have a certain leeway to address such problems (simply by improving their performance). The overall level of efficiency of the local governments as well as the degree of heterogeneity therein across municipalities thus provides an indication of the likely strain of future demographic decline on municipal operations - and which municipalities might suffer harder from these adverse demographic shocks. While this study is not the first to analyse local government efficiency,[14] it is the first study that attempts to provide such an assessment for German local governments.

Secondly, the properties of the municipalities' cost functions with respect to the impact of population size (i.e. *scale elasticities*) are investigated. Given that German municipalities generally have to expect substantial losses of population in the coming decades, it would be useful to know whether the cost of producing public goods is likely to decline at the same, slower or faster pace. In the case of slower cost decline, significant strain on local public budgets is to be expected. More importantly, by regarding the elasticity of costs to population size for various clusters of municipalities (with divisions based on population size), it is possible to find out which type of municipalities (i.e. large, medium or small) is most sensitive to population changes.

This section is organised as follows. In the next subsection the results of the efficiency analysis along with the estimation approach and underlying data set are presented. Subsection 4.3.3 investigates the scale efficiencies in the provision of public goods for the local governments and, finally, conclusions are drawn in subsection 4.3.4.

4.3.2 Local Government Efficiency

Efficiency in the production of public services is one degree of freedom in local governments' policy agenda to counteract the fiscal pressure arising from population ageing and decline. Hence, the measurement of efficiency in local public goods production is a logical first empirical step to assess the impact of these demographic changes on local public finances; moreover, it has a double function: First, it lays the methodological basis to study the link between population size and cost pressure in subsection 4.3.3. Second, it allows a first look at the extent to which municipalities might be able to respond to adverse economic, fiscal, or demographic shocks. Low efficiency scores for municipalities today should therefore not be (exclusively) interpreted as leeway for cost savings tomorrow once population shrinkage occurs. This would effectively be rather naive. On the contrary, current inefficiencies are more likely to

[14]For a review, see chapter 3 or table C.1 of Appendix C.

hint at poor (historical) performance in terms of adjusting service production to a changing environment and an inability to provide public services in the least costly way. Public entities that are currently inefficient may therefore be expected to be particularly severely hit by the changing size and structure of their population.

Estimation Approach and Data

As already mentioned at the beginning of this chapter, the (parametric) one-step approach developed by Battese and Coelli (1995)[15] is employed to determine the efficiency levels of 1022 of the 1102 municipalities of Baden-Württemberg for the year 2001 (data availability precluding the inclusion of the remaining municipalities). In order to determine which input, output, and exogenous variables to include in the analysis, the previous literature studying local government efficiency was consulted.[16] Following this "common standard" has the advantage that the results are to some extent comparable with these studies. As prime input variable, total net current primary expenditures of the municipalities in 2001 are employed. These include all spending on the current budget minus the difference between interest as well as amortisation repayments and income form interest. Spending from the capital budget is ignored as decisions to invest in large infrastructure projects are infrequent events and thus tend to inflate spending in the year they occur. Given the cross-sectional nature of the analysis, the focus on the current budget avoids distortions resulting from fluctuating investments.

To measure the level of local public goods provision, six output variables are included that relate to important responsibilities of the German local governments with respect to educational, recreational, infrastructural, social and economic services: (i) the number of students in local public schools (*Grund- und Hauptschulen*), (ii) the number of kindergarten places,[17] (iii) the surface of public recreational facilities, (iv) total population,[18] (v) the share of population older than 65, and (vi) the number of employees paying social security contributions. Unfortunately, data on factor prices are not available. Factor price divergence, however, does not substantially affect the application since the costs of labour and capital are identical for the municipalities of Baden-Württemberg (i.e. they face the same interest rates and wages). Interest rate homogeneity is given by the fact that a) all municipalities have access to the same capital market, and b) the federal government guarantees the absence of differences in

[15]For more details on the methodology, see chapter 2.

[16]For a review, see subsection 3.9.1 and table C.1 of Appendix C.

[17]Note, that only the total number of public and private kindergarten places was available - and only for the year 2002. While it would clearly be preferable to only use the number of public kindergarten places, such data were not available. Nevertehless, public kindergarten places accounted for 43% of all kindergarten places in 2002.

[18]Population is a key variable in the context of demographic change and expected population losses. Indeed, a population coefficient in the cost function significantly below one would hint at increasing economies of (population) scale and, hence, towards the threat of increasing cost pressure with a declining number of inhabitants. This issue, however, will be discussed in greater detail in the next subsection.

Table 4.5: Descriptive Statistics

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**
Input variable:				
Net current primary expenditures (in mio. €)	19.60	69.90	0.36	1690.00
Output variables:				
Students in public schools	649.25	1292.28	0	26342
Kindergarten places	401.77	804.43	25	17195
Recovery area (in are)	2399.13	5785.49	0	107540
Total population	10185.59	26255.55	237	583843
Share of population older than 65	15.56	2.36	8.26	26.80
Number of social insured employees (at place of work)	3749.57	14912.27	8	353801
Other control variables:				
Unemployment rate (in %)	5.18	1.02	2.60	10.38
Population density (inhabitants per hectare)	3.27	3.28	0.22	28.16
Accommodation facilities	6.57	11.79	0	146
Herfindahl index	0.53	0.25	0.22	1
Share of left-wing parties (in %)	16.47	14.20	0	65

Sample size: 1022 municipalities of the year 2001.

risk premiums for all German jurisdictions. Identical wages are guaranteed via a uniform collective labour agreement.[19]

Finally, exogenous variables are included in the model: variables describing the municipalities' production environment and political variables. The former is accounted for by including population density, the unemployment rate, and the number of accommodation facilities (in the municipalities). Population density proxies the rural/urban divide and is included, since it can influence the ability of the authority to concentrate provision of the local public services (Stevens, 2005). Furthermore, it proxies the heterogeneity of property prices, which tend to differ substantially between rural and urban municipalities (and may thereby affect the cost situation of municipalities). While high population density might entail cost advantages due to regional concentration of services, higher property costs in urban areas (and other problems of agglomeration) may render production more costly. The overall effect on the level of the municipalities' expenditures is therefore ambiguous. A similar ambiguity emerges for the unemployment rate since, on the one hand, it implies higher spending on unemployment and housing benefits (a "cost effect") and, on the other hand, lower demand for high-cost (or high-quality) public services - demand for which is likely to increase with income levels (a "preference effect"). Finally, the number of accommodation facilities is included under the argument that municipalities located in touristic regions (like the Black Forest or the

[19]Note, however, that in 2005 a new collective wage agreement for public service at the local level (*Tarifvertrag für den öffentlichen Dienst der Kommunen*) became effective, which allows for performance-oriented wages.

region around Lake Constance) have a higher demand for high-quality public services (see Sampaio De Sousa and Stosic, 2005). An increase in the number of accommodation facilities is therefore expected to increase costs.

As political variables, a Herfindahl index and the share of seats of left-wing parties in the municipal council is included. The Herfindahl index measures the political concentration or monopolisation in the municipal council; it is calculated using the squared share of seats of the main national parties (from right to left: CDU, FDP, SPD and GRÜNE) as well as the free voters' unions in the municipal council. High concentration (or low fragmentation) represents low political competition and should therefore reduce efficiency (see Ashworth et al., 2006). The latter variable, in contrast, measures the impact of ideology on cost efficiency. This ideological effect, however, is not easy to determine a priori. While left-wing parties are often assumed to prefer a larger government size, this does not necessarily imply less efficient governments. The descriptive statistics of all variables are shown in table 4.5.

Given the above input (C_i), output (y_i) and exogenous (z_i) variables, the model to be estimated can be written as (using a translogarithmic cost frontier):[20]

$$\ln C_i = \beta_0 + \sum_{r=1}^{6} \beta_r \ln y_{r,i} + \frac{1}{2} \sum_{r=1}^{6} \sum_{q=1}^{6} \beta_{r,q} \ln y_{r,i} \ln y_{q,i} + v_i + u_i. \quad (4.1)$$

$$u_i = \delta_0 + \sum_{j=1}^{5} \delta_j z_{j,i} + w_i, \quad i = 1, ..., 1022. \quad (4.2)$$

Results

The summary statistics on the cost efficiency estimates of the local governments are given in table 4.6. As can be seen from the table two models are estimated. The first model disregards the effect of the exogenous variables and could be seen as a "baseline" model (columns 1 and 3); in contrast, the second model includes all exogenous variables (columns 2 and 4). In each case, both a Cobb-Douglas and translogarithmic cost frontier is estimated in order to assess whether the addition of squared values and cross-product terms for the output variables improves the fit of the estimation. In addition, note that, by definition, the municipalities lying on the best practice frontier reach efficiency scores of one; the other less efficient exhibit efficiency scores that are bigger than one.

A closer look at table 4.6 reveals that disregarding the exogenous variables yields cost levels of the local governments which are approximately 21% to 24% above the efficient frontier (columns 1 and 3). But once the exogenous variables are included in the estimation,

[20] A complete coverage of all relevant y_i and z_i would be necessary to derive the real extent of inefficiency - and the possible cost cuts given the municipalities' output. As data limitations are likely to make this unattainable, we must be cautious when equating observed "inefficiencies" with realisable cost savings. Nevertheless, even with an incomplete coverage, u_i offers valuable insights into the municipalities' "value for money". These subtleties should, however, be kept in mind when speaking about inefficiencies in the following analysis.

Table 4.6: Summary statistics on the cost efficiency of the local governments in Baden-Württemberg in 2001

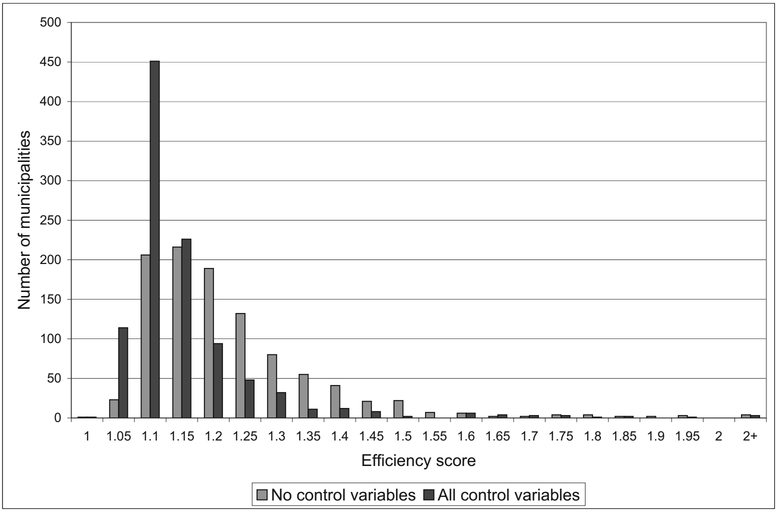
	Cobb-Douglas		**Translog**	
	No control variables	All control variables	No control variables	All control variables
	(1)	(2)	(3)	(4)
Average	1.2350	1.1551	1.2050	1.1294
Standard deviation	0.2147	0.1978	0.1662	0.1466
Minimum	1	1	1	1
Maximum	4.6531	4.8084	3.6781	3.7993
Number efficient	1	1	1	1

inefficiency substantially declines - as expected. Still, costs remain roughly 13% to 16% above the efficient level (columns 2 and 4). Although, as explained above, we should be cautious to equate these inefficiencies with potential cost cuts, it should be kept in mind that the frontier generated by the sample of municipalities will by construction be at least as high as the "true" frontier. This implies that the efficiency ratings provided in table 4.6 are best regarded as a lower limit of true inefficiency.

With respect to the main research question of this section (i.e. the expected effect of predicted demographic decline) it is clear that the local governments show a substantial heterogeneity with regard to their "value for money" - as represented by the standard deviations of the efficiency scores in table 4.6. The variation in the efficiency indices is also represented in figure 4.3. This histogram shows the number of municipalities (on the y-axis) with a given level of inefficiency (on the x-axis), using the results from the translogarithmic specifications. Light-grey cubes are inefficiency scores without including exogenous variables, black cubes represent inefficiency scores when controlling for all of the above mentioned exogenous variables.

It is clear from figure 4.3 that the distribution of inefficiency has a large right-hand tail. Most municipalities have a limited degree of inefficiency, though some are deemed to be very inefficient. This suggests that at least some municipalities have only limited flexibility in addressing adverse economic, fiscal, or demographic shocks and are likely to suffer quite strongly under the generally expected demographic decline. Although a more positive reading of our results might suggest that currently inefficient municipalities have some leeway for improvements in efficiency without resorting to politically costly tax increases, it remains doubtful whether such municipalities would be able to increase their efficiency under adverse conditions. If the municipalities remain equally efficient in the future, public finances are likely to become more severely constrained in inefficient municipalities when their population (and thereby a main source of (tax) revenue) declines. Not shown in the figure is that mainly the smaller municipalities (especially those under 3,000 inhabitants) are found to be

Figure 4.3: Baden-Württemberg local governments' cost inefficiency in 2001



Note: Results are based on the translogarithmic cost function.

relatively inefficient, while municipalities between approximately 6,000 and 9,000 inhabitants are deemed most efficient.

Before we conclude this subsection, it may be of interest to point to the findings of the exogenous variables included in the model which are provided in table B.1 of Appendix B. Turning first to the municipalities' production environment, table B.1 shows that the unemployment rate has a highly statistically significant negative sign, suggesting that the preference effect (i.e. relating to lower demand for high quality public goods among the unemployed) outweighs the cost effect (i.e. higher spending on unemployment benefits). Population density, on the other hand, significantly increases costs indicating that cost disadvantages resulting from, say, higher property prices outweigh agglomeration advantages. Moreover, the (statistically significant) positive effect of the accommodation facilities is in line with our theoretical expectations and indicates that more touristic regions have a higher demand for high-quality services. Finally, concerning the political variables, the Herfindahl index significantly reduces efficiency suggesting that high levels of political concentration or monopolisation are associated with low efficiency. On the other hand, an increasing share of seats of left-wing parties in the local council seems to increase efficiency. The coefficient, however, is only significant in the translogarithmic specification.

Table 4.7: Classes of population size for the different regressions

	Class size (inhabitants in tsd)				
	0-2	2-4	4-6	6-10	>10
	small		*medium-sized*		*large*
Number of municipalities in each class	124	290	196	166	246
In % of all considered municipalities	12.13	28.38	19.18	16.24	24.07

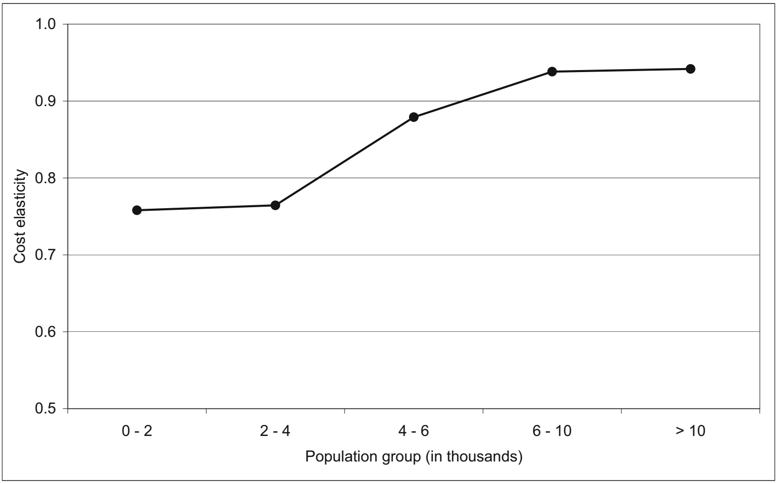
4.3.3 Economies of Scale

The results of the previous subsection indicated that there are significant differences in the levels of inefficiency of local governments in Baden-Württemberg. This suggests that the population decline expected in Germany over the upcoming decades is likely to cause a severe strain on some of these municipalities (especially if they should fail to increase their efficiency). In the current subsection these findings are expounded and the economies of scale in the provision of public goods by the local governments are investigated. Such an analysis can deliver important insights into how costs behave when the number of inhabitants starts to decline (as expected for most German regions; see Federal Statistical Office of Germany, 2006a). Indeed, pressure on local public finances is likely to be more severe when costs change underproportionally to population changes, compared to the case where significant economies of scale are absent (since costs and population will then move in roughly comparable measure).

A key variable for the identification of economies of scale in our setting is the coefficient for the population variable in the cost functions estimated in the previous subsection. Since all output variables as well as the dependent variable in these estimations are in natural logs, this coefficient can be interpreted as the cost elasticity with respect to population. Therefore, it shows how a one percentage increase/decrease of population affects the costs for providing a bundle of public goods. An elasticity significantly below one indicates increasing economies of scale and thereby suggests that the costs of providing public goods for one additional inhabitant rise underproportionally. Focusing on the Cobb-Douglas specification (columns 1 and 2 in table B.1) both coefficients for population are highly statistically significant with values of about 0.83. Hence, municipalities in Baden-Württemberg operate on average under increasing economies of scale. In other words, cost per capita can be cut if the average scale of production were larger - either by merging municipalities or by inter-municipal co-operating on the provision of public goods.

Importantly, one might wonder whether these economies of scale play a different role in small versus large municipalities. To the extent that this is the case, population decline affects small and large municipalities differently. To answer this question, Cobb-Douglas cost functions for five different classes of population size are estimated and, afterwards, it is investigated how the estimated cost elasticity (with respect to population) changes. Table 4.7 shows the five different size classes for which these regressions are carried out. As can

Figure 4.4: Development of the cost elasticities with increasing size of population



Note: Results are based on the Cobb-Douglas cost function with all exogenous variables.

be seen from the table, two classes for "small" municipalities, two classes for "medium-sized" municipalities and one class for "large" municipalities are established. The division of these classes was inspired by the requirement to include a number of municipalities in each class high enough to carry out a reasonable regression.

The results of the estimations are graphically represented in figure 4.4 above. First of all, note that figure 4.4 shows the regression results of the specification where all exogenous variables are included.[21] Moreover, for every size class (x-axis) the graph shows the corresponding estimated cost elasticity; that is, the estimated coefficient for the output variable "total population" (y-axis). It is clear from the figure that for the main part of the range in population size in the sample, cost elasticity is an increasing function of population size. That is, the elasticities appear (much) stronger for smaller municipalities than for larger ones. Indeed, for the smaller municipalities, the results hint towards substantial economies of scale in the sense that a one percentage increase in total population only leads to an increase in costs of approximately 0.75%. Nevertheless, economies of scale become close to exhausted once population size reaches approximately 10,000 inhabitants. Therefore, cost pressure as a result of a shrinking population particularly threatens municipalities in the size class up to approximately 10,000 inhabitants. An important policy implication of this analysis is there-

[21]The results of the baseline model (without control variables), however, are very similar.

fore that smaller municipalities might be more extensively confronted with the question of mergers - or inter-municipal cooperation in the provision of at least certain types of public goods - once the demographic change gains momentum (compared to larger municipalities).[22]

4.3.4 Conclusion

Demographic change constitutes a major challenge for local public finances in Germany. The results of this analysis underscore the importance of taking this demographic shock seriously. The first major finding in this context is the substantial heterogeneity in the efficiency of public service production - even under a uniform institutional setting as it is given for the municipalities in Baden-Württemberg. The analysis shows that, on average, the municipalities of Baden-Württemberg produce their output with costs roughly between 13% to 16% above the efficient frontier as identified by means of a stochastic frontier analysis - even when taking account of different socio-economic and political constraints. At first sight, this unexploited potential might appear to be a cushion for bad times once population shrinkage materialises. A more pessimistic interpretation, however, is to take these inefficiencies as an indicator of poor performance in general, and as adverse economic and fiscal developments in particular. Following this view, municipalities which are characterised by low efficiency scores under the current demographic situation are likely to incur significant difficulties in the future, when demographic decline gains force. One can indeed expect inefficiencies to augment when these low performing municipalities are faced with the challenge of adjusting their public services to the needs of a changing and shrinking population.

The second major finding relates to the properties of the cost function of public service production. In fact, costs are found to fall underproportionally with a shrinking population in small municipalities (with up to approximately 10,000 inhabitants). This substantiates the concern that the upcoming decrease of population will raise per capita costs of public service production for this size class of municipalities. This insight suggests that population shrinkage predominantly poses cost pressure problems for smaller units and could - or should - bring the debate on mergers or more intensive co-operation among smaller entities back on the agenda.

[22] Clearly, this analysis focuses on the "optimal" (population) size of municipalities with respect to cost considerations only. This disregards other characteristics that may play a role here (such as geographical characteristics). For a general discussion of the advantages and disadvantages of mergers or inter-municipal cooperations, see e.g. Kjeld et al. (2006).

4.4 Intergovernmental Grants and Efficiency[23]

4.4.1 Introduction

A key issue in the theoretical and empirical literature of public finance is how intergovernmental grants influence the level of local public spending of the recipient government. Researchers have been particularly interested in whether grants from the federal government stimulate higher levels of overall spending by local governments, or rather substitute for local tax revenue. The first effect is called *flypaper effect* (Courant et al., 1979) following Arthur Okun's observation that "money sticks where it hits". This is because grants entering the public sector also stay there, rather than being distributed to the private sector in the form of lower tax payments. There is a large amount of empirical literature trying to estimate the extent to which intergovernmental grants given to state and local governments are associated with higher government spending (for a review, see e.g. Hines and Thaler, 1995). Some of these studies attempt to explain the flypaper effect by specification errors in the econometric estimation (for a recent study, see e.g. Knight, 2002); other studies suggest that the individuals are subject to a kind of fiscal illusion which leads to a misperception of the "true" tax price (Courant et al., 1979; Oates, 1979).

An aspect which has attracted far less attention in the flypaper literature is the question whether observed changes in expenditures are associated with analogous changes in the actual level of public goods or services or whether increases in expenditures lead (at least to some extent) to a waste of resources (or X-inefficiency, Leibenstein, 1966) and losses in productive efficiency. In fact, only one study has so far attempted to explicitly assess the impact of intergovernmental aid on technical efficiency or X-efficiency (Silkman and Young, 1982). This empirical study investigates the technical efficiency of two public services (school bus transportation and public libraries) in the United States using cross section data. Silkman and Young (1982) show that the non-local proportion of total revenues (that is, the proportion of intergovernmental grants) has a strong negative impact on the productive efficiency of local governments' services. In further studies, Athanassopoulos and Triantis (1998), Balaguer-Coll et al. (2007), De Borger and Kerstens (1996a), and Loikkanen and Susiluoto (2005) analyse the determinants of local governments' cost efficiency in Greece, Spain, Belgium, and Finland - using different parametric and non-parametric estimation techniques. They all come to the conclusion that (intergovernmental) grants stimulate technical or cost inefficiency.[24] Finally, in a recent theoretical analysis, Kotsogiannis and Schwager (2006) show that fiscal equali-

[23]Parts of this section draw on Kalb (2010).

[24]For more details, see also subsection 3.9.1 and table C.1 of Appendix C. Furthermore, in contrast to the above mentioned studies, Geys and Moesen (2009a) find a positive relationship between grants and cost efficiency for a sample of Flemish municipalities. According to the authors, however, this result could be due to the fact that grants from higher level governments in Flanders are linked to strict supervision on expenditures. In addition, Worthington (2000) finds no significant relationship between grants and technical efficiency for a sample of Australian local governments.

sation programmes foster the incentives of the incumbents towards more rent extraction by reducing the intensity of political competition.

Given this background the aim of the present study is to investigate the causal effects of intergovernmental grants on local (cost) efficiency in Germany. For this purpose the seminal bureaucracy model of Niskanen (1975) is used and extended by the possibility that the federal government is able to give (lump-sum) grants to the local government (as a substitute for local tax revenues). Moreover, similar to Moesen and Van Cauwenberge (2000), the citizens of the local jurisdiction are assumed to be susceptible to a misperception of the true tax price of the local public goods or services due to fiscal illusion. In fact, it is assumed that a higher amount of intergovernmental grants leads to an underestimation of the true tax price by the citizens and therefore to a higher demand of public output. Using this framework, it is analysed how a higher degree of redistribution, that is, an increase in the amount of grants to the local government, affects the technical efficiency in the provision of public goods and services in this local jurisdiction. The results show that a higher degree of redistribution has a negative impact on the efficiency in the local jurisdiction. Finally, the results derived in the theoretical analysis are tested in an empirical framework using a panel of Baden-Württemberg's municipalities. To figure out the impact of intergovernmental aid on technical efficiency, again the stochastic frontier model developed by Battese and Coelli (1995) is employed.

The remainder of this section is structured in three main parts: In subsection 4.4.2 the theoretical analysis is presented. This subsection also provides a brief review of the original Niskanen (1971) bureaucracy model and derives a testable proposition. Subsequently, subsection 4.4.3 presents the empirical analysis including the estimation approach as well as the underlying data set and, finally, subsection 4.4.4 draws some final conclusions.

4.4.2 Theoretical Analysis

The Bureaucracy Model of Niskanen

In the original bureaucracy model of Niskanen (1971) the relationship between a bureau and its sponsor or funding agency is that of a bilateral monopoly. One could assume, for instance, that the sponsor is represented by the local government of a municipality which approves a certain budget for a public bureau (e.g. the Road Construction Office) in order to "buy" services and goods from this bureau (e.g. the construction of new highways). It is further assumed that the electoral process in the municipality is dominated by the median voter and that the local government strives to meet the wishes of the median voter.

The total budget, TB^N, which the sponsor is willing to approve, is assumed to be a quadratic function of the public output, Q:

$$TB^N = aQ - bQ^2, \tag{4.3}$$

that is, the total budget is a concave function of Q, reflecting diminishing marginal utility of public output. Moreover, the minimum total production costs for producing the public output, TC, are given by:

$$TC = cQ + dQ^2. \tag{4.4}$$

As can be seen from equation (4.4), total costs are assumed to rise at an increasing rate like a competitive firm's cost schedule. This cost funtion is only known to the bureaucrat. Finally the bureaucrat is constrained by the fact that the total budget must be equal or greater than the minimum total costs:

$$TB^N \geq TC. \tag{4.5}$$

Niskanen (1971) assumes that the bureaucrat seeks to maximise the size of the budget, TB^N; in other words, the bureaucrat maximises the budget-output function (4.3) over Q under the constraint that (in)equality (4.5) is fulfilled. However, as pointed out by Migué and Bélanger (1974), one implication of budget-maximisation is that the production of public output is allocatively inefficient (since the total budget is too large) but it is indeed technically efficient. This, in turn, implies that there remains no surplus revenue for the bureaucrat which can be devoted to his/her own ends since this would compete with output. However, the bureaucrat's preferences can also include things like income, prestige, expansion of personnel, leisure time, etc. Therefore, in a later version of his model, Niskanen (1975) extended the original model by assuming that the bureaucrat has access to the *fiscal residuum* (Orzechowski, 1977) - also called *discretionary profit* (Migué and Bélanger, 1974) or *organisational slack* (Cyert and March, 1963) - which is defined as the difference between the total budget and the minimum production costs,

$$FR = TB^N - TC. \tag{4.6}$$

The fiscal residuum measures the degree of production inefficiency or X-inefficiency (Leibenstein, 1966) at each possible production level.

Assuming that the bureaucrat has access to the fiscal residuum both the production inefficiency and the output enter the utility function of the bureaucrat. That is, the bureaucrat is indirectly able to use parts of the budget for his/her own ends. One could imagine, for instance, that the fiscal residuum or X-inefficiency generates utility for the bureaucrat in terms of leisure, long breaks, large expense accounts, political appointments and so on. Therefore, if the choice variables of the bureaucrat are public output and technical inefficiency, government production is allocatively as well as technically inefficient.

A Bureaucracy Model of Fiscal Illusion

Following Niskanen (1975) it is assumed that the utility function of the bureaucrat is given by:

$$U = \alpha_1 Y^{\beta_1} N^{\gamma_1}, \tag{4.7}$$

where Y represents the present value of the bureaucrat's monetary income and N the set of non-monetary perquisites of his/her position such as leisure time, expensive lunches, reputation and so on. Moreover, Y and N are related to the public output and the fiscal residuum (or maximum level of production inefficiency) as follows:

$$Y = \alpha_2 Q^{\beta_2} FR^{\gamma_2} \tag{4.8}$$

$$N = \alpha_3 Q^{\beta_3} FR^{\gamma_3}. \tag{4.9}$$

Equations (4.8) and (4.9) can be interpreted as the reward structure of the bureaucrat which is established by the sponsor. The main difference between the reward structure of a manager in a profit-seeking firm and a typical bureaucrat is that γ_2 is relatively high for the manager and relatively low for the bureaucrat. In contrast to the manager, the bureaucrat is not able to directly appropriate any of the fiscal residuum as personal income. On the other hand, the bureaucrat is characterised by relatively high values of β_2, β_3, and γ_3.

Substituting Y and N in (4.7) yields an expression of the utility function in terms of the public output, Q, and the fiscal residuum, FR:

$$U = \alpha Q^{\beta} FR^{\gamma}, \tag{4.10}$$

where

$$\begin{aligned} \alpha &= \alpha_1 \alpha_2^{\beta_1} \alpha_3^{\gamma_1} \\ \beta &= \beta_1 \beta_2 + \gamma_1 \beta_3 \\ \gamma &= \beta_1 \gamma_2 + \gamma_1 \gamma_3. \end{aligned}$$

Now, the available combinations of public output and technical inefficiency determine the choice constraint of the bureaucrat.

In a next step, the demand function of the voter is derived. As pointed out by Niskanen (1975) the budget function (4.3) is the integral of the demand function facing the bureaucrat over the whole range of output or, in other words, the monetary reflection of the voter's preferences. Since Niskanen assumes a quadratic budget function, the demand function for public output has to be linear (in prices). In order to derive this demand function, it is first assumed that the utility of the voter is given by:

$$U^V = X - \frac{(Q-\rho)^2}{2\theta}, \quad \text{with} \quad \rho, \theta > 0, \tag{4.11}$$

where X is the amount of the private good, which is assumed to have a price of unity, and ρ and θ are some parameters. Furthermore, the budget constraint of the voter is given by:

$$Y^V = Y + \bar{\tau} g = X + \tau(g) PQ, \tag{4.12}$$

where Y^V denotes the voter's total income, Y the voter's private income, and P the production price of the public output presented to the voter in form of tax payments. Moreover, besides tax revenue from service recipients, the sponsor (or local government) is assumed to receive lump-sum grants, g, from higher levels of government or other local governments (due to limited autonomy in raising own revenues) in order to finance parts of the public output. In addition, the tax share accruing to the voter, τ, is presumed to depend on the amount of grants received by the local government. Similar to Moesen and Van Cauwenberge (2000), it is assumed that the tax share the voter takes into account in his/her consumption decision is a negative function of the amount of grants due to fiscal illusion ($\frac{\partial \tau}{\partial g} < 0$), that is, the higher the grants received by the local government, the lower the perceived tax price of the public output (by the voter). Therefore, the function $\tau(g)$ captures the voter's degree of fiscal illusion.[25] If the local government does not receive any grants, $\tau(g)$ is equal to the real tax share $\bar{\tau}$. If, on the other hand, the local government does receive a positive amount of grants, then $\tau(g)$ falls until it reaches a lower bound $\underline{\tau}$ depending on the amount of grants received. Of course, if the voter is completely free of fiscal illusion, $\tau(g)$ equals the real tax share, $\bar{\tau}$. However, for the rest of this analysis, it is assumed that the voter is subject to at least a certain degree of fiscal illusion. As can be seen from equation (4.12), an increase in g then has two effects on the budget constraint: On the one hand voter's total income, Y^V, increases, since $\bar{\tau}g$ rises (usual income effect), but on the other hand there will also be a reduction in the tax price of the public output due to fiscal illusion (price effect).

Given the utility function and the budget constraint of the (median) voter, the demand function for the public output can easily be derived:

$$Q = \rho - \theta\tau(g)P, \quad \text{with} \quad \rho, \theta > 0, \tag{4.13}$$

which, because of the quasilinearity of the utility function (4.11), does not depend on the voter's wealth. Now, as can be seen from equation (4.13), an increase in the amount of grants leads to an increase in the demand for public output ($\frac{\partial Q}{\partial g} > 0$) since the perceived tax price for the voter decreases due to fiscal illusion.[26]

[25] The difference between this analysis and the study of Moesen and Van Cauwenberge (2000) is that the latter introduces the fiscal illusion in a different context. More specifically, Moesen and Van Cauwenberge (2000) investigate how governmental borrowing affects the demand for public goods and services when the taxpayers are not confronted with the "true" costs of providing the public goods and services due to a certain degree of myopia.

[26] For the sake of simplicity the (median) voter is assumed to have quasi-linear preferences which means that income effects do not matter. The results, however, do not change if a utility function is used which does not exclude income effects. The difference to an equivalent increase in voter's private income, then, would be that the latter only causes an income effect, while in our case higher grants additionally lower the price of public output and therefore also produce a substitution (or price) effect.

In order to investigate the effects of an increase in grants on technical inefficiency, firstly the budget function, TB, has to be derived. Since the total budget is given by P times Q, it follows that:

$$TB = P * Q = \frac{1}{\tau(g)}(aQ - bQ^2) = \frac{1}{\tau(g)} TB^N. \tag{4.14}$$

To be in line with the original Niskanen (1971) model, the terms $\frac{\varrho}{\theta}$, $\frac{1}{\theta}$, and $(aQ - bQ^2)$ were replaced by a, b, and TB^N, respectively. Note that TB^N represents the budget function (4.3) where fiscal illusion is absent, that is TB^N represents the "true" monetary reflection of the sponsor's preferences. Since $\tau(g)$ ranges from $\underline{\tau}$ to $\bar{\tau}$ (the real tax share), TB is either equal to or bigger than the "true" budget, TB^N. Moreover, substituting the total budget, TB, and the minimum total costs from equation (4.4), TC, in (4.6), yields the following expression for the fiscal residuum:

$$FR = TB - TC = \left(\frac{a}{\tau(g)} - c\right) Q - \left(\frac{b}{\tau(g)} + d\right) Q^2. \tag{4.15}$$

In a next step, (4.15) can be replaced in the utility function of the bureaucrat (4.10):

$$U = \alpha Q^\beta \left[\left(\frac{a}{\tau(g)} - c\right) Q - \left(\frac{b}{\tau(g)} + d\right) Q^2\right]^\gamma, \tag{4.16}$$

which yields an expression of the utility function depending solely on public output. Finally, maximising (4.16) with respect to Q then leads to the level of output that maximises the utility of the bureaucrat:

$$Q^* = \frac{\beta + \gamma}{\beta + 2\gamma} \frac{\left(\frac{a}{\tau(g)} - c\right)}{\left(\frac{b}{\tau(g)} + d\right)}. \tag{4.17}$$

If Q^* is differentiated with respect to the amount of grants received by higher levels of government, g, it can be seen that g is an increasing function of Q^*:

$$\frac{\partial Q^*}{\partial g} = -\left(\frac{\beta + \gamma}{\beta + 2\gamma}\right)\left(\frac{ad + bc}{(b + \tau(g)d)^2}\right)\frac{\partial \tau}{\partial g} > 0. \tag{4.18}$$

In other words, if fiscal illusion is present, the demand for public output will rise as long as the amount of grants increase. This is due to the fact that the voter systematically underestimates the true tax price of public output ($\frac{\partial \tau}{\partial g} < 0$) and therefore substitutes private for public goods consumption.

Finally, to determine the desired effect of an increase in g on the fiscal residuum or technical inefficiency, we plug in the level of output that maximises the utility of the bureaucrat, Q^* in the definition of the fiscal residuum (4.15) and differentiate this expression with respect to g:

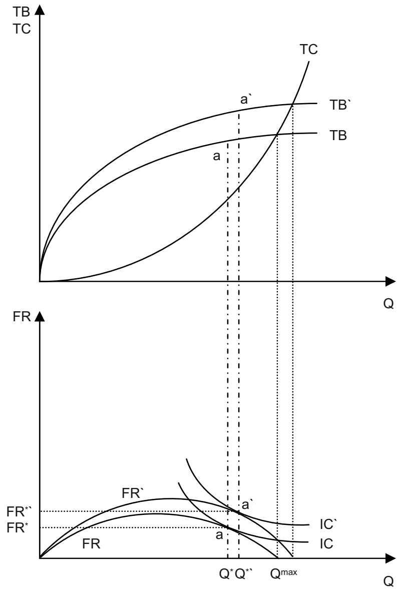
$$\begin{aligned}\frac{\partial FR^*}{\partial g} &= -\frac{\partial \tau}{\partial g}\frac{1}{\tau(g)^2}\left(aQ^* - bQ^{*2}\right) + \frac{\partial Q^*}{\partial g}\left(\frac{1}{\tau(g)}(a-2bQ^*) - (c+2dQ^*)\right) \\ &= -\frac{\partial \tau}{\partial g}\frac{1}{\tau(g)^2}TB^{N*} + \frac{\partial Q^*}{\partial g}\left(\frac{\partial TB^*}{\partial Q^*} - \frac{\partial TC^*}{\partial Q^*}\right), \end{aligned} \quad (4.19)$$

where the asterisks denote the values that maximise the bureaucrat's utility. The sign of the partial derivative of technical inefficiency with respect to the amount of grants now depends on the signs of the two summands in equation (4.19). First, if the budget is positive (that is, if Q ranges between zero and $\frac{a}{b}$) and if the presence of fiscal illusion ($\frac{\partial \tau}{\partial g} < 0$) is assumed, the sign of the first summand is positive. Concerning the second summand, it was shown in equation (4.18) that grants are an increasing function of Q^*, that is the first term of the second summand is larger than zero. If a marginal increase in Q^* causes the total budget to increase more than total costs ($\frac{\partial TB^*}{\partial Q^*} > \frac{\partial TC^*}{\partial Q^*}$), the second summand in equation (4.19) will be positive, too. If, on the other hand, both effects are of equal size ($\frac{\partial TB^*}{\partial Q^*} = \frac{\partial TC^*}{\partial Q^*}$), this term will be zero. The last two statements simply indicate that the increase in the fiscal residuum (due to the increase of grants) must lie within the budget constraint (4.5). Nevertheless, in both cases the overall effect of a marginal change in grants on technical inefficiency would be positive, which proves the intended point that there is a negative incentive effect of intergovernmental grants on technical efficiency. These findings can be summarised by the following proposition:

Proposition: *In the presence of fiscal illusion ($\frac{\partial \tau}{\partial g} < 0$), an increase in grants from higher levels of government or other local governments leads to an increase in the technical inefficiency of the recipient government, if: (i) the budget is positive ($0 < Q < \frac{a}{b}$) and (ii) a marginal increase in output causes the total budget to increase more or as much as total costs ($\frac{\partial TB^*}{\partial Q^*} \geq \frac{\partial TC^*}{\partial Q^*}$).*

Similar to Moesen and Van Cauwenberge (2000), the above-mentioned mechanism can be illustrated as presented in figure 4.5. The upper panel of this figure shows the budget function, TB, and the minimum cost function for producing the public output, TC, whereas the lower panel outlines the corresponding fiscal residuum, FR, as well as the bureaucrat's utility maximising combination of output and technical inefficiency represented by the tangency point of his/her indifference curve, IC, and the fiscal residuum (point a). Now, an increase in the amount of grants received by the local government causes the voter to assume that there has been a reduction in his/her tax price due to fiscal illusion. As a consequence, the voter demands a higher amount of public output, and the local government (which wants to meet the wishes of the median voter) approves a higher budget which is shown in the upper panel by the upward shift of the budget curve from TB to TB'. The higher budget, in turn, leads to an upward shift of the fiscal residuum from FR to FR' (lower panel of figure 4.5),

Figure 4.5: Effects of an increase in the amount of grants



and, finally to the new tangency point a' at which both output and technical inefficiency have risen. In other words, the bureaucrat uses parts of the new budget for the increase in public output, but also diverts parts for his/her own ends.

4.4.3 Empirical Analysis

Estimation Approach and Data

The proposition derived above provides a testable relationship between the amount of grants received by the municipalities and their degree of technical or cost efficiency. In the case of Baden-Württemberg's municipalities, this is of particular interest since intergovernmental grants constitute a considerable share of local government revenues (as shown in section 4.2). As in the last section, the (parametric) one-step approach developed by Battese and Coelli (1995) is used to determine the impact of intergovernmental grants on the efficiency of the municipalities. In contrast to the preceding application, however, the estimation is based on panel data for the period from 1990 to 2004. Moreover, only the municipalities with more than 10,000 inhabitants are employed in order to obtain a more homogenous setting with regard

Table 4.8: Descriptive Statistics

Variable	Mean	Std. Dev.	Min.	Max.
Input variable:				
Net current primary expenditures (in € per capita)	1660.09	486.79	956.38	9644.19
Output variables:				
Students in public schools	1691.08	2293.22	417	27625
Recovery area (in are)	6115.54	10242.25	376	110841
Total population	28483.86	49050.06	8203	598470
Share of population older than 65	15.618	2.394	8.611	27.800
Number of social insured employees (at place of work)	12338.65	28713.05	663	385197
Fiscal control variables:				
Grants (in € per capita)	354.59	132.71	33.48	1898.35
Abundant municipalities	0.084	0.277	0	1
Financially weak municipalities	0.712	0.453	0	1
Financially very weak municipalities	0.204	0.403	0	1
Other control variables:				
Unemployment rate (in %)	6.216	1.807	1.775	13.3
Population density (inhabitants per hectare)	5.718	4.563	0.682	28.86
Students at university	870.40	4160.85	0	35152
Accommodation facilities	12.883	18.028	0	155
Herfindahl index	0.339	0.069	0.211	1
Share of left	29.318	10.478	0	55.556

Sample size: 3675 observations; 245 municipalities over 15 years (1990-2004).

to the different types of tasks performed by the municipalities.[27] The descriptive statistics of the variables for the reduced sample are provided in table 4.8.

As before, the input for providing the public services is approximated by total current net primary expenditures of the single local governments. In contrast to the preceding analysis, however, net primary expenditures per capita are used as dependent variable. As can be seen from table 4.8, the per capita expenditures show a substantial variation within the state (of Baden-Württemberg). Furthermore, the output of the local governments is (again) approximated by five variables: (i) the number of students in public schools (*Grund- und Hauptschulen*), (ii) the surface of public recovery areas, (iii) total population, (iv) the share of population older than 65, and (v) the number of employees paying social security contributions.[28]

As exogenous fiscal variables grants per capita were included in the model. According to the proposition derived in the previous subsection, it is expected that there is a positive

[27]The basic results, however, do not change substantially when including a richer set of municipalities.

[28]Note that the number of kindergarten places used in the preceding analysis as an additional output indicator is only available for the years 1998 and 2002. Therefore, this variable could not be included in this (panel) analysis.

relationship between the amount of grants received by a local government and its technical inefficiency.[29] Moreover, to control for the fiscal capacity of the municipalities, dummy variables for "abundant" and "financially weak" municipalities were created and incorporated into the estimation equation.[30] Since abundant municipalities exhibit the highest fiscal capacity, it is expected that these municipalities have - in comparison to the other two types of municipalities - more money to spend and therefore can afford more or qualitatively higher public goods and services.

As in the preceding application, variables, which describe the production environment of the municipalities, are included in the model. More specifically, population density, local governments' unemployment rates, the number of accommodation facilities (of the municipalities) as well as the number of students enrolled at universities (in the university cities) are included in the model. The impact of the first three variables on the cost frontier has been discussed in section 4.3. The only variable that remains to be explained is the variable "students at university". Similar to municipalities which are more dependent on tourism, it can be argued that university cities have to spend relatively more money on infrastructure services such as a bus line network, student hostels or university administration. Therefore, costs are expected to increase with the number of students enrolled at universities.

In addition, the political variables are again captured through the Herfindahl index of political concentration as well as the share of left-wing party seats (SPD+GRÜNE) in the municipal council. The effect of both variables on the cost efficiency of the municipalities has been discussed in section 4.3. Finally, to control for time effects in the stochastic frontier as well as in the inefficiency model, a time trend was included in the model.

The model to be estimated then slightly changes to (in comparison to the preceding application):

$$\ln C_{i,t} = \beta_0 + \sum_{r=1}^{5} \beta_r \ln y_{r,i,t} + \frac{1}{2} \sum_{r=1}^{5} \sum_{q=1}^{5} \beta_{r,q} \ln y_{r,i,t} \ln y_{q,i,t} + \psi_t + v_{i,t} + u_{i,t} \tag{4.20}$$

$$u_{i,t} = \delta_0 + \sum_{j=1}^{9} \delta_j z_{j,i,t} + \psi_t + w_{i,t}, \quad i = 1, ..., 245; \quad t = 1990, ..., 2004, \tag{4.21}$$

where t is the additional time subscript and ψ_t the time trend controlling for both technical change (in the stochastic frontier) and for time-varying inefficiency effects.

[29] In this context the question arises whether there could be a problem of endogeneity when trying to identify the effects of grants received by the local governments on cost efficiency. With regard to this question it can be argued that the amount of grants received by the municipalities mainly depends on the fiscal capacity, that is on the sum of the different tax revenues of the local governments. Hence, there is no direct relationship between (cost) efficiency and the amount of grants received, since higher inefficiencies primarily lead to increases in expenditures.

[30] For more details on the municipal fiscal equalisation scheme, see section 4.2.

Table 4.9: Estimation Results

Variable	Translog (1)	Cobb-Douglas (2)
Fiscal Variables		
Grants	0.0014**	0.0014**
	(9.5057)	(7.4171)
Abundant municipality	2.6919**	2.8225**
	(14.7291)	(6.9300)
Financially weak municipality	0.8019**	0.8565**
	(7.1502)	(6.0858)
Production environment and political variables		
Unemployment Rate	-0.0271**	-0.0131*
	(-5.3756)	(-2.5538)
Population Density	-0.0104**	-0.0054*
	(-2.9481)	(-2.2538)
Students at university, log	-0.0362**	0.0083*
	(-3.5782)	(2.2066)
Accommodation Facilities	0.0096**	0.0105**
	(7.5573)	(7.3697)
Herfindahl index	2.4637**	2.4308**
	(11.0895)	(8.0659)
Share of left	0.0135**	0.0136**
	(10.2378)	(5.8140)
Sigma-squared ($\hat{\sigma}^2$)	0.1628**	0.1648**
	(13.3290)	(8.0811)
Gamma (γ)	0.9352**	0.9316**
	(143.6191)	(113.7242)
Log-likelihood	2279.94	2174.78

Note: N = 3675. Dependent variable: net current primary expenditures *per capita*. t-values are given in parentheses. ** (*) denotes significance at the 5% (10%) level. Coefficients of the output indicators (and their quadratic and cross-product terms) as well as the constant terms of the frontier and the inefficiency model are not reported (see table B.2 of Appendix B).

Results

The results of the estimation are shown in table 4.9.[31] As can be seen from this table, two types of cost functions were estimated, a translogarithmic cost function and a simple Cobb-Douglas cost function to check the robustness of the results.

First of all, note that the variance parameter γ is close to one in both specifications and highly significant. This parameter (lying between 0 and 1) indicates how much of the variation in the composed error term is due to the inefficiency term, $u_{i,t}$, in equation (4.20). A value close to zero indicates that the vast majority of residual variation is due to the normal disturbance error, $v_{i,t}$, whereas a value close to one indicates that much of the variation is explained

[31] Due to space constraints only the coefficients of the inefficiency model are shown. The coefficients of the full model, however, are reported in table B.2 of Appendix B.

by the inefficiency component, $u_{i,t}$. Therefore, much of the variation in the composed error term (in table 4.9) is due to the inefficiency term, $u_{i,t}$. Moreover, (generalised) likelihood ratio tests were carried out: Firstly, the null hypothesis that all covariates of the inefficiency model (4.21) are jointly equal to zero was tested. This resulted in a test statistic of about 1167 in the translogarithmic and 1328 in the Cobb-Douglas case indicating that in both cases the null hypothesis can strongly be rejected. Secondly, a test of the Cobb-Douglas (restricted model) against the translogarithmic (unrestricted model) cost function yielded a test statistic of about 210 which means that the null hypothesis of the restricted model can be rejected at the one percent level. This indicates that the non-linearities captured by the translogarithmic cost function (quadratic and cross-product terms of the output measures) are highly significant and that the translogarithmic function represents the cost structure of the municipalities better than the Cobb-Douglas function. Nevertheless, as mentioned above, the Cobb-Douglas cost function can be used to check the robustness of the results.

The results in table 4.9 support the negative incentive effect of intergovernmental grants on the cost efficiency of the local governments as stated in the proposition derived in the previous subsection. In the translogarithmic as well as in the Cobb-Douglas case, the coefficient of the variable "grants" is highly significant and has the expected positive sign indicating that an increase in the amount of grants received by the local government leads (through an increase of the expenditures) to a rise in technical inefficiency. As can be seen from the table, however, the effect, with a coefficient of 0.0014 both in the translogarithimic and in the Cobb-Douglas case, is very small. Table 4.9 also shows that the dummy variables for abundant and financially weak municipalities are both positive and highly statistically significant. This supports the hypothesis that abundant or financially weak municipalities have (compared to financially very weak communities, respectively) more money to spend which, in turn, enables these municipalities to afford more or qualitatively higher public goods and services.

Concerning the other control variables a closer look at table 4.9 reveals that the unemployment rate has a negative sign with robust significance in both the translogarithmic and the Cobb-Douglas case. Hence the "preference effect" seems to outweigh the "cost effect". Secondly, population density significantly decreases costs suggesting that densely populated municipalities have cost advantages due to agglomeration economies. Moreover, the variable "accommodation facilities" is positive and highly statistically significant in both cases. All three results are in line with the results obtained in the previous application. Moreover, the variable "students at university" has - contrary to the above-mentioned prediction - a negative sign in the translogarithmic case. In the Cobb-Douglas case, however, the sign is positive. Hence, the effect of this variable on the best practice frontier is ambigious. The political variables included in the estimation equation also attain statistical significance. As expected (and as in the previous section), the Herfindahl index, as an indicator for political concentration and monopolisation, significantly reduces efficiency in both specifications. In addition, local governments with a high share of left-wing parties seem to be associated with higher inefficiency.

4.4.4 Conclusion

This section has investigated the causal effects of intergovernmental grants on local governments' cost efficiency - both theoretically and empirically. In line with the findings of Silkman and Young (1982) and several other studies investigating the main drivers of local governments' efficiency, the theoretical as well as the empirical results of the present analysis support the existence of a negative incentive effect of fiscal equalisation schemes on the efficiency of local governments.

With regard to efficiency considerations, one implication of these results is that, in order to reduce the degree of inefficiency (or to eliminate the fiscal illusion), the federal government should give more autonomy to the local jurisdictions in raising their own revenue since, in this case, the fiscal illusion stemming from the intergovernmental grants would be diminished. It should be noted, however, that the empirical results have been derived using a very limited and "rough" set of indicators representing the outputs (and inputs) of a municipality. Here, of course, a more detailed reproduction of the tasks accomplished by the municipalities would be desirable. So far, this has not been possible due to missing data.

4.5 Voter Involvement, Fiscal Autonomy and Efficiency[32]

4.5.1 Introduction

It has been argued that engagement in social life not only increases interest in and understanding of politics, but also makes one more willing and effective in demanding "good" government performance (see e.g. Boix and Posner, 1998). As such, voter involvement may well help tame the Leviathan. Clearly, however, two crucial assumptions have to be met for this argument to hold. Firstly, civic engagement should foster political awareness and interest. Scheufele et al. (2004), among others, provide some evidence that this is indeed the case. Secondly, this increased interest and involvement in the political sphere should improve government performance. The validity of this second "assumption", however, has received little attention and was recently described as a "plausible, important but insufficiently tested proposition" (Toka, 2008, p. 31).

[32]Parts of this section draw on Geys et al. (2010).

The present analysis takes a first step towards bridging this gap. It empirically assesses whether voters' political involvement improves government performance - and, crucially, whether fiscal autonomy of the local government is a prerequisite for such an effect to establish itself (see below). Good government performance in this case is defined as a higher efficiency of public service provision or, phrased more negatively, as a reduction in budgetary slack or rent-seeking. Again, the efficiency measure employed is based on the public sector as a whole rather than on a given area of public goods provision. While numerous studies examine local government efficiency and its determinants,[33] only one of these includes a measure of political involvement (Borge et al., 2008). This study illustrates that the public's democratic participation tends to improve efficiency - in line with theoretical predictions - even after controlling for numerous political, fiscal and budgetary variables. The present analysis intends to add to our understanding of the participation-efficiency nexus by diverging from and/or extending upon Borge et al. (2008) in four main ways:

1. In contrast to Borge et al. (2008), the present analysis uses a stochastic frontier approach to measure efficiency; Borge et al. (2008) rely on the ratio between aggregate output and local government revenue. As already shown in subsection 2.4.2, the stochastic frontier approach has the benefit of allowing for a distinction between measurement error and inefficiency.

2. The present analysis is based on a broad panel of German municipalities (as opposed to the Norwegian municipalities used in Borge et al., 2008). As a result, the dataset is larger - including across-time variation in crucial variables. Moreover, it implies that the participation-efficiency nexus is examined in a different political and institutional setting - making the results interesting from a comparative perspective.

3. The present analysis employs a broad set of indicators of voter involvement - thus going beyond electoral turnout as a measure of citizen involvement (as in Borge et al., 2008). As such, the present analysis is able to identify how different means of political involvement by voters affect government performance.

4. Finally, the present analysis is the first to assess how the participation-efficiency nexus is affected by the degree of local fiscal autonomy. Building on the fiscal illusion literature, fiscal autonomy (in contrast to dependence on external grants) may be seen as a crucial intervening variable since it implies that voters are effectively confronted with the tax bill for their desires. As a result, it can be argued that an active citizenry is more likely to value the prudent use of public money when it originates mainly from own revenue sources rather than external transfers.

The remainder of this section is structured as follows. In the next subsection the theoretical background and the main hypotheses are derived. The estimation approach along with the

[33]For a review see subsection 3.9.1 and table C.1 of Appendix C.

underlying data set is provided in the empirical analysis in subsection 4.5.3, while subsection 4.5.4 concludes this section.

4.5.2 Theoretical Background and Hypotheses

From a theoretical perspective, the link between voter involvement and the efficiency of public policy can be analysed in a standard principal-agent setting (see Migué and Bélanger, 1974; Niskanen, 1975; Borge et al., 2008). Local government officials act as agents for the population who, as principals, desire the government to provide as many public goods as possible for a given fiscal cost. That is, "voters want more competent politicians in office, as they can provide more public goods for given levels of taxation and private consumption" (Alt and Lassen, 2006, p. 1404) (see also Shi and Svensson, 2006). However, there is a clear conflict of interest in that politicians (or bureaucrats) in charge of public goods provision may benefit from less productive activities: higher salaries, lower effort, over-employment within their service, and so on. Given that politicians (or bureaucrats) tend to be better informed about the true cost of providing public goods than the general population, there exists an incentive to invest in such less-productive activities. These, however, induce budgetary slack (or inefficiency).

More importantly, the extent of budgetary slack is likely to be affected by the formal as well as the informal institutional setting. One crucial element in this respect is whether or not the principal assumes an active role in informing himself about and supervising the actions of his agent. Specifically, agency theory assumes that principals can resolve part of their imperfect information of the agent's work effort through stricter monitoring (Alchian and Demsetz, 1972; Jensen and Meckling, 1976; Holmström, 1979; Laffont and Tirole, 1986). This reduces information asymmetries between principal and agent, thereby limiting possibilities for wasteful spending and rent extraction by the agent. In other words, the "information rent" extracted by the agent is likely to become considerably smaller with monitoring such that budgetary slack is reduced when the principal is actively involved (see e.g. Moene, 1986; Chan and Mestelman, 1988).[34]

The analysis in this section concentrates on the political involvement of voters as one means to actively monitor politicians (see also Strumpf, 1998; Borge et al., 2008) and to thereby improve policy outcomes. The reason for this focus is that participating citizens have been argued to be more critical, better informed and more vigorous in demanding particular policies (Boix and Posner, 1998; Scheufele et al., 2004). A more active citizenry therefore increases supervision of and pressure on government officials and, following the predictions from agency theory, increases their effort levels. To the extent that higher effort enhances performance, a first hypothesis can thus be stated as follows:

[34]Recent experimental evidence is generally supportive of a disciplining effect of monitoring (see e.g. Nagin et al., 2002; Dickinson and Villeval, 2008). Still, in personal interactions, this disciplining effect may be counterbalanced by a crowding-out effect because supervision diminishes the intrinsic motivation of the agent (see Frey, 1993a,b; Barkema, 1995). As the principal-agent relation is impersonal here (i.e. voter-government), dominance of the disciplining effect of monitoring is assumed.

Hypothesis 1: *Higher voter involvement increases local government performance (i.e. efficiency).*

Clearly, hypothesis 1 rests on the assumption that voters desire efficiency in the provision of local public goods. This, however, is not necessarily always the case. In fact, the extensive literature on fiscal illusion argues that when government revenues employed to finance public goods provision are at least in part unobserved by voters, the latter might have an inaccurate perception of the true cost of public goods provision. This, in turn, affects the behaviour of politicians. One consequence of fiscal illusion is the *flypaper effect* (see e.g. Hines and Thaler, 1995) which entails that revenues that a jurisdiction obtains from lump-sum grants are used differently than revenues from own tax sources. In fact, while economic theory would suggest that an increase in revenues from both sources is equivalent and has similar implications on the jurisdiction's spending pattern (Bradford and Oates, 1971), unconditional grants are de facto more likely to be used for additional spending rather than tax cuts (for a review, see e.g. Mueller, 2003, p. 221-223).

Another potential consequence of fiscal illusion is that voters may end up caring about government efficiency only when they are directly confronted with the tax bill for public goods provision. When there is an imperfect mapping of citizens who consume and finance public services or, in other words, when fiscal institutions are not built on the principle of *fiscal equivalence* (Olson, 1969), the function of voters as efficiency guards may be impaired because other people's money is being wasted. In this case, voters are likely to pay less attention to the prudent use of public money (since it originates, at least in part, from external transfers). This line of argument suggests that in transfer-dependent municipalities with a low fiscal autonomy, high voter involvement need not be associated with higher efficiency. Fiscal autonomy (in contrast to dependence on external grants) can therefore be seen as a crucial intervening variable in the involvement-efficiency relation.[35] This leads to the second hypothesis:

Hypothesis 2: *The effect of voter involvement on local government performance (i.e. efficiency) is mediated by the degree of local fiscal autonomy.*

4.5.3 Empirical Analysis

Estimation Approach and Data

As in the two preceding applications, the (parametric) one-step approach proposed by Battese and Coelli (1995) is employed to test the above-derived hypotheses.[36] In addition, the analysis

[35] In a similar vein, fiscal decentralisation has been argued to increase government efficiency by giving "voters increased electoral control over incumbents" (Barankay and Lockwood, 2007, p. 1198). The reason is that decentralisation strengthens the negative relation between rent extraction and the probability of re-election (see e.g. Seabright, 1996; Persson and Tabellini, 2000; Hindricks and Lockwood, 2005).

[36] For more details on the methodology, see chapter 2.

is based on data for 987 of the 1102 municipalities of Baden-Württemberg for the years 1998, 2002 and 2004 (data availability precluded the use of the remaining 122 municipalities). As before, input is approximated by total current net primary expenditures of the municipalities (in absolute terms),[37] and output is (again) approximated by six variables: (i) the number of students in local public schools (*Grund- und Hauptschulen*), (ii) the number of kindergarten places, (iii) the surface of public recreational facilities, (iv) total population, (v) the population older than 65, and (vi) the number of employees paying social security contributions.[38]

The crucial part of the analysis, however, refers to the inclusion of the exogenous variables. There are two kinds of exogenous variables: measures for voter involvement and, as before, other control variables. Starting with the former variables - as they intend to test the core hypotheses - three measures indicating the extent of voters' political involvement in the municipalities are introduced. These capture various means through which voters are able to voice their concerns to politicians, and may affect efficiency in differing ways. The first measure of political involvement is voter turnout, defined as the number of votes cast relative to the number of eligible voters of the municipality. Voter turnout is strongly positively related to people's interest in and knowledge of politics (see e.g. Squire et al., 1987; Brady et al., 1995). As such, high turnout indicates a politically interested electorate that has the ability (in terms of knowledge and interest) and desire (given that it actively turns out to vote) to supervise and hold its politicians accountable.

The second measure of voter involvement is an indicator variable for the existence of free voters' unions in the municipal council. As argued in section 4.2, the existence of free voters' unions indicates that at least some citizens are ready to incur the cost of organisation to resolve local policy issues. Since free voters' unions cannot rely on support from a state- or country-wide party apparatus, personnel and financial resources, their members must feel sufficiently politically involved to create such an organisation. The direction of their effect on efficiency is, however, a priori uncertain. On the one hand, their presence could benefit municipal efficiency given the oft-cited beneficial role of associations for socio-political and economic outcomes (Putnam, 1993; Stolle and Rochon, 1998; Paxton, 2002; Coffé and Geys, 2007, 2008; Geys and Murdoch, 2008). On the other hand, the economic literature on special interest groups suggests the reverse effect, since accommodation of special interest groups might also lead to less efficient policies (see e.g. Mueller and Murrell, 1986).

The third and final measure of voter involvement is the share of eligible voters to total population. This captures the extent to which inhabitants of a given municipality are able

[37]Alternatively, the model was re-estimated using expenditures only for the six output factors defined below. This mitigates the possible concern that expenses falling outside of the six output indicators are interpreted as inefficiency, and lead to biased inferences. The main findings are largely unaffected by this alternative specification, emphasising the robustness of the estimation results (see table B.4 of Appendix B).

[38]Note that data about kindergarten places were only available for the years 1998 and 2002. Therefore, the kindergarten places of the year 2004 were approximated by the the kindergarten places of the year 2002. Moreover, only the total number of public and private kindergarten places are available. Still, public kindergarten places make up a large fraction of total kindergarten places (43% and 44% in 1998 and 2002 respectively).

Table 4.10: Descriptive Statistics

Variable	Mean	Std. Dev.	Min.	Max.
Input variable:				
Net current primary expenditures (in mio. €)	20.40	86.30	0.35	2890.00
Output variables:				
Students in public schools	662.14	1308.41	0	27126
Kindergarten places	417.85	825.17	0	17554
Recovery area (in are)	2480.27	5901.94	0	110841
Total population	10525.13	26837.23	242	589231
Population older than 65	1747.26	4625.50	31	105289
Number of social insured employees (at place of work)	3769.91	14788.02	10	355536
Voter involvement variables:				
Voter turnout (in %)	63.219	8.337	37.216	88.736
Free voters' unions	0.957	0.203	0	1
Ratio of eligible voters to total population (in %)	73.122	3.307	60.978	99.753
Other control variables:				
Unemployment rate (in %)	6.574	1.321	2.900	12.700
Population density (inhabitants per hectare)	3.358	3.328	0.207	28.416
Herfindahl index	0.515	0.247	0.211	1
Share of left	17.838	14.680	0	65
Abundant municipalities	0.082	0.275	0	1

Sample size: 2961 observations; 987 municipalities over the years 1998, 2002 and 2004.

to control their politicians through the ballot box (not the extent to which they actually do, which is captured by the voter turnout measure above). When a substantial share of taxpayers has no voting rights (e.g. because they are of non-EU nationality), popular intervention through the electoral process is likely to be reduced.

To assess how the degree of fiscal autonomy affects the involvement-efficiency nexus (see hypothesis 2), each of the above measures is interacted with a dummy variable for "abundant" municipalities.[39] Since these municipalities exhibit the highest degree of fiscal autonomy - making the tax price for local expenditures more visible - the effect of voter involvement is expected to be stronger in these municipalities. The reason, as mentioned, is that citizens are likely to put more weight on the prudent use of public money which stems from own revenue sources rather than from external transfers (see also the literature on fiscal illusion mentioned in the introduction of this section). Hence, a more active citizenry is more likely to be a force for efficiency in fiscally more independent (abundant) municipalities.

As in the two preceding approaches, other external influences are included in the estimation equation. Again, population density, the municipalities' unemployment rates, and two political variables (Herfindahl index of political concentration in the municipal council as well

[39]For more details on the municipal fiscal equalisation scheme, see section 4.2.

as the share of seats of left-wing parties in the municipal council) are incorporated in the model. The impact of all of these variables (on costs and efficiency, respectively) were already discussed in the first application. Finally, the descriptive statistics for all variables are given in table 4.10.

Given the above input, output and exogenous variables, the model to be estimated is essentially the same as that of the preceding application:

$$\ln C_{i,t} = \beta_0 + \sum_{r=1}^{6} \beta_r \ln y_{r,i,t} + \frac{1}{2}\sum_{r=1}^{6}\sum_{q=1}^{6} \beta_{r,q} \ln y_{r,i,t} \ln y_{q,i,t} + \psi_t + v_{i,t} + u_{i,t} \quad (4.22)$$

$$u_{i,t} = \delta_0 + \sum_{j=1}^{8} \delta_j z_{j,i,t} + \psi_t + w_{i,t}, \quad i = 1, ..., 987; \quad t = 1998, 2002, 2004, \quad (4.23)$$

where the definitions of the variables are exactly the same as in the preceding approach.

Results

The results of the analysis are summarized in table 4.11. The first three columns provide the results using the three different indicators of voter involvement separately. Column 4 includes all three involvement measures to check the robustness of the individual findings and assess how the relation between all three measures affects their respective findings. In the last four columns, the mediating effect of fiscal autonomy is assessed by including interaction effects between voter involvement and fiscal autonomy, whereas the last specification is included to check (again) the robustness of the individual interaction effects. Before discussing the findings, it should be noted that the variance parameter gamma is close to one in all specifications and highly significant (see bottom row of table 4.11). This indicates that the majority of the variation in the composed error term is due to the inefficiency component, $u_{i,t}$, in equation (4.22). Moreover, one-sided generalised likelihood ratio tests of the inefficiency effects indicate that in all specifications the null hypothesis that the inefficiency effects are absent from the model(s) can be strongly rejected. This implies that all covariates of the inefficiency model (given in equation (4.23) above) are jointly significant.

Turning now to the central voter involvement variables, table 4.11 shows that all three indicators of voter involvement add significantly to the explanatory power of the model - both independently (see columns (1) to (3)) and jointly (see column (4)). Hence, a first conclusion clearly is that voter involvement matters for local government (in)efficiency. A closer look reveals, moreover, that all three measures of voter involvement have a positive impact on cost efficiency. This provides support for hypothesis 1. Interestingly, the size of the coefficient estimates indicates that a one standard deviation change in voter involvement has the largest effect on efficiency in the case of free voters' unions and the smallest effect in the case of voter turnout. This relative size of the effects makes intuitive sense. Indeed, establishing a free voters' union is a very active way of involvement compared to the simple act of voting, which is often seen as the easiest and least costly way of participating in politics - in terms of money, time and other resources (see Milbrath, 1965; Verba and Nie, 1972).[40] As such, it can be expected to have less far-reaching consequences in the conduct of political decision-making.[41]

Finally, columns (5) to (7) provide significant support for hypothesis 2. That is, the interactions between the dummy variable for fiscally autonomous (i.e. "abundant") municipalities and voter turnout (AM*VT) as well as its interaction with the presence of free voters' unions (AM*FVU) show highly significant negative coefficients. The coefficient of the third interaction variable (AM*RatioEV/POP) is unexpectedly positive but remains insignificant. The results of column (8) basically confirm the individual findings. These results strongly suggest that in municipalities with a higher degree of fiscal autonomy, the positive effect of voter involvement on municipal cost efficiency is more powerful. This is most strongly the case in column (6). There, we actually observe that the positive effect of free voters' unions on municipal efficiency is driven by those municipalities that are fiscally autonomous. In municipalities that are strongly dependent on external funds, the effect of voter involvement is positive (and statistically significant). One explanation for this result, as suggested above, is that an active citizenry is likely to put more weight on the prudent (i.e. cost-efficient) use of public money when these public funds originate from own revenue sources rather than from external transfers.

Finally, the effects of the included control variables (unemployment rate, population density, Herfindahl index, share of left and the dummy variable for abundant municipalities) are basically in line with the results obtained in the two preceding applications.

[40]It should be noted that reverse causality may be an issue. Indeed, since inefficiency might lead to the creation of free voters' unions or stimulate people to turn out to vote (see above), the coefficient of voter turnout (VT) and the free voters' unions (FVU) variables may suffer from an endogeneity bias. Nevertheless, to the extent that this reversed channel of causation exists, the VT and FVU coefficients in columns (1) and (2) are biased upwards and our results provide an underestimate of the true effect.

[41]Two other reasons might explain the stronger impact of free voters' unions. First, they can be interpreted as a highly independent political actor in political negotiations and monitoring activities (which, given the positive effect on efficiency, does not appear to work as a narrowly defined interest group with very specific efficiency-deterring demands). Second, the presence of free voters' unions might intensify political competition since it implies a non-ideological player entering the political stage. As discussed above, political monopolies are prone to administrative slack and inefficiencies in public service production. Free voters' unions can be seen as undermining such political monopolies.

Table 4.11: Estimation Results

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
				Production Environment and Political Constraints				
Unemployment Rate	-0.0247**	-0.0514**	-0.0439**	-0.0365**	-0.0235**	-0.0490**	-0.0410**	-0.0409**
	(-3.5136)	(-6.7206)	(-5.7417)	(-4.5828)	(-2.5856)	(-6.8962)	(-4.3281)	(-4.1713)
Population density	-0.0555**	-0.0464**	-0.0485**	-0.0409**	-0.0529**	-0.0468**	-0.0447**	-0.0427**
	(-6.3933)	(-7.4453)	(-7.4488)	(-5.9351)	(-5.8337)	(-7.6972)	(-5.9409)	(-5.7470)
Herfindahl index	0.3453**	0.1254*	0.1264**	0.0036	0.3317**	0.1607**	0.1343*	0.0118
	(5.0724)	(2.4019)	(2.6597)	(0.0779)	(3.8551)	(2.6988)	(2.0125)	(0.1834)
Share of left	-0.0025*	-0.0090**	-0.0015	-0.0058**	-0.0015	-0.0090**	-0.0005	-0.0066**
	(-2.4930)	(-4.9833)	(-1.4163)	(-4.4367)	(-1.2759)	(-4.0450)	(-0.4546)	(-4.6701)
Dummy abundant municipality (AM)	2.5062**	2.2549**	1.7430**	1.6732**	2.7270**	3.3852**	1.1467*	2.5648**
	(6.1182)	(6.0632)	(7.6678)	(6.4256)	(5.3425)	(5.9887)	(1.9620)	(3.9890)
				Voter Involvement				
Voter turnout (VT)	-0.0124**	-	-	-0.0045**	-0.0056*	-	-	-0.0010
	(-4.6643)			(-2.4775)	(-2.4660)			(-0.4705)
Dummy free voters' union (FVU)	-	-0.6658**	-	-0.5210**	-	0.1469*	-	0.0545
		(-6.5112)		(-6.1659)		(2.3723)		(0.6892)
Ratio eligible voters/population	-	-	-0.0631**	-0.6020**	-	-	-0.0608**	-0.0607**
(Ratio EV/POP)			(-8.0803)	(-6.4779)			(-5.3781)	(-5.3160)
AM * VT	-	-	-	-	-0.0079*	-	-	-0.0052
					(-2.0309)			(-1.5209)
AM * FVU	-	-	-	-	-	-1.2045**	-	-0.8644**
						(-5.7661)		(-5.5882)
AM * Ratio EV/POP	-	-	-	-	-	-	0.0078	0.0043
							(0.8322)	(0.4811)
Sigma-squared	0.2976**	0.2689**	0.2113**	0.1976**	0.2499**	0.2693**	0.1984**	0.1981**
	(6.5733)	(6.5343)	(8.2073)	(6.8306)	(6.5530)	(6.1351)	(7.7788)	(7.5684)
Gamma	0.9559**	0.9518**	0.9392**	0.9334**	0.9470**	0.9517**	0.9349**	0.9335**
	(140.2274)	(139.0069)	(131.9161)	(96.7381)	(119.0643)	(116.1515)	(103.7188)	(114.5398)
Log-likelihood	1393.22	1394.94	1399.64	1403.48	1391.88	1397.87	1399.75	1406.78

Note: N=2961. Dependent variable: net current primary expenditures. ** (*) denotes significance at the 5% (10%) level. Coefficients of the output indicators (and their quadratic and cross product terms) as well as the constant terms of the frontier and the inefficiency model are not reported due to space constraints (see table B.3 of Appendix B). Note also that the estimation accounts for both technical change in the stochastic cost frontier and time-varying inefficiency effects.

4.5.4 Conclusion

This section investigated the relationship between voter involvement and local governments' cost efficiency. While higher social and political involvement within the population is often argued to be beneficial for the performance of the public sector, it remains unclear from a theoretical point of view whether higher voter involvement necessarily results in a higher or lower performance of (local) governments. One reason is that voters may only care about the prudent use of public money when it stems from own (tax) revenue sources rather than from external transfers. As a consequence, high voter involvement is more likely to result in better (or more efficient) performance only in municipalities with a high - rather than low - degree of fiscal autonomy. The empirical analysis illustrates that higher voter involvement is on the whole associated with higher rather than with lower levels of cost efficiency. This conclusion is in line with previous findings by Borge et al. (2008) for Norwegian municipalities - despite the differences in institutional setting, methodological approach and measurement of government efficiency between the latter and the study at hand. Moreover, this efficiency-stimulating effect of voter involvement is significantly positively affected by local governments' fiscal autonomy.

While caution is due when drawing policy implications from this analysis (given that the analysis relies on proxies for voter involvement), the results of this analysis clearly provide some food for thought. At first sight, they suggest that one should try to encourage citizens to be more active in the political process (e.g. via casting a ballot). Indeed, higher levels of voter involvement on the whole increase government performance. This is, however, not an easy route to take. Voter involvement in Baden-Württemberg (as elsewhere) is de facto decreasing. For example, in the period considered here, voter turnout in municipal council elections fell from approximately 67% in 1994 to 52% in 2004. A more detailed reading of the results obtained, however, shows that this is not the only way to increase local government performance. Indeed, an alternative route is to increase the degree of local governments' fiscal (or revenue) autonomy. The results suggest that the effect of voter involvement is stronger in fiscally more autonomous (and therefore less dependent on external transfers) municipalities. Even though actual involvement declines (see above), higher budgetary slack can then still be avoided by making municipalities depend to a higher degree on own funding. In such a setting, an active citizenry will put more weight on the prudent use of public money.

4.6 Determinants of Efficiency: The Case of Road Maintenance

4.6.1 Introduction

While there are numerous studies on the measurement of local governments' technical or cost efficiency, the analysis of the main drivers of this efficiency has attracted far less attention in the literature.[42] Information about the main sources of efficiency, however, are not unimportant since they can "provide useful information to policy-makers" (De Borger and Kerstens, 1996a, p. 147). In the two preceding sections, two specific determinants of local governments' (cost) efficiency (namely intergovernmental grants and voter involvement) were already investigated and discussed. However, it would also be useful to learn more about the general determinants of local governments' efficiency. Therefore, the aim of this section is to study the main drivers of efficiency in a much broader context.

However, one of the main problems of the preceding applications is that the input as well as the outputs are approximated by a very "rough" set of indicators - due to a lack of more detailed data. For this reason, the focus in this section will be on one particular area of local public goods provision - namely the construction and maintenance of roads - instead of the local government as a whole. This avoids, at least to a certain degree, the problem of defining a comprehensive set of reasonable input and output indicators fully describing the activities of local governments. In addition, since there are more key variables (like the disposable income of the citizens) available at the county level, this section concentrates on the counties (rather than on the municipalities) of Baden-Württemberg. The counties are an interesting case to study, since one of their main tasks is the construction and maintenance of county roads. The importance of this responsibility is stressed by the fact that the county road network currently covers approximately 12,000 kilometers which constitutes about 43% of the total road network outside of built-up areas in Baden-Württemberg.[43]

Despite the numerous studies measuring either the technical efficiency of (local) governments as a whole or particular areas of (local) public goods provision, only few studies have tried to assess the efficiency of local road maintenance. In fact, there are only a couple of studies investigating the scale and technical efficiency of local road maintenance for several US states: Deller et al. (1988) and Chicoine et al. (1989) examine the size efficiency in the production of rural roads by means of cost functions. Both studies identify substantial size inefficiencies and conclude that cost reductions could be realised by restructuring the production of rural roads. Deller and Nelson (1991), Deller et al. (1992), Deller (1992) and Deller and Halstead (1994), on the other hand, investigate the technical efficiency of rural road mainte-

[42]For a review of the literature investigating the efficiency (along with its determinants) of local governments, see chapter 3 and table C.1 of Appendix C.

[43]In Germany there are basically four different types of roads (with regard to the financing of the roads): roads that have to be financed (1) by the federal state (*Bundesfernstraßen*), (2) by the states (*Landstraßen*), (3) by the counties (*Kreisstraßen*), and (4) by the municipalities (*Gemeindestraßen*).

nance using different parametric and non-parametric estimation techniques. Their estimation results suggest that road maintenance costs are 14 to 50 percent higher than necessary due to production inefficiencies.[44] As yet, however, there is no study that tries to identify the (main) determinants of efficiency for the case of local road maintenance.

This section is structured as follows. In the next subsection the estimation approach as well as the data set are presented. Subsection 4.6.3 shows the results of the analysis, while the last subsection (4.6.4) draws some final conclusions.

4.6.2 Estimation Approach and Data

In contrast to the three previous applications, the determinants of efficiency for the case of local road maintenance are analysed by using and comparing four different estimation approaches. This broad variety of estimation approaches allows us to test and check the robustness of the derived results. More specifically, the parametric two-step and one-step approach as well as the two non-parametric two-stage approaches (Tobit regression and truncated regression with the bootstrapping correction proposed by Simar and Wilson, 2007) derived in sections 2.3 and 2.5, respectively, are employed.[45] In addition, the analysis is based on data for all of the 44 counties of Baden-Württemberg for the period of 1990 to 2004, i.e. the whole sample consists of 660 observations. The descriptive statistics of all variables used in the analysis are given in table 4.12.[46]

Following Deller and Halstead (1994), the input necessary to construct and maintain the county roads is approximated by total expenditures (for county roads). As can be seen from table 4.12, the expenditures for county roads show substantial variation within the sample used here. In addition, the output - that is the supply of roads to the populace - is measured by the area of the total road network which is under the jurisdiction of the counties. Table 4.12 shows that the area of the county roads in the sample varies between approximately 12 and 350 hectares indicating that there are substantial variations among the counties. A variable which approximates the quality of the services provided is included in the model as a second output indicator.[47] As pointed out by Balaguer-Coll et al. (2007) this is of great importance, since local governments are often unable to directly affect the quantity of outputs (at least in the short run), but have a decisive impact on their quality. As an indicator of the quality of the county roads the number of accidents caused by bad road conditions like

[44]For more detailed information, see also section 3.8.

[45]Note that in the present analysis only the results of the double bootstrap procedure proposed by Simar and Wilson (2007) ("algorithm 2", see subsection 2.3.2) are presented, since - according to Simar and Wilson - the double bootstrap procedure outperforms the single bootstrap procedure (in terms of coverage of estimated confidence intervals). The results of the single bootstrap procedure are, however, (qualitatively) very similar.

[46]For more details on the sources of the data as well as the calculation of some of the variables, see Appendix A.

[47]This is one major advantage of the present analysis compared to the three previous applications. The latter do not include data on the quality of the whole bundle of public goods and services provided by the municipalities (e.g. from surveys).

Table 4.12: Descriptive Statistics

Variable	Mean	Std. Dev.	Min.	Max.
Input variable:				
Total expenditures, county roads (in mio. €)	3.92	2.53	0.09	18.20
Output variables:				
Area of county roads (in hectare)	158.753	90.336	12.293	349.992
Number of accidents due to bad road conditions	167.755	98.699	15	509
Exogenous variables (characteristics):				
Unemployment rate (in %)	6.499	1.955	2.275	13.900
Population density (inhabitants per hectare)	5.067	5.761	0.946	28.863
Total Population	233296.80	122651.50	50891	598470
Accommodation facilities	156.827	144.421	19	883
Average (weighted) kilometres travelled on county roads per year (in 10000 km)	2473.16	1489.25	217.63	8311.67
Maximum geographical point of county (in metre)	637.29	225.34	146.51	1281.91
Urban county	0.205	0.404	0	1
Exogenous variables (determinants):				
Disposable income (in € per capita)	16413.27	1928.27	11836.23	23180.12
Payments to counties (in € per capita)	256.61	144.38	87.81	1065.81
Grants for county roads (in € per capita)	16.66	12.74	0	60.43
Herfindahl index	0.295	0.040	0.217	0.413
Share of left	31.090	7.623	10.714	50.000

Sample size: 660 observations; 44 counties over 15 years (1990-2004).

potholes, ruts and so on is included.[48] An increase in the number of accidents (meaning a deterioration in quality) is then expected to lower the costs for the provision of roads.

Since the purpose of this analysis is to investigate the determinants of technical efficiency (in road maintenance), the crucial part of the model refers to the inclusion of the exogenous variables. Concerning the characteristics of the counties, firstly a measure is included which accounts for the volume of traffic on the county roads: the average (weighted) kilometres travelled on county roads per year. This indicator is calculated out of the sum of kilometres travelled on county roads by motorcycles, cars and trucks with a maximum total weight of below and above 12 tons, each of the four categories having been given a special weight. Since higher traffic loads are associated with higher repair costs, a positive relationship between costs and average kilometres travelled is expected. Moreover, to account for the geographical location of the county, the maximum geographical point of the county is incorporated in the

[48] Note that this variable also contains accidents caused by other bad road conditions (e.g. by slippery roads). Unfortunately, a more detailed indicator was not available. In addition, the number of accidents caused by bad road conditions were available only for the total road network. But given the fact that county roads constitute 43% of the total road network (outside of built-up areas) in Baden-Württemberg, this is a minor problem.

model. Here, the hypothesis is that counties located in more hilly regions have to spend comparatively more money on the construction and maintenance of roads since the development of the landscape is much more complicated (e.g. via bridges and tunnels). Furthermore, total population of the counties (along with its squared term) is included in order to control for potential (dis)economies of scale (see Geys and Moesen, 2009a); it is assumed that expenditures increase with total population. Finally, as in the preceding approaches, the production environment is further accounted for through the inclusion of the population density, the unemployment rate as well as the number of accommodation facilities of the counties. The impact of all three variables on expenditures has been discussed in section 4.3 in the context of municipalities; on the county level, however, there should be no differences concerning the interpretation of these variables.

The main focus of this analysis, however, is on the determinants of technical or cost efficiency. Regarding this, first the per capita disposable income of the counties' citizens is included to the model, since "it is well known that incomes and wealth of citizens affect the incentives of both politicians and taxpayers to monitor expenditures" (De Borger and Kerstens, 1996a, p. 162). Higher income levels increase the fiscal capacity and therefore may foster potential inefficiencies (by the incumbents). In addition, the motivation of high-income citizens to monitor incumbents could be relatively low due to higher opportunity costs. On the other hand, as argued by Knack (2002), high-income citizens are more educated and might therefore be more effective in demanding more efficient governments. For this reason, the effect of the per capita disposable income on technical efficiency is ambiguous.

Second, variables are incorporated into the specification that account for the financing of the provision of the public goods and services (here: county roads). As pointed out by De Borger and Kerstens (1996a), higher tax burdens may increase the awareness of the citizens regarding the use of public funds. This, in turn, could lead to an increase in the monitoring activities of the populace and therefore to a decrease in the budgetary slack (or inefficiency). Moreover, recent studies for Germany and Belgium have found evidence for significant (tax) competition effects between local jurisdictions (see Buettner, 2001; Geys, 2006). One means of reducing the tax rates (due to higher tax competition), is to remove or at least to reduce potential inefficiencies. To proxy for the above-mentioned effects, the payments to the counties - which can be interpreted as a kind of tax levied by the counties (see also section 4.2) - are included in the specification.[49] Apart from the autonomously raised revenue, the counties also receive (intergovernmental) grants (see section 4.2). From the literature on the *flypaper effect* (for a review, see e.g. Hines and Thaler, 1995) it is well known that money obtained from lump-sum grants is used differently than money which stems from own income sources. In addition, the analysis of section 4.4 showed that - on the municipal level - a higher degree of redistribution within a system of fiscal equalisation fosters

[49]Since the urban counties do not receive payments from municipalities (because they are county and municipality at the same time), the revenue from the trade tax was taken to approximate the above-mentioned effects.

the incentives of the incumbents to extend organisational slack (or inefficiency). Using data on libraries and school bus transportation, Silkman and Young (1982) came to similar conclusions for the United States. Therefore, it is hypothesised that technical efficiency decreases with the amount of grants. In order to take theses effects into account, the per capita grants for county roads are added to the specification.

Furthermore, political variables are included in the model, since there are a number of reasons why politicians may lack proper incentives to effectively monitor and control public spending (see e.g. Mueller, 2003). As in the three previous approaches, a Herfindahl index of political concentration or monopolisation in the council was calculated. In contrast to the previous approaches, however, this index is calculated using the share of seats of the main national parties (from right to left: CDU, FDP, SPD and GRÜNE) and of the "free voters' unions" in the county council rather than the municipal council. As before, it is hypothesised that high political concentration is associated with lower efficiency levels, since high political concentration involves low political competition (see e.g. Besley et al., 2005). Again, a measure of ideology is incorporated into the specification: the share of seats of left-wing parties (SPD and GRÜNE) in the county council. As pointed out previously, however, the relationship between ideology and (technical) efficiency is not easy to determine a priori. Indeed, left-wing parties are often associated with preferences for higher spending, a larger government size, however, does not necessarily imply lower levels of efficiency. Therefore, the sign of this variable is ambiguous.

Finally, a dummy variable for urban counties as well as a time trend to control for time effects in the stochastic frontier and in the (second-stage) inefficiency model is added to the specification.

4.6.3 Results

The results of the four different estimation approaches are shown in the following two tables: In table 4.13 the results of the one-step procedure proposed by Battese and Coelli (1995) (columns 1 and 2) as well as the results of the two-step procedure (columns 3 and 4) are presented, where - according to equation (2.27) (with the Battese and Coelli (1992)-parameterisation) - in a first stage[50] efficiency scores are estimated and, in a second step, the efficiency scores are regressed on the exogenous variables in a pooled OLS regression. On the other hand, the effects of the exogenous variables on DEA-based efficiency estimates are shown in table 4.14, whereas the results of the Tobit regression are given in columns 1 and 2 and the results of the truncated regression with the bootstrap corrected t-values proposed by Simar and Wilson (2007) are shown in columns 3 and 4. Note that in table 4.13 (4.14) a positive signs means inefficiency (efficiency) enhancing and vice versa.[51]

[50]For the results of the first-stage stochastic frontier regression see table B.5 of Appendix B.

[51]The differences in the interpretation of the signs in table 4.13 and 4.14 are due to the fact that either the efficiency scores (lying between 0 and 1) or their reciprocals (lying between 1 and ∞) can be used as

Before we begin with the discussion on the (main) determinants of efficiency, we first consider the estimation results of the stochastic frontier in the one-step approach in table 4.13. As expected, the area of the county roads has a positive and highly statistically significant impact on total expenditures for county roads. However, the impact of the second output variable, the number of accidents due to bad road conditions approximating the quality of the county roads, is - contrary to our predictions - positive and not statistically significant. This could be due to the fact that county roads (in Baden-Württemberg) are (generally) in good condition (see Neser, 2004, p. 75) and therefore quality is of minor importance. Finally, note that a likelihood ratio test of the translogarithmic against the Cobb-Douglas functional form rejected the Cobb-Douglas function at the one percent level indicating that the (more flexible) translograrithmic model (used here) seems to be more appropriate.

Turning now to the discussion of the impact of the exogenous variables on technical or cost efficiency, tables 4.13 and 4.14 illustrate that it is first important to account for the characteristics and the production environment of the counties. More specifically, the average (weighted) kilometres travelled on county roads show the desired positive relationship with costs (due to higher costs of wear on much frequented roads) in all four specifications. Second, total population also shows a positive relationship, the coefficients of the full specifications are, however, insignificant (exception: specification (3) in table 4.14). But this changes once the variable “kilometres travelled on county roads” is removed from the model (see specifications (2) and (4) of table 4.13 and specifications (2) of table 4.14). This could be due to the fact that the kilometres travelled are a substitute for the total population.[52] Third, the influence of population density on costs is - in contrast to the three previous applications for the municipalities - not clear; indeed, three of the four specifications hint at cost advantages from agglomeration economies (see table 4.13 and specifications (3) and (4) of table 4.14), the significance of the coefficients among the specifications is, however, not very robust.

Fourth, the coefficient of the variable “accommodation facilities” shows the desired sign in all four specifications and is (mostly) highly statistically significant supporting the hypothesis of Sampaio De Sousa and Stosic (2005) that touristic regions have a greater demand for high-cost or high-quality services. This is also in line with the results of the preceding applications. Fifth, concerning the unemployment rate, three of the four specifications show a negative relationship between the unemployment rate and costs; only the truncated regression in table 4.14 points to the inverse relationship. Therefore, it can carefully be concluded that the cost effect (i.e. higher spending for unemployment benefits) outweighs the preference effect (i.e. lower demand for high-quality public services) on the county level. Note that the inverse

independent variables in the (second-stage) regression. In the present analysis, both values were used as independent variables (for the non-parametric as well as the parametric efficiency estimates) and, in a second step, the models were chosen that yielded the highest (adjusted) pseudo-R^2. The results of the (two) remaining models, however, are very similar.

[52]Note that in the truncated regression of table 4.14, the total population (along with its squared term) was removed to get a negative coefficient (which, however, is insignificant) for the kilometres travelled on county roads.

Table 4.13: Determinants of the counties' efficiency in road maintenance (parametric approach)

Variable	One-step approach (1)	(2)	Two-step approach (3)	(4)
Stochastic Frontier				
Constant	6.7679**	6.8571**	-	-
	(8.0387)	(8.0346)		
A: Area of county roads, log	2.2347**	2.2229**	-	-
	(8.6781)	(8.5072)		
B: Number of accidents due to	0.1439	0.1188	-	-
bad road conditions, log	(0.4994)	(0.3915)		
A^2	-0.0868**	-0.0881**	-	-
	(-3.4372)	(-3.2509)		
B^2	0.0457	0.0442	-	-
	(1.2728)	(1.1329)		
A*B	-0.1055**	-0.0998**	-	-
	(-2.8573)	(-2.6337)		
Inefficiency model (Characteristics)				
Constant	-4.9460**	-5.9786**	-1.5424**	-1.9363**
	(-5.3071)	(-5.6275)	(-3.4214)	(-4.5991)
Urban county	1.2917**	1.3689**	0.4840**	0.5679**
	(3.2212)	(3.3538)	(3.2589)	(3.7093)
Unemployment rate	0.0365	0.0132	0.0359**	0.0260**
	(1.2563)	(0.4935)	(3.1332)	(2.2659)
Population density	-0.0166	-0.0430**	-0.0152	-0.0296**
	(-0.7649)	(-2.0863)	(-1.2747)	(-2.5425)
Population, 1000	0.0021	0.0094**	0.0017	0.0045**
	(0.8008)	(4.4835)	(1.5408)	(5.4865)
Population, squared	-0.0000	-0.0000**	-0.0000**	-0.0000**
	(-1.9588)	(-5.0751)	(-3.5775)	(-6.7445)
Accommodation facilities	0.0022**	0.0020**	0.0007**	0.0007**
	(5.3274)	(5.1476)	(8.0395)	(7.5632)
Kilometres travelled on	0.0002**	-	0.0001**	-
county roads per year	(3.1148)		(4.1315)	
Maximum geographical	-0.0027**	-0.0027**	-0.0010**	-0.0011**
point of county	(-8.1105)	(-7.8784)	(-8.4669)	(-9.0977)
Inefficiency model (Determinants)				
Disposable income	0.0003**	0.0004**	0.0002**	0.0002**
	(7.1705)	(7.7649)	(7.4924)	(9.1871)
Payments to counties	0.0010**	0.0013**	0.0009*	0.0010*
	(2.0855)	(2.6275)	(1.6944)	(1.9603)
Grants for county roads	0.0241**	0.0277**	0.0039**	0.0063**
	(4.0151)	(4.4685)	(2.1661)	(3.4896)
Herfindahl index	-0.4356	-1.1957	0.8954*	0.6381
	(-0.4433)	(-1.1059)	(1.8979)	(1.3195)
Share of left	-0.0171**	-0.0180**	0.0062*	0.0051
	(-2.0879)	(-2.1694)	(1.8585)	(1.5438)
Sigma-squared ($\hat{\sigma}^2$)	0.2395**	0.2365**	-	-
	(7.6112)	(7.1200)		
Gamma (γ)	0.6768**	0.6762**	-	-
	(12.3088)	(11.9631)		
Log-likelihood	-222.76	-227.25	-	-
Adjusted R^2	-	-	0.45	0.44

Note: N = 660. Dependent variable of (1) and (2): total expenditures for county roads; dependent variable of (3) and (4): efficiency scores obtained from the stochastic frontier regression of total expenditures for county roads on the output variables (for the results see table B.5 of Appendix B). All specifications include time fixed effects. (Robust) t-values are given in parentheses. ** (*) denotes significance at the 5% (10%) level.

Table 4.14: Determinants of the counties' efficiency in road maintenance (non-parametric approach)

Variable	Tobit		Truncated Regression	
	(1)	(2)	(3)	(4)
Characteristics				
Constant	2.3272**	2.4574**	1.3791**	0.8687**
	(7.6584)	(8.2648)	(5.0067)	(3.5213)
Urban county	0.4264**	0.3998**	-0.3199**	-0.3717**
	(5.1512)	(4.8913)	(-4.3903)	(-6.2430)
Unemployment rate	-0.0090	-0.0059	0.0154**	0.0113*
	(-1.2346)	(-0.8315)	(2.2640)	(1.6479)
Population density	-0.0302**	-0.0256**	0.0064	0.0070*
	(-4.8975)	(-4.4995)	(1.2023)	(1.8762)
Population, 1000	-0.0002	-0.0011**	-0.0022**	-
	(-0.3422)	(-2.2798)	(-3.6922)	
Population, squared	0.0000	0.0000**	0.0000**	-
	(1.5133)	(3.1168)	(3.8005)	
Accommodation facilities	-0.0003**	-0.0003**	-0.0000	-0.0000
	(-3.6491)	(-3.5996)	(-0.3465)	(-0.5397)
Kilometres travelled on	-0.0000*	-	0.0000	-0.0000
county roads per year	(-1.9242)		(1.6043)	(-1.4763)
Maximum geographical	0.0002**	0.0002**	0.0002**	0.0002**
point of county	(2.6083)	(2.9794)	(3.3656)	(3.3750)
Determinants				
Disposable income	-0.0001**	-0.0001**	-0.0000**	-0.0000**
	(-6.3317)	(-7.3054)	(-3.9027)	(-2.6283)
Payments to counties	-0.0001	-0.0001	-0.0002	-0.0001
	(-0.5128)	(-0.7704)	(-1.3029)	(-0.6553)
Grants for county roads	-0.0040**	-0.0047**	-0.0085**	-0.0064**
	(-2.7416)	(-3.3824)	(-6.6625)	(-5.6441)
Herfindahl index	-0.3102	-0.2337	0.2650	0.2942
	(-0.9172)	(-0.6939)	(0.8428)	(0.9228)
Share of left	-0.0094**	-0.0091**	-0.0028	-0.0037*
	(-3.9710)	(-3.8336)	(-1.2839)	(-1.6860)
$\hat{\sigma}_\epsilon$	0.2512**	0.2512**	0.3062**	0.3167**
	(31.8031)	(31.1772)	(58.0588)	(60.0377)
Log-likelihood	-149.10	-150.95	-70.82	-81.65
Adjusted Pseudo-R^2	0.27	0.27	-	-

Note: N = 660. Dependent variable: efficiency indices obtained using DEA. All specifications include time fixed effects. t-values are given in parentheses. The efficiency indices and t-values of specification (3) and (4) are corrected by the bootstrap procedure ("algorithm 2") proposed by Simar and Wilson (2007) (see also section 2.3). ** (*) denotes significance at the 5% (10%) level.

relationship was obtained on the municipal level (i.e. the preference effect dominated). This could be due to the fact that it is mainly the responsibility of the counties (and not of the municipalities) to finance benefits such as housing or social welfare benefits to the unemployed people. Finally, the maximum geographical point of the counties which accounts for the geographical location of the counties has - contrary to our predictions - a positive impact on costs. One explanation for this (surprising) result could be the fact that this variable approximates the differences in road construction and maintenance between rural and urban areas (rather than just the geographical location of the counties), because (more densely populated) urban areas are more often located in flat regions. Since urban areas require bypasses (i.e. highways that redirect traffic around urban areas) more often than do (hilly) rural areas, and since bypasses often include the construction and maintenance of expensive bridges and tunnels, the expenditures for (county) roads are much higher in urban areas.

Furthermore, concerning the determinants of technical efficiency, which are the main focus of this analysis, tables 4.13 and 4.14 reveal that the disposable income of the citizens significantly reduces efficiency in all four specifications. This (very) robust result is in accordance with the findings of De Borger and Kerstens (1996a) and strongly supports the hypotheses that (1) higher income levels foster potential inefficiencies since they increase the fiscal capacity of the counties, and (2) the monitoring activities of high-income citizens are (comparatively) lower since opportunity costs are higher.

Second, the payments to the counties have - contrary to our predictions - a negative, and in the parametric approach (see table 4.13) also a (highly) significant impact on technical efficiency. One of the arguments brought forward for a positive relationship between the payments to the counties and (technical) efficiency in the previous subsection was that higher tax burdens increase the awareness of the local jurisdictions' citizens of how public funds are used, and therefore also increase monitoring activities. Since the (rural) counties consist of different municipalities which, in turn, levy own taxes (e.g. trade and property tax), the populace of the different municipalities may be more intent on monitoring the incumbents of their own municipalities (rather than those of the counties) because they may think that other citizens of other municipalities (belonging to the same county) will monitor the incumbents of the counties. In other words, the monitoring mechanism on the county level may fail. This, however, increases the possibilities for the counties' incumbents to rise budgetary slack (or inefficiency). Third, tables 4.13 and 4.14 show that the grants for the county roads reduce efficiency. Moreover, this effect is highly statistically significant in all four specifications. This (very) robust result is in accordance with the findings of section 4.4 and Silkman and Young (1982) and supports the hypothesis that intergovernmental grants stimulate the incentives of the local jurisdictions' incumbents to extend budgetary slack.

Turning now to the political variables, no clear impact of the Herfindahl index - measuring the political concentration or monopolisation of the county council - on efficiency can be identified. While the Tobit regression and the two-step approach hint at a negative relationship between political concentration and efficiency, the other two approaches point to the inverse relationship. Moreover, almost all coefficients are insignificant. Therefore, the hypothesis that efficiency increases with political monopolisation in the county council cannot be confirmed. This stands in sharp contrast to the results obtained on the municipal level. There, a strong (positive) impact of political competition on efficiency was identified (in all three applications). This finding suggests that political competition seems to be more effective on the municipal rather than on the county level. Finally, concerning the ideology measure ("share of left"), three of the four specifications show a negative and statistically significant relationship between the share of the left-wing parties in the county council and efficiency. Only the one-step approach in table 4.14 points to the inverse relationship. Therefore, it can cautiously be concluded that local governments with a high share of left-wing parties seem to be associated with higher inefficiency. This is basically in line with the results obtained in the previous applications for the municipal level.

4.6.4 Conclusion

The results of this analysis can be summarised as follows: Disposable income of the counties' citizens, intergovernmental grants (for county roads), and the payments to the counties were shown to influence (technical) efficiency negatively. In addition, the results show that (technical) efficiency decreases with an increasing share of seats of left-wing parties in the county council; on the other hand, the hypothesis that (technical) efficiency decreases with the degree of political concentration in the county council (as in the case of the municipalities) could not be confirmed. Concerning the characteristics of the counties, it was shown that costs increase with population size, the kilometres travelled on county roads per year (accounting for the volume of traffic on the county roads), and the number of accommodation facilities (approximating the degree of the regions' tourism), whereas the effect of population density is ambiguous across the different estimation specifications. Moreover, the unemployment rate was found to be weakly positively related to costs, whereas costs decrease with the maximum geographical point of the county (accounting for the geographical location of the counties).

Furthermore, the analysis shows that not all of the four estimation approaches (mentioned above) are consistent concerning both the sign of the coefficients as well as the (statistical) significance. Therefore, focusing solely on one estimation method (e.g. DEA + Tobit regression), as was done in most of the previous studies investigating local governments' (general determinants of) technical efficiency, may be deceptive. To test the robustness of the results, different estimation approaches should be applied and compared (in such a broad context). In addition, useful policy implications can be drawn from this analysis. First, the negative relationship between the grants and technical efficiency points out that the arrangement of the intergovernmental grants is important with regard to efficiency considerations. As put forward by Silkman and Young (1982) this may suggest the need "to include explicit productivity clauses and performance incentives [in grant-in-aid formulas] which link efficiency or productivity with the levels of payments"(p. 395). On the other hand, the results of section 4.4 suggest that local governments should be given more autonomy in raising their own revenue, since this could reduce fiscal illusion (which may be one source of technical inefficiency). Second, the negative relationship between the payments to the counties and technical efficiency suggests that there is a failure in the monitoring mechanism (of the citizens) on the county level. Similar to the intergovernmental grants, proxies for the efficiency of the counties could be incorporated into the design mechanism of the payments to the counties to minimise potential inefficiencies.

Chapter 5

Summary and Conclusions

The aim of this book is to investigate different aspects of the technical or cost efficiency of local governments in Germany. Thereby, technical efficiency is defined as producing as much output as possible given a certain amount of inputs ("output-orientation") or, vice versa, the usage of the minimum amount of input(s) given a certain amount of output ("input-orientation"). In contrast, cost efficiency is defined as reducing costs (e.g. for providing a certain amount of public goods and services) as much as possible given a certain amount of input(s). Investigations on the efficiency of (local) governments and its causes or determinants can be very helpful, since they provide useful information for policy makers or politicians concerning the reduction of potential inefficiencies. The elimination of potential (cost) inefficiencies, in turn, reduces (public) expenditures and therefore can help to consolidate public finances.

The literature review in chapter 3, however, revealed that there are only few studies on the efficiency of the German public sector. More specifically, there are only three studies on the efficiency of German universities (Fandel, 2007; Kempkes and Pohl, 2008, 2009), and one study on the efficiency of electricity distribution utilities (Von Hirschhausen et al., 2006), hospitals (Staat, 2006) as well as water supply utilities (Haug, 2008), respectively. Investigations on the efficiency of the public sector as a whole (e.g. of municipalities or counties), however, do not exist at all. Therefore, the main focus of this book is on different aspects of the technical or cost efficiency of local governments as a whole (*global* approaches). Using (panel) data on municipalities of the German state Baden-Württemberg, three different applications are considered: The first application focuses on the cost efficiency of the municipalities and relates the results to the negative demographic change, which will take place over the next decades in Germany. The second application examines the relationship between intergovernmental grants and cost efficiency, whereas in the third application the relationship between voter involvement (in political processes), fiscal autonomy, and cost efficiency is analysed. In addition, and in order to reduce potential measurement errors resulting from the rather "rough" approximation of the inputs and outputs in global approaches, the (general) determinants of efficiency are examined in a further application for one specific area of public goods provision: the construction and maintenance of county roads; in the latter case, (panel) data on the counties (rather than municipalities) of Baden-Württemberg are employed.

All four applications share the common feature that they use the parametric one-step approach developed by Battese and Coelli (1995) to investigate the above-mentioned relationships. Thereby, input is approximated by the total expenditures of the municipalities as well as by the expenditures for the county roads which, in turn, implies that the applications are based on stochastic cost rather than on production frontiers. In addition, the determinants of efficiency for the case of road maintenance are examined by using the two-stage procedure proposed by Simar and Wilson (2007).

The results of the first application show that, on average, the municipalities of Baden-Württemberg produce their outputs with costs that are approximately 13% to 16% (depending on the specification of the cost function) above the efficient frontier. There are two possible interpretations for this result with regard to the consequences of the negative demographic change: On the one hand, this unexploited potential of the less efficient municipalities can be seen as a "cushion" for bad times once population starts to decline. On the other hand - and this is a more pessimistic interpretation - these inefficiencies can be seen as an indicator of poor performance generally, that is, once population starts to decline, these municipalities will also have difficulties in adjusting the public services to the needs of the shrinking population. Following the latter interpretation, municipalities which are characterised by low efficiency indices should try to increase their efficiency levels, since an increase also rises the ability of the municipalities to (better) respond to adverse economic and fiscal shocks (e.g. negative demographic change). However, it should be noted, that the present analysis is not able to state how the municipalities can reduce their inefficiencies, that is whether e.g. staff costs are inefficiently high or the local governments do not choose the most competitive provider for certain tasks. The exact sources of inefficiencies can only be uncovered by conducting case studies for certain (inefficient) municipalities. In addition, a second major finding of the first analysis is that costs fall underproportionally with population size in smaller municipalities (with up to approximately 10,000 inhabitants). This implies that especially smaller municipalities are vulnerable to increasing cost pressures under a declining population. Taken together, these results provide a case for boundary reviews or increased inter-municipal cooperation in the provision of (certain) public goods among smaller municipalities. This is exactly what can be observed in reality. In 2006, 2007 and 2009 several smaller municipalities (with respect to population size) in Baden-Württemberg merged in order to establish larger administrative units (and reduce administrative costs).

The second application, by contrast, investigates the causal effects of intergovernmental grants on the cost efficiency of local governments - theoretically and empirically. Using an extension of the seminal bureaucracy model of Niskanen (1975), it is analysed how a higher degree of redistribution, that is an increase in the amount of grants to local governments, affects the technical efficiency in the provision of public goods and services in this local jurisdiction. The comparative static analysis shows that a higher degree of redistribution has a negative impact on the efficiency in the local jurisdiction. In addition, the results derived in the theoretical analysis are tested in an empirical framework using a panel of Baden-Württemberg's municipalities. The empirical results support the existence of such a (negative) incentive effect of fiscal equalisation on the cost efficiency of the local governments. Therefore, one implication of this analysis is that, in order to eliminate fiscal illusion or, in other words, to reduce the degree of inefficiency, the local governments should be given more autonomy in raising their own revenues. As discussed in the two major political initiatives to reform the most important (autonomously raised) local taxes, namely the trade tax and property tax (in 2000 and 2003), one possibility to increase the fiscal autonomy of the local governments is to abolish the trade tax and allow the municipalities to engage in the income tax and the tax on capital income via an autonomously determined collection rate (*Hebesatz*).[1] This would contribute to an increase in the fiscal autonomy of the municipalities, since the trade tax is a very volatile revenue source which depends strongly on the economic development and the number of businesses located in one municipality.

Moreover, the application on the relationship between voter involvement (in political processes), fiscal autonomy and public sector efficiency shows that higher voter involvement is on the whole associated with higher rather than with lower (cost) efficiency levels. In addition, the further results suggest that this efficiency-stimulating effect of voter involvement is significantly positively affected by local governments' fiscal autonomy. Two main policy implications can be derived from these results: Firstly, since higher levels of voter involvement seem to improve civil servants' performance, politicians should try to encourage citizens to (actively) take part in the political process (e.g. via casting a ballot). Recent figures from the Statistical Office of Baden-Württemberg, however, show that voter involvement in terms of voter turnout is decreasing: In the period considered here voter turnout of municipal council elections fell from approximately 67% in 1994 to 52% in 2004. This trend, however, is not restricted to the local level. Indeed, voter turnout also decreased on the state or federal level in Germany in the last decades. In order to combat this "voter vatigue", politicians or political groups could start campaigns - for instance in schools - to encourage more eligible voters or first-time voters to cast their ballots whenever there is an important election. Similar to the previous approach, a second possibility of reducing the degree of inefficiency is to increase the degree of local governments' fiscal (or revenue) autonomy. In such a setting, an active citizenry will pay more attention to the prudent use of public money. The way how the fiscal autonomy of the municipalities could be increased was already discussed above.

The investigation on the general determinants of efficiency on the county level, finally, reveals that the disposable income of the counties' citizens, intergovernmental grants (for county roads), and the payments to the counties reduce technical efficiency. In addition, the results show that (technical) efficiency declines with an increasing share of seats of left-wing

[1]For a general discussion about the reform of the local tax system in Germany, see Fuest and Thöne (2005).

parties in the county council. On the other hand, the hypothesis that (technical) efficiency decreases with the degree of political concentration in the county council (as in the case of the municipalities) could not be confirmed. These findings provide some food for thought in terms of their policy implications: Firstly, the negative relationship between the grants and technical efficiency points out that the arrangement of the intergovernmental grants is important with regard to efficiency considerations. In order to reduce potential inefficiencies, explicit productivity clauses and performance incentives could be incorporated into grant formulas. On the other hand, and as already mentioned above, an increase in the fiscal autonomy could also contribute to the reduction of potential inefficiencies resulting from intergovernmental grants. Secondly, the negative relationship between the payments to the counties and technical efficiency suggests that there is a failure in the monitoring mechanism (of the citizens) on the county level. It seems that the payments to the counties can be rather characterised as grants than taxes. Therefore, and similar to the intergovernmental grants, proxies for the efficiency of the counties could be incorporated into the design mechanism of the payments to the counties to minimise potential inefficiencies.

Finally, it should be noted that some of the (independent) variables used in the estimation equations in the four applications presented above may suffer from an endogeneity bias or, more specifically, from reverse causality. As already mentioned in section 4.5, the coefficients of the variables "voter turnout" and "free voter unions", for instance, may suffer from such a bias. Of course, a suitable technique to overcome this problem would be the usage of instrumental variable (IV) estimation techniques. However, the methods employed here (especially the one-step approach proposed by Battese and Coelli, 1995) do not allow for the introduction of instrumental variables. Since the "traditional" two-step approaches (see sections 2.3 and 2.5) lead to biased inferences, the one-step approach is, in my opinion, nonetheless preferable - as long as we try to make statements about the direction of the estimated coefficients rather than exact (numerical) interpretations of the coefficients. For future research, however, it would be interesting to implement estimations on the determinants of (technical) efficiency also with an instrumental variable estimation technique.

In addition, it should be kept in mind that the output and input indicators of the first three applications are only "rough" approximations of the "real" outputs and inputs. Here, of course, a more detailed reproduction of the tasks accomplished by the municipalities would be desirable. Unfortunately, this has not been possible so far due to poor data availability. Of course, the usage of a specific rather than a global approach (as in the last application for the case of road construction and maintenance) considerably reduces potential sources of measurement errors in the inputs and outputs. In future research, it would be of interest to replicate e.g. the second and third study using data from specific government outputs. Although I do not necessarily believe that the relation we observe for the local government sector as a whole must necessarily also be present for each and every government output independently, it would certainly be interesting to analyse for which government sectors the relations uncovered in the above analyses holds and for which it does not. The negative relationship between the grants and efficiency, for example, could be detected for the government sector as a whole (in section 4.4) and for one specific area of public goods provision, namely the construction and maintenance of county roads (in section 4.6).

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Appendices

Appendix A

Data Sources and Definitions

All variables employed in chapter 4 come from the Statistical Office of Baden-Württemberg (*Statistisches Landesamt Baden-Württemberg*) with the exception of the variables “area of county roads” and “maximum geographical point of county” used in section 4.6. The area of the county roads is obtained from the State Office for Street Engineering (*Landesstelle für Straßentechnik Baden-Württemberg*), the maximum geographical points of the counties by the State Surveying Office of Baden-Württemberg (*Landesvermessungsamt Baden-Württemberg*).

Furthermore, the variables “total expenditures, county roads”, “area of county roads” and “average (weighted) kilometres travelled on county roads per year” used in section 4.6 are defined as follows:

1. **Total expenditures, county roads:** These include all expenditures spent on county roads by the counties. However, according to the street law (*Straßengesetz Baden-Württemberg*), in municipalities with more than 30,000 inhabitants, the cross-town links that are classified as county roads have to be financed by the municipalities and not by the counties (art. 43, para. 3). Moreover, all other municipalities have to finance the pavements and the parking spaces of cross-town links which are classified as county roads (art. 43, para. 4). Finally, county roads can sometimes be financed by third parties (e.g. administration unions), too (art. 45, para. 2). I deal with this problem by adding all the money spent on county roads by municipalities and third parties to the expenditures of the respective county. Formally, total expenditures (exp) for county roads (cr) are then given by (dropping time subscripts and subscripts for the counties):

$$\exp^{total,\ cr} = \exp^{counties,\ cr} + \exp^{municipalities,\ cr} + \exp^{third\ parties,\ cr}.$$

2. **Area of county roads:** The area of the county roads is calculated by multiplying the length and the (average) width of the county roads (separated into cross-town links and roads outside of built-up areas), with the width including the traffic lanes and hard shoulders. Cycle tracks and pavements are not contained in the width. Unfortunately, only the width of the county roads in 1996 was available. Therefore, the width of 1996

was employed to approximate the width of the roads for the other years.[1] Formally, the area of the county roads is then calculated as follows:

$$\text{area}_{i,t}^{county\ roads} = \text{total length}_{i,t}^{county\ roads} * \text{width}_{i,1996}^{county\ roads} \quad ,$$

where i is the subscript for the counties and t is the time subscript.

3. **Average (weighted) kilometres travelled on county roads per year:** This indicator is composed of the kilometres travelled on county roads by (1) motorcycles, (2) cars, and (3) trucks with a maximum total weight of (a) below (and equal to) 12 tons and (b) above 12 tons. Since the wearing rate of roads varies (substantially) between the four types of vehicle, every of the above-mentioned categories is weighted differently. More specifically, I weighted the kilometres travelled by the four types of vehicle by the cost per kilometre caused by the respective type of vehicle (*Wegekosten*) calculated by Doll et al. (2002).[2] Then, the average weighted kilometres travelled on county roads (AWKT) are calculated as follows (dropping time subscripts and subscripts for the counties):

$$\text{AWKT} = \frac{\text{AWKT}^{mc} + 2 * \text{AWKT}^{car} + 2.5 * \text{AWKT}^{trucks \leq 12t} + 15 * \text{AWKT}^{trucks > 12t}}{\sum_{j=1}^{4} w_j},$$

where w represents the weights of the four types of vehicle.

[1] Since the width of the county roads changed only marginally in recent years, this is a minor problem.

[2] Doll et al. (2002) calculate costs of 0.02 €/kilometre for motorcycles, of 0.04 €/kilometre for cars, of 0.05 €/kilometre (0.30 €/kilometre) for trucks with a maximum total weight of below (above) 12 tons for federal highways in Germany (in 2003).

Appendix B

Tables: Estimation Results

Table B.1: Complete results of the frontier estimation of section 4.3

Variable	Cobb-Douglas		Translog	
	(1)	(2)	(3)	(4)
Stochastic frontier				
Constant (β_0)	7.0675**	7.1520**	11.6094**	10.9849**
	(54.6119)	(57.9278)	(8.0420)	(8.8920)
A: Students in public schools	-0.0122	-0.0089	-0.0850	-0.0276
	(-1.3743)	(-0.9903)	(-0.3634)	(-0.1172)
B: Kindergarten places	0.0597**	0.0634**	1.9353**	1.6295**
	(1.9752)	(2.2613)	(2.6938)	(2.3287)
C: Recovery Area	0.0178**	0.0131*	0.1359	0.1691
	(2.1837)	(1.6460)	(0.6573)	(0.8708)
D: Total population	0.8299**	0.8295**	-2.2186**	-1.9546**
	(24.2852)	(25.3933)	(-2.9795)	(-2.9150)
E: Share of population older than 65	0.0994**	0.0975**	0.0403	0.2356
	(2.5766)	(3.0774)	(0.0522)	(0.2995)
F: Number of social insured employees	0.1316**	0.1294**	1.1087**	1.0598**
	(10.8956)	(11.2646)	(4.8151)	(4.5850)
A^2	-	-	-0.0051	-0.0046
			(-0.7059)	(-0.6382)
B^2	-	-	0.0198	0.0216
			(0.4450)	(0.5007)
C^2	-	-	0.0013	0.0032
			(0.2055)	(0.5328)
D^2	-	-	0.4231**	0.3946**
			(3.9625)	(3.8066)
E^2	-	-	-0.0568	-0.0589
			(-0.3168)	(-0.3388)
F^2	-	-	0.1033**	0.0951**
			(7.0662)	(6.4597)
F*E	-	-	-0.0182	-0.0215
			(-0.2599)	(-0.3089)
F*D	-	-	-0.4025**	-0.3704**
			(-6.5330)	(-6.0614)
F*C	-	-	0.0192	0.0154
			(1.2902)	(1.0577)

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Table B.1 – continued from previous page

Variable	Cobb-Douglas		Translog	
	(1)	(2)	(3)	(4)
F*B	-	-	0.1617**	0.1467**
			(2.9089)	(2.7123)
F*A	-	-	0.0151	0.0158
			(1.0112)	(1.0501)
E*D	-	-	0.2204	0.1668
			(0.9749)	(0.7907)
E*C	-	-	0.1097*	0.0858
			(1.8675)	(1.5237)
E*B	-	-	-0.4639**	-0.3556
			(-2.0378)	(-1.6068)
E*A	-	-	0.0555	0.0316
			(0.9929)	(0.5564)
D*C	-	-	-0.0817	-0.0786
			(-1.5147)	(-1.5493)
D*B	-	-	-0.2413*	-0.2232
			(-1.6465)	(-1.5614)
D*A	-	-	-0.0267	-0.0188
			(-0.6450)	(-0.4605)
C*B	-	-	0.0127	0.0140
			(0.2698)	(0.3145)
C*A	-	-	0.0089	0.0080
			(0.8415)	(0.7562)
B*A	-	-	0.0082	-0.0047
			(0.1717)	(-0.0973)
Inefficiency model				
Constant (δ_0)	-	-3.9960**	-	-2.6085**
		(-3.8033)		(-4.9032)
Unemployment Rate	-	-0.3096**	-	-0.2561**
		(-4.1415)		(-4.7601)
Population Density	-	0.0732**	-	0.0180**
		(6.3647)		(2.4064)
Accommodation Facilities	-	0.0316**	-	0.0279**
		(4.3126)		(5.9013)
Herfindahl index	-	2.4936**	-	1.4874**
		(4.5800)		(5.0794)
Share of left	-	-0.0031	-	-0.0080**
		(-0.9963)		(-2.9065)
Sigma-squared ($\hat{\sigma}^2$)	0.0737**	0.5334**	0.0613**	0.3664**
	(16.6900)	(4.3066)	(16.0723)	(6.0075)
Gamma (γ)	0.8689**	0.9755**	0.8350**	0.9630**
	(43.7066)	(190.6747)	(36.9221)	(135.4187)
Log-likelihood	296.25	365.85	358.93	414.95
Cobb-Douglas vs. tranlogarithmic	-	-	125.36	98.19

Note: N = 1022. All variables are in natural logs except the variables of the inefficiency model. t-values are given in parentheses; ** (*) denotes significance at the 5% (10%) level. Cobb-Douglas vs. translogarithmic tests the restriction that the coefficients for all quadratic and cross-product terms are jointly insignificant. Both tests have a χ^2-distribution. The results are obtained using FRONTIER 4.1 (Coelli, 1996b).

Table B.2: Complete results of the frontier estimation of section 4.4

Variable	**Translog** (1)	**Cobb-Douglas** (2)
	Stochastic frontier	
Constant (β_0)	8.3308**	6.3365**
	(7.6637)	(92.8964)
A: Students in public schools	0.6218	-0.1042**
	(1.5662)	(-6.9166)
B: Total Population	-0.7061	0.0286*
	(-1.4636)	(1.8029)
C: Share of population older than 65	0.2981	-0.0152
	(0.6275)	(-0.8436)
D: Number of social insured employees	-0.4393*	0.1500**
	(-2.2049)	(21.6474)
E: Recovery Area	0.3238**	0.0047
	(2.6256)	(1.0680)
A^2	0.0801	-
	(1.2610)	
B^2	0.0044	-
	(0.0592)	
C^2	-0.1026	-
	(-1.3724)	
D^2	0.0477**	-
	(3.8634)	
E^2	0.0254**	-
	(4.6239)	
A*B	0.0096	-
	(0.0797)	
A*C	-0.2153*	-
	(-2.0287)	
A*D	-0.0563	-
	(-1.3021)	
A*E	-0.1048**	-
	(-3.4756)	
B*C	0.1958*	-
	(1.8423)	
B*D	-0.0112	-
	(-0.2224)	
B*E	0.0091	-
	(0.2899)	
C*D	0.0625	-
	(1.4124)	
C*E	-0.0829**	-
	(-2.7055)	
D*E	0.0154	
	(1.3177)	
Year1	0.0141**	0.0135**
	(21.2349)	(24.4005)
	Inefficiency model	
Constant (δ_0)	-4.4927**	-4.6840**
	(-15.7318)	(-6.6462)

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Table B.2 – continued from previous page

Variable	**Translog** (1)	**Cobb-Douglas** (2)
Grants	0.0014**	0.0014**
	(9.5057)	(7.4171)
Abundant municipality	2.6919**	2.8225**
	(14.7291)	(6.9300)
Financially weak municipality	0.8019**	0.8563**
	(7.1502)	(6.0858)
Unemployment Rate	-0.0271**	-0.0131*
	(-5.3756)	(-2.5538)
Population Density	-0.0104**	-0.0054*
	(-2.9481)	(-2.2538)
Students at university	-0.0362**	0.0083*
	(-3.5782)	(2.2066)
Accommodation Facilities	0.0096**	0.0105**
	(7.5573)	(7.3697)
Herfindahl index	2.4637**	2.4308**
	(11.0895)	(8.0659)
Share of left	0.0135**	0.0136**
	(10.2378)	(5.8140)
Year2	0.0379**	0.0356**
	(7.0673)	(7.5478)
Sigma-squared ($\hat{\sigma}^2$)	0.1628**	0.1648**
	(13.3290)	(8.0811)
Gamma (γ)	0.9352**	0.9316**
	(143.6191)	(113.7242)
Log-likelihood	2279.94	2174.78

Note: N = 3675. Dependent variable: Net current primary expenditures per capita. The dependent and output variables as well as the variable students at university are in natural logs. t-values are given in parentheses. ** (*) denotes significance at the 5% (10%) level. The variables "year1" and "year2" account for both technical change in the stochastic frontier and time-varying inefficiency effects. The results were obtained using FRONTIER 4.1 (Coelli, 1996b).

Table B.3: Complete results of the frontier estimation of section 4.5

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
				Stochastic frontier				
Constant (β_0)	13.0831**	13.0077**	13.1690**	13.2472**	12.9712**	12.9762**	12.9268**	12.8570**
	(17.3273)	(17.3178)	(17.5426)	(17.6644)	(17.0529)	(17.2719)	(17.0307)	(16.7663)
A: Students in	0.1297	0.1261	0.1447	0.1556*	0.1272	0.1285	0.1469	0.1416
public schools	(1.4091)	(1.3491)	(1.5744)	(1.6834)	(1.3744)	(1.3627)	(1.6144)	(1.5521)
B: Kindergarten	0.5836*	0.6137*	0.6094*	0.5807*	0.5630*	0.5836*	0.5527*	0.5196**
places	(2.1895)	(2.3180)	(2.2803)	(2.2498)	(2.1181)	(2.2088)	(2.1213)	(1.9782)
C: Recovery Area	0.4265**	0.4189**	0.4110**	0.4097**	0.4358**	0.4241**	0.4275**	0.4220**
	(3.7748)	(3.7472)	(3.6441)	(3.6851)	(3.9515)	(3.7747)	(3.9533)	(3.8607)
D: Total population	-2.1708**	-2.1479**	-2.2452**	-2.3001**	-2.0837**	-2.1281**	-1.9993**	-1.9585**
	(-3.8502)	(-3.8262)	(-3.9976)	(-4.0987)	(-3.6670)	(-3.7923)	(-3.4750)	(-3.3432)
E: Population	0.4689	0.4569	0.4981	0.5565	0.4123	0.4533	0.2912	0.2928
older than 65	(1.0869)	(1.0722)	(1.1627)	(1.3154)	(0.9731)	(1.0619)	(0.6793)	(0.6703)
F: Number of social	0.7946**	0.7794**	0.8180**	0.8230**	0.7812**	0.7842**	0.8121**	0.8171**
insured employees	(5.1448)	(5.0693)	(5.3491)	(5.3313)	(5.1547)	(5.0996)	(5.4090)	(5.4716)
A^2	-0.0053	-0.0055	-0.0045	-0.0042	-0.0051	-0.0055	-0.0042	-0.0045
	(-1.3451)	(-1.4093)	(-1.1445)	(-1.0776)	(-1.3191)	(-1.3951)	(-1.1150)	(-1.1862)
B^2	0.0243**	0.0256**	0.0250**	0.0250**	0.0239**	0.0242*	0.0246*	0.0245**
	(2.5927)	(2.4510)	(2.6013)	(2.7472)	(2.4644)	(2.4970)	(2.5470)	(2.6230)
C^2	0.0022	0.0026	0.0027	0.0029	0.0021	0.0025	0.0024	0.0028
	(0.5882)	(0.7302)	(0.7046)	(0.7739)	(0.6026)	(0.7076)	(0.6746)	(0.7857)
D^2	0.3614**	0.3618**	0.3764**	0.3879**	0.3441**	0.3569**	0.3222**	0.3172**
	(3.0547)	(3.0646)	(3.1935)	(3.2825)	(2.9090)	(3.0275)	(2.6795)	(2.5892)
E^2	-0.0439	-0.0354	-0.0406	-0.0280	-0.0463	-0.0373	-0.0666	-0.0593
	(-0.5818)	(-0.4743)	(-0.5415)	(-0.3721)	(-0.6374)	(-0.5017)	(-0.9188)	(-0.8033)
F^2	0.0480**	0.0485**	0.0485**	0.0472**	0.0481**	0.0494**	0.0490**	0.0491**
	(5.2278)	(5.2535)	(5.2462)	(5.2196)	(5.3775)	(5.3744)	(5.4751)	(5.5137)
F*E	0.0520	0.0486	0.0633*	0.0651*	0.0478	0.0475	0.0588	0.0580
	(1.3939)	(1.3297)	(1.7040)	(1.7959)	(1.3037)	(1.2870)	(1.6052)	(1.6002)
F*D	-0.3014**	-0.2977**	-0.3102**	-0.3109**	-0.2966**	-0.2977**	-0.3061**	-0.3072**
	(-5.2010)	(-5.1877)	(-5.4021)	(-5.3834)	(-5.2233)	(-5.1659)	(-5.4184)	(-5.4888)
F*C	0.171*	0.0161*	0.0156*	0.0157*	0.0170*	0.0168*	0.0163*	0.0166**
	(1.9666)	(1.8674)	(1.8026)	(1.8185)	(2.0280)	(1.9568)	(1.9388)	(1.9691)
F*B	0.1326**	0.1346**	0.1298**	0.1301**	0.1332**	0.1321**	0.1283**	0.1291**
	(4.2382)	(4.2850)	(4.1563)	(4.1632)	(4.3391)	(4.1842)	(4.1667)	(4.2181)
F*A	0.0105	0.0098	0.0089	0.0096	0.0098	0.0099	0.0091	0.0093
	(1.1284)	(1.0370)	(0.9661)	(1.0206)	(1.0839)	(1.0365)	(1.0098)	(1.0253)
E*D	0.0452	0.0388	0.0271	0.0018	0.0649	0.0437	0.1084	0.1037
	(0.2438)	(0.2109)	(0.1471)	(0.0098)	(0.3597)	(0.2381)	(0.5960)	(0.5598)
E*C	0.0921**	0.0890**	0.0893**	0.0863**	0.0941**	0.0897**	0.0925**	0.0884**
	(3.1953)	(3.1064)	(3.0789)	(3.0808)	(3.3635)	(3.1277)	(3.3370)	(3.1660)
E*B	-0.2060*	-0.2069*	-0.1940*	-0.1983*	-0.2165*	-0.2082*	-0.2199*	-0.2247**
	(-2.3771)	(-2.3975)	(-2.2362)	(-2.2633)	(-2.5143)	(-2.4103)	(-2.5469)	(-2.5926)
E*A	-0.0088	-0.0100	-0.0133	-0.0093	-0.0101	-0.0097	-0.0128	-0.0124
	(-0.3407)	(-0.3837)	(-0.5206)	(-0.3576)	(-0.3885)	(-0.3651)	(-0.4970)	(-0.4868)
D*C	-0.1310**	-0.1279**	-0.1265**	-0.1243**	-0.1345**	-0.1297**	-0.1322**	-0.1287**
	(-3.0948)	(-3.0644)	(-2.9988)	(-3.0309)	(-3.2680)	(-3.0891)	(-3.2643)	(-3.1474)
D*B	-0.0538	-0.0600	-0.0635	-0.0566	-0.0433	-0.0517	-0.0359	-0.0268
	(-0.5971)	(-0.6694)	(-0.7037)	(-0.6304)	(-0.4764)	(-0.5761)	(-0.3971)	(-0.2937)
D*A	-0.0441	-0.0417	-0.0421	-0.0461	-0.0418	-0.0426	-0.0422	-0.0404
	(-1.2612)	(-1.1776)	(-1.2199)	(-1.3327)	(-1.1822)	(-1.1886)	(-1.2166)	(-1.1637)
C*B	-0.0202	-0.0197	-0.0205	-0.0201	-0.0189	-0.0198	-0.0184	-0.0190
	(-0.9299)	(-0.9095)	(-0.9382)	(-0.9309)	(-0.8788)	(-0.9018)	(-0.8572)	(-0.8880)
C*A	0.0092	0.0088	0.0093	0.0087	0.0094	0.0092	0.0090	0.0089
	(1.5046)	(1.4362)	(1.5172)	(1.4835)	(1.6267)	(1.4981)	(1.5559)	(1.5393)
B*A	0.0400*	0.0394	0.0388*	0.0376*	0.0383	0.0397	0.0377	0.0355
	(1.6878)	(1.6348)	(1.6513)	(1.6641)	(1.6187)	(1.6374)	(1.6169)	(1.5288)
Year1	0.0339**	0.0344**	0.0332**	0.0324**	0.0352**	0.0357**	0.0328**	0.0324**
	(8.3878)	(8.7181)	(7.4540)	(7.4079)	(7.5768)	(8.7792)	(6.7549)	(6.5178)
				Inefficiency model				
Constant (δ_0)	-1.6025**	-1.1508**	3.1445**	4.0774**	-1.6503**	-1.9804**	2.9785**	3.1532**
	(-4.1933)	(-3.3095)	(9.4701)	(7.5925)	(-3.7218)	(-3.8106)	(5.3281)	(5.3604)
Unemployment Rate	-0.0247**	-0.0514**	-0.0439**	-0.0365**	-0.0235**	-0.0490**	-0.0410**	-0.0409**

Continued on next page

Table B.3 – continued from previous page

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	(-3.5136)	(-6.7206)	(-5.7417)	(-4.5828)	(-2.5856)	(-6.8962)	(-4.3281)	(-4.1713)
Population Density	-0.0555**	-0.0464**	-0.0485**	-0.0409**	-0.0529**	-0.0468**	-0.0447**	-0.0427**
	(-6.3933)	(-7.4453)	(-7.4488)	(-5.9351)	(-5.8337)	(-7.6972)	(-5.9409)	(-5.7470)
Herfindahl index	0.3453**	0.1254**	0.1264**	0.0036	0.3317**	0.1607**	0.1343*	0.0118
	(5.0724)	(2.4019)	(2.6597)	(0.0779)	(3.8551)	(2.6988)	(2.0125)	(0.1834)
Share of left	-0.0025**	-0.0090**	-0.0015	-0.0058**	-0.0015	-0.0090**	-0.0005	-0.0066**
	(-2.4930)	(-4.9833)	(-1.4163)	(-4.4367)	(-1.2759)	(-4.0450)	(-0.4546)	(-4.6701)
Dummy abundant	2.5062**	2.2549**	1.7430**	1.6732**	2.7270**	3.3852**	1.1467*	2.5648**
municipality (AM)	(6.1182)	(6.0632)	(7.6678)	(6.4256)	(5.3425)	(5.9887)	(1.9620)	(3.9890)
Voter turnout (VT)	-0.0124**	-	-	-0.0045**	-0.0056**	-	-	-0.0010
	(-4.6643)			(-2.4775)	(-2.4660)			(-0.4705)
Dummy free voters'	-	-0.6658**	-	-0.5210**	-	0.1469**	-	0.0545
unions (FVU)		(-6.5112)		(-6.1659)		(2.3723)		(0.6892)
Ratio eligible voters	-	-	-0.0631**	-0.6020**	-	-	-0.0608**	-0.0607**
(EV)/population (POP)			(-8.0803)	(-6.4779)			(-5.3781)	(-5.3160)
AM * VT	-	-	-	-	-0.0079*	-	-	-0.0052
					(-2.0309)			(-1.5209)
AM * FVU	-	-	-	-	-	-1.2045**	-	-0.8644**
						(-5.7661)		(-5.5882)
AM * RatioEV/POP	-	-	-	-	-	-	0.0078	0.0043
							(0.8322)	(0.4811)
Year2	-0.1326**	-0.0945**	-0.0131	-0.0411*	-0.1359**	-0.0949**	-0.0101	-0.0318
	(-5.2779)	(-5.8795)	(-0.9589)	(-2.4968)	(-4.5517)	(-6.1454)	(-0.5494)	(-1.4257)
Sigma-squared ($\hat{\sigma}^2$)	0.2976**	0.2689**	0.2113**	0.1976**	0.2499**	0.2693**	0.1984**	0.1981**
	(6.5733)	(6.5343)	(8.2073)	(6.8306)	(6.5530)	(6.1351)	(7.7788)	(7.5684)
Gamma (γ)	0.9559**	0.9518**	0.9392**	0.9334**	0.9470**	0.9517**	0.9349**	0.9335**
	(140.2274)	(139.0069)	(131.9161)	(96.7381)	(119.0643)	(116.1515)	(103.7188)	(114.5398)
Log-likelihood	1393.22	1394.94	1399.64	1403.48	1391.88	1397.87	1399.75	1406.78

Note: N = 2961. Dependent variable: net current primary expenditures. The dependent as well as the output variables are in natural logs. t-values are given in parentheses; ** (*) denotes significance at the 5% (10%) level. The variables "year1" and "year2" account for technical change in the stochastic frontier as well as time-varying inefficiency effects. The results were obtained using FRONTIER 4.1 (Coelli, 1996b).

Table B.4: Sensitivity analysis: Estimation results of section 4.5 with an alternative definition of the municipalities' expenditure

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Unemployment Rate	-0.0245**	-0.2449**	-0.1473**	-0.0272**	-0.0362**	-0.2249**	-0.2208**	-0.1412
	(-3.6669)	(-3.1444)	(-5.3444)	(-3.9264)	(-4.6356)	(-3.1408)	(-3.6254)	(-1.0844)
Population density	0.0010	0.0098*	0.0033	0.0008	0.0033	0.0115**	0.0074*	0.0042
	(1.3341)	(1.6863)	(0.7970)	(0.3824)	(1.1387)	(2.2251)	(1.8273)	(0.4622)
Herfindahl index	0.0882**	0.7770**	0.5060**	0.1101**	0.1206**	0.6613**	0.7347**	0.4473
	(2.4189)	(3.4419)	(5.7243)	(2.5103)	(2.6476)	(3.0193)	(3.2288)	(1.1675)
Share of left	0.0010**	0.0003	0.0019*	0.0014*	0.0002	0.0001	0.0009	-0.0011
	(4.9282)	(0.2293)	(1.7175)	(1.8311)	(0.2313)	(0.0893)	(0.9103)	(-0.3233)
Dummy abundant municipality (AM)	0.0753**	0.4933**	0.3087**	0.0849**	0.1533	1.3621**	6.3988**	6.3984
	(4.7770)	(3.4264)	(6.6730)	(4.5565)	(0.8899)	(3.4727)	(2.2542)	(1.1081)
Voter turnout (VT)	-0.0035**	-	-	-0.0042**	-0.0046**	-	-	-0.0117*
	(-3.7717)			(-2.8652)	(-2.5355)			(-1.7070)
Dummy free voters' union (FVU)	-	-0.2463**	-	0.0025	-	0.1512**	-	0.1302
		(-2.0133)		(0.0717)		(2.3611)		(1.0648)
Ratio eligible voters/population	-	-	-0.0067**	-0.0032	-	-	0.0130**	0.0061
(Ratio EV/POP)			(-2.1565)	(-1.4963)			(2.2831)	(0.5257)
AM * VT	-	-	-	-	-0.0004	-	-	-0.0114
					(-0.1486)			(-0.9709)
AM * FVU	-	-	-	-	-	-1.0142**	-	-0.8319
						(-3.4911)		(-1.1610)
AM * Ratio EV/POP	-	-	-	-	-	-	-0.0826**	-0.0638
							(-2.1667)	(-1.0899)
Sigma-squared	0.0312**	0.1491**	0.0973**	0.0309**	0.0369**	0.1296**	0.1427**	0.0978
	(205.4895)	(3.3643)	(6.5987)	(27.9620)	(11.0568)	(3.3156)	(3.1744)	1.3796
Gamma	0.0096	0.8371**	0.7518**	0.0167	0.2771**	0.8127**	0.8318**	0.7510**
	(0.0919)	(16.0853)	(18.8513)	(0.5868)	(3.2544)	(14.0780)	(14.7760)	(4.0978)
Log-likelihood	949.44	946.84	946.21	951.27	948.58	950.10	949.24	956.44

Note: N=2961. Dependent variable: total expenditures for the output factors defined in subsection 4.5.3: (1) total population includes the expenditures on general administration, (2) number of students includes the expenditures on schools, (3) number of kindergarten places and (4) population over age 65 include parts of the expenditures on social security, (5) surface of public recreational facilities includes the expenditures on recovery, and (6) number of employees paying social security contributions includes the expenditures on business development. For the shares of the different expenditure categories see table 4.4. ** (*) denotes significance at the 5% (10%) level.

Table B.5: Results of the first stage frontier estimation of section 4.6

Variable	
Constant	8.1160**
	(8.2819)
A: Area of county roads, log	1.7123**
	(5.3731)
B: Number of accidents due to	-0.0170
bad road conditions, log	(-0.0589)
A^2	-0.0224
	(-0.6629)
B^2	0.0732**
	(1.9690)
A*B	-0.1213**
	(-2.9633)
Log-likelihood	-234.89
Adjusted Pseudo-R^2	0.21

Note: N = 660. Dependent variable: total expenditures for county roads. t-values are given in parentheses. ** (*) denotes significance at the 5% (10%) level.

Appendix C

Synoptic Table: Literature Review on Efficiency Studies in the Public Sector

Table C.1: Overview of the studies on the technical and cost efficiency of the public sector - ordered by responsibilities

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
Culture					
Chen (1997)	DEA	23 university libraries in Taipei, Taiwan, 1995.	*Inputs:* library staff, book collection, book acquisition expenditure, area of library space, seating capacity. *Outputs:* reader visits or attendance, book circulation, reference transaction and online search, reader satisfaction, annual service hours, interlending service.	-	From the 23 university libraries, 11 libraries were found to operate efficiently. 9 out of these 11 universities have relatively high academic research functions.
Hemmeter (2006)	SFA	3308 libraries, USA, 1994-2001.	*Inputs:* total operating expenditures (expenditures on staff, collection and other operating expenditures); fixed inputs: collection size, total number of outlets; input prices: yearly salary of librarians, average benefits, price index for other operating expenditures. *Outputs:* book circulation, total yearly hours open, number of visits per collection size.	Number of large bookstores and other libraries, dummies for library internet access and type of library, percentage of income from local and other sources, population classes, staff ratio. *Embedding:* second-stage Tobit regression.	The results suggest that competition, regardless of its source, does not have a large effect on cost efficiency. Moreover, nonprofit libraries seems to be more inefficient than public libraries, and efficiency increases for smaller libraries the larger the share of their budget from local sources.
Sharma et al. (1999)	DEA	47 public libraries in Hawaii, USA, 1996-1997.	*Inputs:* book collection, library staff (in full time equivalents), days open, annual non-personnel operating expenditures. *Outputs:* book circulation, reader visits, reference transactions.	Total floor area, size of collection, type of operation, population density, location. *Embedding:* division of the libraries in specific groups.	The estimated overall technical (pure technical, allocative) mean efficiency scores for the libraries are 0.77 (0.81, 0.96). From the 47 libraries 14 are deemed to be efficient.
Silkman and Young (1982)	Quasi-Minimum Total Cost Frontier	773 public libraries, USA, 1977-1978.	*Inputs:* total operating expenditures. *Outputs:* number of volume-hours (=total numbers of volumes held · number of hours the libraries are opened).	Locally raised revenue, median family income, median property value, population density, number of branches, grants. *Embedding:* second-stage OLS regression.	The main result suggest that inefficiency increases with the (local) share of grant-dependence - suggesting the presence of fiscal illusion and/or collective incentive accountability effects.

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
Stevens (2005)	DEA, SFA	Libraries, England, 1998.	*Inputs:* net expenditure on libraries. *Outputs:* number of books issued by the authority's libraries, number of other items issued by the authority's libraries, number of visits to public libraries, Number of books and recordings available in the council's libraries.	Population density, percentage of population who are income deprived, with English as a second language, aged between 5-15, and over 65, dummy variable for region. *Embedding:* second-stage Tobit regression and one-step approach.	The mean efficiency scores range from 0.65 (DEA) to 0.97 (SFA) depending on the specification used. Moreover, efficiency decreases with the percentage of the population that is income deprived.
Vitaliano (1997)	SFA	235 public libraries in New York State, USA, 1992.	*Inputs:* total costs; input prices: librarian's starting salary, director's salary. *Outputs:* total circulation of books, serials and non-book items, weekly hours of operation, number of books added during the year, total holdings (of books, serials, etc.).	Dummy variable for type of library, sources of library funding, population served. *Embedding:* second-stage Tobit regression.	The results suggest that the libraries operate at cost which are approximately 24% above the efficient level. Moreover, the author find that public libraries are more inefficient than private not-for-profits ones.
Vitaliano (1998)	DEA	184 public libraries in New York State, USA, 1992.	*Inputs:* total holdings of all items (books, audiovisuals, maps, etc.), hours of operation, new books purchased, total serial subscriptions. *Outputs:* total circulation of books, reference questions answered (proxy for the in-library use of materials).	Dummy variable for type of library, librarian's starting salary, director's salary, population served. *Embedding:* second-stage Tobit regression.	The results suggest that, on average, the libraries could reduce their inputs by one third without reducing outputs. The main source of inefficiency are too long opening hours of the libraries.
Worthington (1999)	DEA	168 libraries in New South Wales, Australia, 1993.	*Inputs:* gross library expenditure. *Outputs:* library issues.	Population, area, proportion of non-residential borrowers, of residents with non-English speaking background, that are aged or students, socioeconomic index, location dummies. *Embedding:* second-stage Tobit regression	Libraries which are located in non-metropolitan, costal and rural areas are found to be more efficient. Moreover, (pure) technical library efficiency decreases with population size.

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
Education					
Afonso and St. Aubyn (2005)	DEA, FDH	17 (mostly) OECD countries in 2000.	*Inputs:* number of teachers per student, time the 12- to 14- year-olds spent at school. *Outputs:* PISA results of 15-year-olds in mathematics, reading and science.	-	The mean efficiency scores range from 0.83(DEA) and 0.94 (FDH).
Afonso and St. Aubyn (2006)	DEA	25 (mostly) OECD countries in 2003.	*Inputs:* number of teachers per student, time the 12- to 14- year-olds spent at school. *Outputs:* PISA results of 15-year-olds in mathematics, problem solving, reading, and science.	GDP per head, parent's educational attainment. *Embedding:* second-stage tobit regression and truncated regression.	On average, countries could increase their results by 11.6% using the same resources; GDP per head and parent's educational attainment influences performance positively.
Avkiran (2001)	DEA	36 universities, Australia, 1995.	*Inputs:* academic staff, non-academic staff (full-time equivalents, respectively). *Outputs:* undergraduate enrolments, postgraduate enrolments, research quantum, student retention rate, student progress rate, graduate full-time employment, overseas fee-paying enrolments, non-overseas fee-paying enrolments.	-	The mean technical efficiency scores of the universities range from 0.64 to 0.97 depending on the specification used.
Banker et al. (2004)	DEA	585 Texas school districts, USA, 1993-1999.	*Inputs:* operating expenditures (instruction, administration, support). *Outputs:* total school enrolment in elementary schools, middle schools and high schools.	-	The results suggest that technical inefficiency increased over the six year period, while allocative efficiency remained relatively stable.
Bates (1993)	DEA, OLS	96 Local Education Authorities, England, 1980-1983.	*Inputs:* teaching expenditure, non-teaching expenditure *Outputs:* examination results (O-level, GCSE-exams, A-level).	-	The results obtained by the two methods are similar: The top seven Local Education Authorities as judged by the OLS regressions also obtain efficiency scores of one in the Data Envelopment Analysis.
Bessent et al. (1982)	DEA	167 elementary schools in Houston, USA, 1978.	*Inputs:* previous year's achievement scores (2nd and 5th grades), percentage of non-minority enrolment, attendance and students paying full lunch price, number of professionals and special programmes in school, local and state expenditures, federal money allocated, percentage of teachers with masters degrees and more than 3 years experience, percent of teaching days the teachers were present in the classroom. *Outputs:* mean of the composite score for grade three and six.	-	Of the 167 schools, 78 were found to be inefficient.

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
Bonesrønning and Rattsø (1994)	DEA	34 Norwegian high schools.	*Input:* number of teachers man-years. *Outputs:* number of graduates of the school, average value added.	-	School size and efficiency are positively correlated. Large and medium sized schools achieve high efficiency scores, while small comprehensive schools are inefficient within this group.
Cooper and Cohn (1997)	SFA, OLS	541 classes in South Carolina, USA.	*Inputs:* years of teaching experience, number of students in class, grade level of students. *Outputs:* gain scores on standardized tests designed to measure reading and math achievement.	Sex, race, percentage of students who are female, black and receive free lunch *Embedding:* included in the production frontier (as input indicators).	The mean efficiency scores range from 0.79 to 0.95 depending on the specification used.
Deller and Rudnicki (1992)	SFA, OLS	147 public elementary schools in Maine, USA, 1985-1989.	*Inputs:* average total school expenditure; input prices: male and female teacher salaries, administration expenses per pupil, operations and maintenance expenditures per pupil. *Outputs:* cumulative test achievement scores.	Percentage of parents with a college diploma, school size *Embedding:* included in the cost frontier (as output variables)	The results suggest that managerial inefficiencies may be incorrectly attributed to size economies. Smaller schools appear to exhibit higher levels of managerial inefficiency.
Duncombe et al. (1997)	DEA	585 school districts, New York State, USA, 1990-1991.	*Inputs:* district level approved operating expenses per pupil. *Outputs:* average PEP (Pupil Evaluation Program) test scores (reading, math, social studies).	Environmental and teacher salary index, total enrolment, percentage of children in poverty, households with school age children, adults with college degree, single parent female households, children at risk and students with limited English proficiency. *Embedding:* second-stage Tobit regression.	12% of the districts were identified as cost efficient. Efficiency decreases with school district size, district wealth, nonresidential property values, labour intensity and the percentage of tenured teachers. Efficiency increases with the percentage of adults who are college educated.
Färe et al. (1989b)	DEA variant	40 school districts in Missouri, USA, 1985-1986.	*Inputs:* number of 8th graders taking the BEST (Basic Essential Skills Test), net current expenditures, net assessed valuation, number of 8th grade teachers *Outputs:* number of students passing the three subsections of the BEST.	-	Efficiency values range from 0.95 to 1, with more than half of the observations deemed to be efficient.
Fandel (2007)	DEA	15 universities in North Rhine-Westphalia, Germany, 1997.	*Inputs:* number of students, number of personnel, outside funding. *Outputs:* number of graduates, number of doctorates.	-	The mean efficiency scores range from 0.92 (Natural Science) to 0.97 (Engineering Sciences).

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
Glass et al. (1998)	DEA	54 publicly-funded universities, UK, 1989-1992.	*Inputs:* labour (academic staff, academic-related staff and other staff) and capital (net assets), research grant income. *Outputs:* research, postgraduate teaching and undergraduate teaching.	-	Overall efficiency in the university system has, on average, increased by 3% during period considered.
Grosskopf et al. (1997)	Cost-indirect output distance function	310 school districts in Texas, USA, 1988-1989.	*Inputs:* various inputs: expenses for school administrators, school teachers, school support staff, teacher aides; fixed inputs: fraction of the student body that is Asian, Black, Hispanic or that is receiving free or reduced-price lunches, percentage change in the size of the grade between 1987 and 1989. *Outputs:* the output measure is constructed using the Test scores of TEAM (Texas Educational Assessment of Minimum Skills) in mathematics, reading and writing.	-	The mean efficiency score of the school districts is 0.71. The analysis demonstrates that budgetary reforms designed to equalise expenditures could actually increase the inequality of student achievment.
Grosskopf et al. (1999)	DEA	244 school districts in Texas, USA, 1988-1989.	*Inputs:* variable inputs: number of teachers, number of administrators, number of teaching aides, number of professional support staff; quasi-fixed inputs: fraction of the student body that is non-Hispanic White, Hispanic or that is receiving free or reduced-price lunches, percentage change in the size of the grade between 1987 and 1989. *Outputs:* the output measure is constructed using the Test scores of TEAM (Texas Educational Assessment of Minimum Skills) in mathematics, reading and writing.	-	The results indicate that removing personnel restrictions would, on average, encourage many school districts to substitute teacher aides for teachers, administrators and professional staff.
Grosskopf et al. (2001)	Shepard-type distance function	302 school districts in Texas, USA, 1996-1997.	*Inputs:* variable inputs: number of teachers, number of administrators, number of teacher aides, number of support personnel; Fixed inputs: fraction of the student body that is Asian, Black, Hispanic or that is receiving free or reduced-price lunches, percentage increase in cohort size between 1995 and 1997, change in the share of students in a certain ethnic group. *Outputs:* the output measure is constructed using the Test scores of TAAS (Texas Assessment of Academic Skills) in mathematics and reading.	Two measures for the degree of competition for students, effective tax rate, share of occupied housing that is owner-occupied, share of population over 20 that attended at least some college and that completed high school but did not attend college, school district enrolment in all grades, share of households that have school age children. *Embedding:* second-stage ML-regression.	Texas school districts could reduce inputs by roughly 20 percent without reducing measured output. Technical inefficiency is lower in school districts with higher proportions of homeowners, highly educated individuals, and households with school-age children. An increased competition for enrollments could enhance the allocative efficiency.

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
Johnes (2006)	DEA	109 Universities in the UK, 2000-2002.	*Inputs:* index for undergraduate students, number of postgraduate students and full-time academic staff, total depreciation and interest, total expenditure on central libraries, information services, central computer and computer networks, expenditure on central administration. *Outputs:* number of first degrees awarded weighted by degree classification, number of higher degrees awarded, research grants.	-	The results suggest that the level of efficiency in English universities is relatively high.
Kempkes and Pohl (2008)	SFA	67 German universities, 1998-2003.	*Inputs:* total costs (without third party funds); input price: wages. *Outputs:* number of graduates, acquired third-party funds.	Students of different faculty groups, institutional and regional dummies, variable for type of graduates, share of population aged 18–35. *Embedding:* one-step approach.	The results suggest that more liberal state regulation is significantly linked to higher efficiency levels while a restrictive framework is associated with lower efficiency levels.
Kempkes and Pohl (2009)	DEA, SFA	72 German universities, 1998-2003.	*Inputs:* number of technical and research personnel, financial means, total costs (without third party funds); input price: wages. *Outputs:* number of graduates, amount of research grants.	Faculty composition, GDP per capita, dummy variables for engineering and medical faculties. *Embedding:* second-stage Tobit and OLS regression (DEA) and one-step approach.	The results suggest that Eastern German universities are less efficient than Western German universities. Regional GDP per capita has a small but positive influence on the efficiency of higher education institutions.
Kirjavainen and Loikkanen (1998)	DEA	291 Finnish senior secondary schools, 1988-1991.	*Inputs:* teaching hours per week, non-teaching hours per week, experience of teachers, education of teachers, admission level, educational level of student's parents. *Outputs:* number of students who passed their grade, number of graduates, score in compulsory subjects in matriculation examination, score of additional subjects in matriculation examination.	School size, class size, school type, grants, sex, heterogeneity of students, type of municipality, parents' education. *Embedding:* second-stage Tobit regression.	The mean efficiency scores range from 0.66 to 0.94 depending on the specification used. Inefficiency decreases with class size and parents' education. Private schools were found to be more inefficient than public schools.
Mancebon and Muniz (2008)	DEA	293 high schools in Spain, 2001-2002.	*Inputs:* percentage of pupils whose father is a white-collar worker, percentage of pupils who usually study more than 10 hours a week. *Outputs:* percentage of passes in the university entrance programme, average grade obtained.	-	The results suggest that the efficiency scores of private schools are (mostly) higher than those of public schools. This is not the consequence of comparatively more effective management but rather of having pupils with a more favorable background for the educational process.

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
McMillan and Chan (2006)	DEA, SFA	45 Canadian universities, 1992-1993.	*Inputs:* operating expenditure and sponsored research expenditure. *Outputs:* undergraduate enrolment in sciences and in other programmes, enrolment in master's and doctoral level programmes, sponsored research expenditures, average salary and benefit for faculty, number of active research council grants, share of science faculties, dummy variable for no PhD programme.	Total student enrolment in universities, undergraduate enrolment, percentage of part-time student enrolment, proportion of 3rd and 4th year classes with less than 26 students, Herfindahl index (for specialization). *Embedding:* second-stage Tobit regression and one-step approach	The mean efficiency scores range from 0.90 (SFA) to 0.98 (DEA) depending on the specification used.
Mizala et al. (2002)	DEA, SFA	2000 schools in Chile, 1996.	*Inputs:* socioeconomic level, vulnerability index, type of school, geographical index, school size, pupil-teacher ratio, dummy variable for pre-school education, sex, average teacher experience. *Outputs:* schools' average score for the Simce's Spanish and Mathematics tests.	-	The results suggest that private fee-paying schools are the most efficient, followed by private subsidized and public schools.
Oliveira and Santos (2005)	FDH	42 Portuguese secondary schools, 1999-2000.	*Inputs:* indicators on student performance, education, teaching and learning, educational environment, organization and management. *Outputs:* success rate (ratio of the total number of students who were approved to the total number of students registered in that year) in the 1st, 2nd and 3rd year.	GDP per capita, unemployment rate, social development index, divorce rate, number of physicians per 1000 people. *Embedding:* second-stage truncated regression.	A high percentage of secondary schools is inefficient. The number of physicians per 1000 people has a positive impact on efficiency whereas the unemployment rate has a negative impact on school performance.
Ouellette and Vierstraete (2005)	DEA	852 school boards in Québec, Canada, 1992-1998.	*Inputs:* variables inputs: numbers of teachers, other staff (management, support and professional workers), equipment and supplies, energy, other (remaining) resources; quasi-fixed input: surface area of buildings owned by school boards. *Outputs:* number of primary school pupils, number of secondary school pupils.	Low education population, non-English speaking population, population density, proportion of pupils who obtain a diploma. *Embedding:* second-stage Tobit regression.	The mean technical efficiency scores range from 0.91 to 0.94. Some of the school boards' inefficiencies can be attributed to their socio-economic environment.

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
Ray (1991)	DEA	122 districts in Connecticut, USA, 1980-1981.	*Inputs:* classroom teachers, support staff, administrative staff (all per pupil and in full time equivalents), (dollar) value of non-personnel expenditure. *Outputs:* scores of 9th grade students in the State Wide Proficiency Test (mathematics, language, writing and reading).	Parental education, per capita income, median value of owner occupied housing units, percentage of students of ethnic minorities and from families receiving welfare aid, percentage of families with income below the poverty level, percentage of children with single-parent families. *Embedding:* second-stage OLS-regression.	The findings suggest that while productivity of school inputs varies considerably across the school districts, this can be ascribed to a large extent to differences in the socio-economic background of the communities served.
Ray and Mukherjee (1998)	Non-parametric method using mixed integer programming	166 school districts in Connecticut, USA, 1980-1984.	*Inputs:* number of teachers, support staff and administrators (full time equivalent units), capital (expenditure on operation and maintenance on buildings, facilities, and real property). *Outputs:* enrolment (elementary, middle, and (junior) high schools), average test score in a state level equivalency examination (at the beginning of the 9th grade), percentage of graduating students pursuing further education.	Proportion of students from minority families, per capita income. *Embedding:* second-stage ML-regression.	Most of the urban cities have school districts which should be restructured into a number of small districts resulting in considerable cost economies. On average, the total cost of the school districts could be reduced by approximately 11.5 percent.
Ruggiero (1996)	Modified DEA	556 school districts in New York State, USA, 1990-91.	*Inputs:* teacher salary expenditures, pupil personnel instructional expenditures, all other instructional expenditures, books, micro-computers *Outputs:* average score on standardized tests (Pupil Evaluation Program) in reading, math and social studies, drop out rate	Percentage of adults with college education *Embedding:* integration in the DEA programming model.	80% of the school districts were found to be inefficient. Efficient districts face a harsher environment on average than do inefficient districts.

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
Energy Supply					
Bagdadioglu et al. (1996)	DEA	70 electricity distribution organizations, 1991, Turkey.	*Inputs:* manpower, transformer capacity, network size, general expenses, network losses. *Outputs:* customer number, electricity supplied, maximum demand, service area.	-	The mean overall technical (pure technical, scale) efficiency scores are 0.90 (0.94, 0.96). The results suggest that private organizations are more efficient than public organizations.
Chien and Hu (2007)	DEA	Production of renewable energy for 45 countries from 2001-2002.	*Inputs:* labour, capital stock, and energy consumption. *Outputs:* real GDP	GDP, labour force, capital stock, traditional and renewable energy, share of hydro geothermal, solar, tide and wind fuel in renewable energy. *Embedding:* second-stage OLS regression.	Efficiency increases with the use of renewable energy and decreases with the use of traditional energy. The efficiency scores of OECD countries are higher than those of non-OECD countries.
Färe et al. (1983)	Generalised Farrell-measure	Electric utilities in Illionis, USA, 1975-1979 (unbalanced panel).	*Inputs:* annual number of employees, fuel (in 10^{10} Btus), installed generating capacity in megawatts. *Outputs:* net generation in millions of kilowatt hours.	-	Of the 86 observations four were overall technically efficient, 24 were purely technically efficient and only 14 were scale efficient.
Färe et al. (1985)	Farrell-measure	153 electric utilities, USA, 1970.	*Inputs:* full-time equivalent employees, fuel in BTUs, installed generating capacity. *Outputs:* millions of kilowatt-hours generated by each plant.	-	The publicly- and privately-owned utilities are not significantly different in terms of the overall technical and allocative efficiency measures.
Färe et al. (1986)	Multi-output Farrell-measure	100 steam electric utility plants, USA, 1975.	*Inputs:* installed generating capacity, average number of employees, fuel in coal, oil and gas. *Outputs:* net generation in million kilowatt-hours; Pollution: particulate matter, Sulfur dioxide, Nitrogen oxide, heat discharge in the water.	Plant vintage, plant factor, ownership (private or public), state thermal regulations. *Embedding:* variance test and two non-parametric tests.	Almost one fifth of the plants in the sample are deemed to be inefficient. Plant size affects efficiency.
Färe et al. (1989a)	Farrell-measure	23 electric utility plants, USA, 1969 and 1975.	*Inputs:* installed generating capacity, average number of employees, fuel in in BTUs, installed cost of all types of precipitators. *Outputs:* net generation in million kilowatts.	-	For the majority of the plants in the sample, technical efficiency fell between 1969 and 1975.

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
Farsi and Filippini (2004b)	COLS, SFA (several variants)	59 Swiss electricity distribution utilities, 1988-1996.	*Inputs:* total annual costs per kWh output; labour price: average annual salary of the firm's employees, capital price: residual costs (total cost minus labour and purchased power costs) *Outputs:* total number of kWh delivered.	'Load factor', number of customers, size of the service area, dummy variable for type of utility, dummy variable for utilities whose share of auxiliary revenues exceed 25% and for cases in which more than 40% of the service area is covered by forests. *Embedding:* included in the cost frontier.	The mean efficiency scores range from 0.74 to 0.87 depending on the specification used. The results suggest that sensitivity analyses should be preformed to identify the limitations of different (parametric) models.
Farsi et al. (2006a)	SFA (several variants)	59 Swiss electricity distribution utilities, 1988-1996.	*Inputs:* total annual costs per kWh output; labour price: average annual salary of the firm's employees, capital price: ratio of capital expenses to the total installed capacity of the utility's transformers. *Outputs:* total number of kWh delivered.	See Farsi and Filippini (2004b) without the dummy utilities for cases in which more than 40% is covered by forests *Embedding:* included in the cost frontier.	The mean efficiency scores range from 0.87 to 0.96 depending on the specification used. The results suggest that the estimation errors for individual efficiency scores are rather high.
Hattori et al. (2005)	DEA, SFA	12 (9) electricity distribution utilities, 1985-1986 (1997-1998), UK (Japan).	*Inputs:* total expenditure (operational expenditure used for comparison). *Outputs:* number of customers, electricity units delivered in megawatt-hours.	Customer density, load factor. *Embedding:* DEA: in programming problem; SFA: one-step approach	Efficiency scores are generally higher for UK utilities.
Hjalmarsson and Veiderpass (1992)	DEA	285 Swedish retail electricity distributors, 1985.	*Inputs:* hours worked by all employees, kilometers of low-voltage and high-voltage electricity power lines, total transformer capacity. *Outputs:* consumption of low-voltage and high-voltage electricity (in MWh), numbers of low-voltage and high voltage electricity customers.	-	The mean efficiency scores range from 0.71 to 0.85. The results suggest that urban distribution is slightly more efficient than rural distribution.
Hu and Wang (2006)	DEA	29 administrative regions, China, 1995-2002.	*Inputs:* labour, capital stock, energy consumption, total sown area of farm crops. *Outputs:* real GDP.	-	The central area of China has the worst energy efficiency. Energy efficiency improves with economic growth.
Kopp and Smith (1980)	PLP, COLS, SFA	43 steam electric generating plants, USA, 1969-1973.	*Inputs:* coal consumed (in BTUs), capital in installed nameplate capacity. *Outputs:* net electric generation (of a plant).	-	The mean technical efficiency scores range from 0.88 to 1 depending on the specification and estimation approach used.

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
Miliotis (1992)	DEA	45 distribution districts of the Greek Public Power Corporation (PPC).	*Inputs:* network total length, capacity of installed transformation points, general expenses, administrative labour, technical labour. *Outputs:* number of customers, energy supplied (in kWhs), total area.	-	The DEA results show that electricity distribution utilities corresponding to big urban centres have a relatively high efficiency. Low efficiencies scores were observed for less developed districts with more sparse population and network.
Nemoto and Goto (2006)	SFA	9 Japanese electric utilities, 1981-1998.	*Inputs:* labour input: total number of regular employees; labour price: expenditures for salaries divided by the number of regular employees; price of capital: capital expenditures divided by the capital stock, share of industrial use in total electricity demand, ratio of high voltage transmission line length. *Outputs:* weighted sum of electricity sales (kwh) for four classes of customers.	-	Removing technical inefficiencies could reduce costs by 1% to 28% while removing allocative inefficiencies by% 8 to 30%.
Pollitt (1996)	DEA	78 nuclear power plants in different countries (USA, UK, Canada, Japan and South Africa), 1989.	*Inputs:* capital (in megawatts of nameplate gross capacity), labour (number of employees at the power station site), fuel (in 10^{12} BTUs); price of labour, capital and fuel. *Outputs:* millions of kilowatt-hours produced.	Ownership type (public or private), capital in megawatts, load factor, age, dummy for reactor type. *Embedding:* statistical testing and second-stage Tobit regression.	The DEA and Tobit results suggest that there is little evidence of differing performance (either on a current cost or a historic cost basis) between the two ownership forms (public and private).
Price and Weyman-Jones (1996)	DEA (Malmquist indices)	12 distribution regions of the UK natural gas utility, 1977 to 1991.	*Inputs:* number of employees, length of the gas mains transmission and distribution system. *Outputs:* domestic gas sales, industrial gas sales, commercial gas sales, number of customers served, gas using appliances sold.	Population density. *Embedding:* integration in the programming model.	The results suggest that the rate of productivity growth increased significantly in the regions after privatization. However, the technical efficiency still varies substantially among the regions.
Sickles and Streitwieser (1992)	DEA, SFA	14 natural gas transmission companies, USA, 1977-1985.	*Inputs:* labour, natural gas consumed in production, total horsepower ratings of transmission compressor stations, tons of steel; price of labour, energy and capital. *Outputs:* total volume of gas delivered $*$ miles transported.	-	The findings suggest that the technical efficiency has declined during 1977 and 1985 (in which a major regularity intervention was introduced).
Sueyoshi (1999)	DEA	9 Japanese electric power companies, 1993 and 1994.	*Inputs:* number of employees, amount of total assets, number of customers; price of labour, capital and materials. *Outputs:* electricity sales.	-	The overall efficiency of large electric power companies is higher than the overall efficiency of smaller ones.

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
Sueyoshi and Goto (2001)	DEA variant	25 Japanese electric power companies, 1984-1993.	*Inputs:* amount of total fossil fuel generation capacity (in megawatts), amount of total fuel consumption (oil, coal, gas), number of total employees in fossil fuel plants. *Outputs:* amount of total generation (in GWh).	-	WG (Wholesale Generation) companies have operated more efficiently during 1984 and 1993 than VIIO (Vertically Integrated and Investor-Owned) companies.
Von Hirschhausen et al. (2006)	DEA, SFA	307 German electricity distribution utilities, 2001.	*Inputs:* number of workers, length of the existing electricity cables, maximum peak load. *Outputs:* amount of electricity distributed to end users, total number of customers.	-	The results suggest that low customer density affects the efficiency scores significantly. The efficiency scores of East German utilities are higher than those of their West German counterparts.
Whiteman (1999)	DEA, SFA	39 electricity suppliers, Australia, 1994-1995.	*Inputs:* hydro-capacity, thermal capacity, number of full-time employees. *Outputs:* electricity generated (in GWh).	-	Australian electricity suppliers could improve total factor productivity by up to 20%.
Yaisawarng and Klein (1994)	DEA	61 (60) coal-fired electric generating plants, USA, 1985-1987 and 1989 (1988).	*Inputs:* desirable inputs: fuel in 10^{12} BTUs, labour (average number of employees), capital in thousands of Dollars; undesirable input: sulfur. *Outputs:* desirable output: net generation in millions of kilowatt hours; undesirable output: sulfur dioxide emission in tons.	-	The mean technical efficiency scores range from 0.92 to 0.99 depending on the year and specification used. Most plants experienced relatively stable productivity during the sample period.
Yunos and Hawdon (1997)	DEA	27 electricity producers in Malaysia, Thailand and the UK, 1975-1990.	*Inputs:* installed capacity, labour, total system losses, public generation capacity factor, thermal efficiency. *Outputs:* gross electricity produced (in GWh).	-	Compared to Thailand and the UK, the electricity sector in Malaysia is, on average, less efficient in electricity generation. The results suggest that costs in Malaysian electricity sector could be reduced by approximately 40% (in 1987 prices).
Zhang and Bartels (1998)	DEA	Electricity distribution industries in Australia (32), New Zealand (51) and Sweden (173).	*Inputs:* number of employees, total kilometers of distribution lines, total transformer capacity. *Outputs:* total number of customers served.	-	The simulation study shows that an increasing sample size generally decreases estimated mean technical efficiency indices. The rates of decrease also depend on the sample size.

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
Health Care					
Afonso and St. Aubyn (2005)	DEA and FDH	17 (mostly) OECD countries in 2000.	*Inputs:* number of doctors, number of nurses, number of inpatient beds per thousand habitants. *Outputs:* "infant survival rate", life expectancy.	-	The mean efficiency scores range from 0.82 (DEA) to 0.98 (FDH).
Banker et al. (1986)	DEA, translog cost function	114 hospitals, North Carolina, USA, 1978.	*Inputs:* nursing, ancillary, administrative and general services, capital. *Outputs:* patient days for inpatients below age 14, patient days for inpatients between 14 and 65, patient days for inpatients aged above 65.	-	The translog estimates point to the presence of constant returns to scale in the industry, while the DEA estimates identify a richer, and more diverse set of behaviour.
Bradford et al. (2001)	SFA	645 cardiac revascularization patients, USA, 1994.	*Inputs:* total cost for treatment. *Outputs:* index for comorbidities, gender, patient age, dummy for smoking and myocardial infarction, patient's ejection fraction, number of vessels, number of adverse events experienced by the patient, number of days the patient received her revascularization, physician indicator.	-	The results suggest that inefficiencies for coronary bypass surgery (balloon angioplasty) represent between 22% and 38% (9% and 27%) of total costs.
Brown (2003)	SFA	1907 hospitals, USA, 1992-1996.	*Inputs:* number of full-time equivalent employees, number of beds, capital equipment (total expenses - labour expenses). *Outputs:* hospital's diagnosis related group (DRG) cases.	Number of full- and part-time residents, hospital mean DRG weight, dummy variables for hospital's teaching responsibility and public or for-profit hospitals, market characteristics. *Embedding:* one-step approach.	The study finds strong evidence that managed care insurance is associated with increases in hospital technical efficiency.
Burgess and Wilson (1996)	DEA	137 non-psychiatric hospitals, USA, 1988.	*Inputs:* number of acute care hospital beds, number of long-term hospital beds, registered nurses, licensed practical nurses, other clinical and nonclinical labour, long-term care labour. *Outputs:* acute care inpatient days, case-mix-adjusted acute care inpatient discharges, long-term care inpatient days, number of outpatient visits, ambulatory surgical procedures, inpatient surgical procedures.	-	The results suggest that there are differences in the technical efficiency among the private nonprofit, private for-profit, federal, and state and local hospitals, whereas the federal hospitals seem to be most efficient.

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
Chilingerian (1995)	DEA	36 physicians in a single hospital.	*Inputs:* total length of each patient's stay, total charges for all ancillary services. *Outputs:* low severity cases, high severity cases.	Relative weight of caseload, average age of patients, proportion of high severity cases, affiliation with HMO (Health Maintenance Organization), physician's age, size of caseload, dummy for practice speciality, different diagnostic related groups (DRG) diversification. *Embedding:* second-stage Tobit regression.	DEA identifies 24 inefficient physicians. The efficiency of the physicians increases with the HMO affiliation and decreases with the average age of the patients.
Defelice and Bradford (1997)	SFA	924 primary care physicians, USA, 1984 and 1985.	*Inputs:* weekly visits per physician. *Outputs:* weekly number of hours the surveyed physician spends in the practice of medicine, hours of nursing time and clerical worker time per physician, percentage of visits for which the physician utilizes laboratory tests or orders x-rays.	Annual malpractice premiums, physician's experience, number of HMOs (Health Maintenance Organization) and hospitals in the country, number of physicians per 1000 population in country, number of physicians in practice, several other characteristics of the physicians. *Embedding:* included in the cost frontier.	The authors find no significant differences in the efficiency levels of solo practice physicians on the one hand, and group practice physicians on the other hand.
Deily and McKay (2006)	SFA	Hospitals in Florida, USA, 1999-2001 (unbalanced panel).	*Inputs:* total hospital expenses; input prices: price of patient care personnel; price of capital: depreciation and interest per bed; price of support services: non-patient care and non-capital expenses per bed. *Outputs:* total admissions, total outpatient visits.	Hospital's overall case-mix index, intensive care days, emergency visits, dummy for transplant program, number of open-heart cases and board-certified active medical staff, full-time equivalent medical residents per bed. *Embedding:* included in the cost frontier.	The average costs of the hospitals in the data set are approximately 13.4% higher than the costs of the hospitals located on the best practice frontier. Moreover, the results suggest that observed in-hospital mortality rates increase with the inefficiency levels (of the hospitals).

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
Dismuke and Sena (1999)	DEA, SFA	Portuguese public hospitals, 1992-1994.	*Inputs:* number of computerized axial tomography scans, number of electrocardiograms, number of echo-cardiograms. *Outputs:*: number of alive and dead discharges.	Dummies for hospital type, overall case-mix for the hospital, number of beds, percentage of overall discharges paid for by diagnosis related groups (DRG). *Embedding:*: second-stage regression (SURE).	The results suggest that central hospitals are less productive than district hospitals. Bed size has a negative impact on productivity, whereas case-mix has a positive impact on productivity.
Farsi and Filippini (2004a)	SFA	36 nursing homes in canton Ticino, Switzerland, 1993-2001.	*Inputs:* total annual expenditures of the nursing home; labour price: average wage rates of different professional categories; capital price: residual price divided by capital stock (= number of beds). *Outputs:* total number of patient-days, average dependency index, nursing staff ratio.	-	The mean efficiency scores of the nursing homes range from 0.78 to 0.93 depending on the ownership of the nursing homes and the specification used.
Farsi et al. (2005b)	SFA (several variants)	36 nursing homes in canton Ticino, Switzerland, 1993-2001.	*Inputs:* total annual expenditures of the nursing home; labour price: average wage rates of different professional categories; capital price: residual price divided by capital stock (= number of beds). *Outputs:* total number of patient-days, average dependency index, nursing staff ratio.	-	The results show that the estimated cost frontier is sensitive to the adopted (parametric) estimation approach. In particular, the results largely depend upon how the unobserved heterogeneity among firms is accounted for.
Ferrari (2006)	SFA	52 Scottish hospitals, UK, 1991-1997.	*Inputs:* total capital charges, medical staff, nursing staff, other staff, total number of beds. *Outputs:* inpatients and outpatients index.	Dummy variable for teaching hospital. *Embedding:* included in the production function.	The results show a structural break (in 1994) after which hospitals change not only the way in which they provide their services, but also the mix of services they provide.
Fizel and Nunnikhoven (1993)	DEA	104 nursing homes in Michigan, USA, 1987.	*Inputs:* hours worked by registered nurses, licensed practical nurses, and aides and orderlies. *Outputs:* patient days for skilled- and intermediate-care.	Percentage of skilled nursing care, quality of nursing home care (measured by 3 different indicators), ownership status, number of beds, market competition (measured by a Herfindahl index). *Embedding:* second-stage OLS regression.	The results indicate that for-profit chain homes are approximately 8% percent more efficient in labour use than for-profit independent homes. Moreover, the efficiency indices of chain homes are, on average, 10.3% higher than those of non-profit homes.

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
Giokas (2001)	DEA variant	91 hospitals, Greece, 1992.	*Inputs:* total cost (total staff earnings, expenditure on operating services, supplies). *Outputs:* number of inpatient days in medical care, inpatient days in surgical care, outpatient visits and ancillary services (anesthesiology, laboratory and x-ray).	Dummy for ownership type of the hospital (general or teaching). *Embedding:* included in the cost function.	The average degree of efficiency for general hospitals is 0.75 and for teaching hospitals 0.84.
Giuffrida and Gravelle (2001)	DEA, COLS, SFA, canonical regression	90 Family Health Service Authorities (FHSAs), UK, 1993-1994 and 1994-1995.	*Inputs:* gross expenditure, remuneration of general practitioners (GPs) and practice nurses, number of GPs. *Outputs:* variables for the different types of GPs, number of patients registered with a GP in the FHSA and living in wards classified as (non)deprived, number of deaths (aged 0-64), number of practice nurses, number of practices in the FHSA employing practice nurse and which satisfy certain minimum standard set outs, area of the FHSA.	-	The mean efficiency scores of the FHSAs range from 0.80 to 0.99 depending on the estimation approach and specification used.
Grosskopf and Valdmanis (1987)	Farrell-measure	82 hospitals in California, USA, 1982.	*Inputs:* number of physicians, full time equivalent employment of non-physician labor, admission, net plant assets. *Outputs:* acute care, intensive care, surgeries, ambulatory and emergency care.	Ownership type (public or not-for-profit) *Embedding:* non-parametric test.	The results suggest that ownership affects efficiency: Public and not-for-profit hospitals have different best practice frontiers, and public hospitals appear to use relatively fewer resources.
Grosskopf et al. (2006)	DEA	143 countries, 1977-1990 and 1997.	*Inputs:* private and public health expenditures as a percentage of per capita GDP, gross capital formation per capita, per capita labour force, enrollment rate in primary education. *Outputs:* life expectancy at birth, reciprocal of the under-five mortality rate, per capita GDP.	-	The results suggest that developed countries typically have higher efficiency scores than less developed countries. The comparison of the performance of the countries over time shows that improvement (in efficiency) varies by level of development.
Hsu and Hu (2007)	DEA	127 hospitals, Taiwan, 2003.	*Inputs:* number of beds, number of physicians, number of other medical personnel, number of nurses. *Outputs:* treatment cost for inpatients and outpatients, number of outpatients and inpatients, number of visits to emergence service and surgical service.	Ownership structure. *Embedding:* Kruskal-Wallis test.	The results point to differences in the efficiency levels of the different types of hospitals.

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
Kooreman (1994)	DEA	320 Dutch nursing homes, 1989.	*Inputs:* number of medical doctors, nurses, nurse trainees, therapists, general staff, other personnel. *Outputs:* number of full and day care patients (physically disabled patients and patients with psycho-geriatric disability).	Number of beds, occupancy rate, proportion of patients over 85, length of stay, quality of care, characteristics of the personnel, dummies for the region, the religious affiliation, the type of management and the medicine supply system. *Embedding:* second-stage Probit and Tobit regressions.	The mean efficiency scores range from 0.80 to 0.94 depending on the specification used. The quality indicators have a negative impact on efficiency; the statistical evidence, however, is not very strong.
Linna (1998)	DEA, SFA	43 Finnish hospitals, 1988-1994.	*Inputs:* net operating costs; fixed input: number of beds; input price: wage rate of labour, price index. *Outputs:* number of emergency visits, sum of scheduled and follow-up visits, number of bed days, number of residents receiving 1 year of training, number of on-the-job training weeks of nurses, number of impact-weighted scientific publications.	Dummy variables for teaching status and readmission rate for admissions. *Embedding:* included in cost frontier and one-step approach (SFA).	The findings indicate that the choice of the estimation approach does not affect the results. Although the SFA and DEA produced different average efficiency scores for the considered period, there are moderate positive correlations between the indivdual efficiency scores.
Luoma et al. (1996)	DEA	202 Finnish health care centres, 1991.	*Inputs:* operating costs without rehabilitation costs and costs of purchased services. *Outputs:* outpatient care: health care and medical visits to a physician, health care or medical care visits to other personnel, visits of supervised domiciliary care, dental care visits, special examinations; inpatient care: short-term inpatients days, long-term inpatient days for patients in heavy and non-heavy dependence categories.	Percentage of state subsidy, income subject to local government taxation, distance to nearest hospital, proportion of population over 65, personnel variables, dummy variable for ownership. *Embedding:* second-stage Tobit regression.	Of all health care centres, 12% were deemed to be efficient. The results support the hypothesis that in the subsidy system before the reform in 1993 incentives for cost-efficient behaviour were weak.
Maniadakis and Thanassoulis (2000)	DEA (Malmquist indices)	75 Scottish hospitals, UK, 1991-1996.	*Inputs:* number of doctors, nurses and other personnel, number of beds, area of hospital; input prices: doctor, nurse and other personnel salaries, capital charge per bed and cubic meter. *Outputs:* number of accident and emergency attendances, outpatient attendances, day cases and inpatient discharges.	-	The results suggest that the efficiency levels of the hospitals increased from 1991 to 1996. Moreover, the efficiency gains are mainly due to improvements in allocative efficiency.

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
McCallion et al. (2000)	DEA (Malmquist indices)	23 hospitals in Northern Ireland, 1986-1992.	*Inputs:* nursing, administration and ancillary staff (in full time equivalents), annual expenditure on specialists, number of beds. *Outputs:* total number of in- and outpatients (for the categories general surgery, general medical, maternity accident and emergency).	-	The results suggest that smaller hospitals, starting from a less efficient base, achieved greater productivity gains than larger hospitals in the period considered.
Mobley and Magnussen (1998)	DEA	52 (178) hospitals, Norway (California, USA), 1991.	*Inputs:* physicians and residents, other staff (in full time equivalents), number of beds (= proxy for capital). *Outputs:* number of inpatient days in three age groups (0-15, 16-64 and 65+), number of outpatient visits, case-mix index for patients over 65.	-	The results support the hypothesis that hospitals operating in an environment which is private and largely unregulated perform better than hospitals operating in an public and heavily regulated environment.
Nyman and Bricker (1989)	DEA	184 Wisconsin nursing homes, USA, 1979.	*Inputs:* total nursing hours, total social service worker hours, total therapist hours, and total other worker hours in an average day. *Outputs:* skilled Nursing Facility (SNF) patients, Intermediate Nursing Care (INC) patients, patients requiring "limited", "personal" and "residential" care.	Dummy for ownership and hospital affiliation, occupancy rate, proportion of Medicaid and SNF patients and patients over 85, number of actual and empty beds, length of stay, income of county, number of Medicaid code certification violations, wage index. *Embedding:* second-stage OLS regression.	The results point to significantly higher efficiency scores of for-profit hospitals. A for-profit nursing home uses approximately 4.5% fewer labour resources per patient day than a non-profit home.
Ouellette and Vierstraete (2004)	DEA	15 hospitals in Montreal, Canada, 1997-98 and 1998-99.	*Inputs:* variable inputs: hours worked (excluding physicians), expenditure on furniture and equipment; quasi-fixed inputs: number of stretchers and number of physicians (in full time equivalents). *Outputs:* number of cases.	-	The findings indicate that the productivity as well as the efficiency of the hospitals, on average, decreased in the considered period.
Parkin and Hollingsworth (1997)	DEA	75 Scottish hospitals, UK, 1991-1994.	*Inputs:* number of staffed beds, number of trained learning and other nurses, number of professional, technical, administrative and clerical staff, junior and senior non-nursing medical and dental staff, cost of drug supply, hospital's capital charge. *Outputs:* medical and surgical discharges, accident and emergency attendance, outpatient attendances, obstetrics and gynecological discharges, other specialty discharges.	-	The mean (technical) efficiency scores range from 0.80 to 0.97 depending on the specification used. The authors point to the problem that the divergence between the results obtained under constant and variable returns to scale is problematic since there is no theoretical or empirical evidence about the correct assumption.

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
Prior (1996)	DEA	50 hospitals, Spain, 1989.	*Inputs:* doctors and upper-grade staff, nursing assistants and other middle-grade staff, number of beds. *Outputs:* number of discharges, stays (in total number of days), number of visits, number of activities (rehabilitation, radiotherapy and chemotherapy treatments).	-	The results confirm the presence of technical inefficiencies and potential economies of scope for the sample of Spain hospitals.
Puenpatom and Rosenman (2008)	DEA	92 hospitals, Thailand, 2000-2002.	*Inputs:* number of beds, physicians (in full time equivalents), nurses, dentists and pharmacists, and other personnel. *Outputs:* number of inpatient visits (categories: surgery primary care, other), number of surgical and non-surgical outpatient visits.	Input mix, service and geographic variables, market factors, indicators reflecting the effect of the introduction of Universal Health Coverage (UC). *Embedding:* second-stage truncated regression.	The results suggest that the implementation of Universal Health Coverage (UC) improved the efficiency of the hospitals, whereas the increase in efficiency was highest in regional hospitals.
Sahin and Ozcan (2000)	DEA	Hospitals in 80 provinces, Turkey, 1996.	*Inputs:* number of beds, number of specialists, number of general practitioners, number of nurses, number of health care service providers, revolving funds expenditures. *Outputs:* outpatient visits, discharged patients, hospital mortality rate.	-	The mean efficiency score of the hospitals in the provinces is approximately 0.88, whereas 45% of the hospitals in the provinces operate on the best practice frontier.
Staat (2006)	DEA	160 hospitals, Germany, 1994.	*Inputs:* per diem rate, number of beds. *Outputs:* number of cases per year, reciprocal of the length of stay (in internal medicine and surgery).	-	The mean efficiency scores for all hospitals is 0.79; local hospitals are on average less efficient than hospitals with facilities that are of regional importance.
Steinmann and Zweifel (2003)	DEA	89 Swiss hospitals, 1993-1996.	*Inputs:* inpatient days (version 1), academic, nursing and administrative staff, non-labour expenses. *Outputs:* inpatient days (version 2), medical, pediatric, surgical, gynaecological and intensive care discharges.	Ownership type, dummy variables for hospitals which receive subsidies and deficit coverage or which have emergency admissions, percentage of interns and privately insured and billed patient days. *Embedding:* second-stage ML-regression (random effects).	Efficient observations can be found among the smallest and largest hospitals (in terms of beds), but not in the medium-sized hospitals. Ownership does not affect efficiency.

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
Street and Jacobs (2002)	SFA, OLS	217 hospitals, UK, 1999.	*Inputs:* case mix cost index. *Outputs:* number of transfers into and out of hospital, emergency sessions, finished consultant episode inter-specialty transfers, non-primary outpatient attendances, index of unexpected emergency admission, episodes per spell, Healthcare Resource Group (HRG) index, proportion of patients under 15 and over 60, female patients, student whole-time teaching equivalents, market forces factor.	-	The mean efficiency scores range from 0.74 (OLS) to 0.92 (SFA). These results suggest that inefficiency among hospitals is less prevalent than suggested by the OLS model.
Thanassoulis et al. (1995)	DEA variant	83 District Health Authorities (DHAs), England, 1988.	*Inputs:* Whole Time Equivalent (WTE) obstetricians, pediatricians and midwives and nurses, General Practitioners' (GP) fees, numbers of babies at risk. *Outputs:* number of birth episodes, deliveries to mothers and abortions, number of Special Care and Intensive Care consultant episodes; quality variables: number of (very) satisfied mothers, numbers of babies at risk surviving.	-	The results show how the incorporation of (output) quality measures into a "usual" DEA model can lead to biased results (for some observations) with regard to the efficiency scores.
Valdmanis (1992)	DEA	41 hospitals in Michigan, USA, 1982.	*Inputs:* number of attendings (total active and associate physicians), total house staff, number of full time equivalent physicians, nurses and other staff, total admissions, number of short-term acute beds, net plant assets. *Outputs:* adult, pediatric, elderly, acute and intensive care inpatient days, number of surgeries, number of ambulatory emergency room and other ambulatory care visits, total house staff.	-	The results suggest that public hospitals are more (technically) efficient than non-profit hospitals. Moreover, slight variations in the input and output variables also result in small changes in the (mean) efficiency scores.
Vitaliano and Toren (1994)	SFA	164 Nursing Facilities and 443 Skilled and Health Related Facilities in New York State, USA, 1987 and 1990.	*Inputs:* total costs. *Outputs:* patient days, admissions and transfers, percentage of low-care patients, number of deficiencies, wages-aids, wages-registered nurses, property expenses, ownership type (not-for profit, publicly or corporate owner, proprietorship, partnership).	Managerial and supervisory personnel, dummies for receivership, unionization, region and size, total of activities and services available. *Embedding:* second-stage OLS regression.	The authors find evidence for substantial inefficiencies among the facilities (which imply annual extra costs for the facilities of approximately $1 billion). Moreover, the results suggest that inefficiency is not related to the profit status.
Wilson and Jadlow (1982)	PLP	922 hospitals, USA, 1973.	*Inputs:* nuclear medical technologists, nuclear medicine personnel (in full time equivalents, respectively), sum of the quantity of each type of nuclear medicine equipment. *Outputs:* price weighted nuclear medical services.	Competitive intensity index, dummy variables for ownership type. *Embedding:* second-stage OLS regression.	The results suggest that proprietary hospitals tend to operate closer to the efficient production frontier than non-profit hospitals.

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
Zuckerman et al. (1994)	SFA	4149 hospitals, USA, 1986 and 1987.	*Inputs:* actual expenses incurred by each hospital; input prices: average annual salary per full-time equivalent employee (price of labour), depreciation and interest expenses per bed (price of capital). *Outputs:* inpatient admissions, post-admission inpatient days, outpatient visits.	Percentage of beds, outpatient visits and admissions, ratio of births to admissions, Medicare case-mix, inpatient surgical operations, index of high technology services, ratio of residents to beds, individual Medicare-specific variables. *Embedding:* included in cost frontier.	The mean efficiency ranges from 13.4% to 18.8% of total costs depending on the specification used. The application shows that the inefficiency measure generated by the stochastic frontier model is not very sensitive to the specification of the output control variables.
Public Facilities					
Aida et al. (1998)	DEA	127 water supply utilities, Japan, 1993.	*Inputs:* number of employees, operating expenses, net plant and equipment, total population, length of pipes. *Outputs:* operating revenue, amount of water billed net of leakage.	-	The results suggest that there are substantial inefficiencies among the water supply utilities in the districts considered.
Althin and Behrenz (2004)	DEA	297 Swedish employment offices, 1993.	*Inputs:* assistants, placement officers, counsellors, office space, computer grid connections. *Outputs:* jobs in the open market, jobs with wage subsidies or sheltered employment, placements in labour market policy measures; quality measures: average unemployment duration, average vacancy duration.	Number of unemployed and vacancies, office municipality population. *Embedding:* second-stage Tobit regression.	The efficiency scores range from 0.28 to 1 with a mean value of 0.70. Efficiency increases with the number of unemployed and vacancies.
Bjurek et al. (1990)	DEA, deterministic parametric approaches.	392-462 Swedish social insurance offices, 1974-1984.	*Inputs:* number of working days. *Outputs:* income evaluation assessments, sickness reports and control, minor reimbursements of personal outlays for travel expenses, evaluation of pension and social insurance payments.	-	The results suggest that the number of fully efficient offices varies substantially between the different estimation approaches.
Bjurek et al. (1992)	DEA	200 public day care centres in Gothenburg, Sweden, 1988 and 1989.	*Inputs:* preschool teachers, nursery nurses, cooking and cleaning personnel, size of the day care centre. *Outputs:* contracted time of full and part time children aged 0-2 and 3-6 years.	Share of substitutes by teachers and nurses, mean income of the parents, dummy for response on questionnaire, director's experience, index for cooperation with parents. *Embedding:* second-stage Tobit regression.	The mean efficiency scores range from 0.85 to 0.90. depending on the year and specification used. Efficiency increases with parents' income as well as contacts, director's experience and the share of substitutes by teachers and nurses.

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
Borenstein et al. (2004)	DEA	113 Brazilian post office stores, 2000.	*Inputs:* number of employees, vehicles and training hours, area of the store, total expenses. *Outputs:* rate of external client satisfaction, quality program, total revenue, served clients, number of objects delivered, indicator for the workload.	-	The mean efficiency scores of the different store types are 0.92 (client service stores), 0.86 (distribution stores) and 0.85 (integrated stores).
Bosch et al. (2000)	DEA, FDH, COLS, SFA	75 Catalan municipalities, Spain, 1994.	*Inputs:* number of containers, vehicles and workers (non-administrative employees). *Outputs:* tons of organic waste collected.	Population density, influence of seasonal factors. *Embedding:* included in the production frontier (only DEA).	The mean efficiency scores of the municipalities range from 0.55 (COLS) to 0.96 (FDH).
Callan and Thomas (2001)	Cost function	110 cities and towns in Massachusetts, USA, 1997.	*Inputs:* total annual cost of disposal and recycling for each town. *Outputs:* tons of municipal solid waste service disposed and recycled.	Housing density, dummy variable for provider of disposal services, number of pick ups per month, regional dummy, grants, dummy for recycling facility. *Embedding:* included in the cost function.	The authors find evidence for economies of scope in the provision of recycling services for the sample of US cities and towns: The results suggest that the cost of providing recycling services plus the cost of providing disposal services is approximately 5% higher than the joint cost of providing both services.
Cubbin and Tzanidakis (1998)	DEA, COLS	29 English and and Welsh water supply utilities, 1994-1995.	*Inputs:* operating expenditure. *Outputs:* amount of water delivered, length of pipes.	Proportion of water delivered to measured non-households. *Embedding:* included in the cost frontier.	The mean efficiency scores range from 0.78 (COLS) to 0.91 (DEA).
Deprins et al. (1984)	DEA, FDH, PLP	792 post offices, Belgium, 1980.	*Inputs:* number of hours effectively worked during the month in the station by the personnel. *Outputs:* financial operations, registered mail, special delivery mail, unaddressed printed matter, outgoing mail, delivery points.	-	The results point to an estimated average labour-efficiency in Belgian post offices of approximately 0.90.
Doble (1995)	DEA	1281 post offices, UK, 1989.	*Inputs:* counter clerk serving hours. *Outputs:* number of transactions performed; quality: Average waiting time of a customer.	Region, quality of management, experience of the counters staff, staff turnover. *Embedding:* verbal discussion.	The author find evidence for substantial inefficiencies among the post offices. Reasons for the differences are due to differing working practices, turnovers of staff and local labour market conditions.

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
Domberger et al. (1986)	Cost function	305 local authorities, UK, 1983-1985.	*Inputs:* gross expenditure of waste collection. *Outputs:* number of pick-up points, frequency of collection, method of collection.	Density of units, distance to disposal points, percentage of household units, amount of waste paper reclaimed, number of abandoned vehicles collected and bottle-banks operated, average earnings of manual workers, dummy variables for tendered contract or in-house services. *Embedding:* included in the cost function.	The findings show that where services have been tendered, costs are significantly lower (by roughly 20%) than where they have not been tendered.
Fox and Hofler (1986)	Dual output SFA	176 water supply utilities, USA, 1981.	*Inputs:* total man-hours, maximum treatment capacity; input price: percentage of user charge revenues. *Outputs:* gallons of potable water produced, miles of distribution pipeline; quality: tests of water quality and for organic contamination.	Percent of water distributed to non-residents, surface water collected, potable water purchased, storage capacity, regional dummies *Embedding:* included in the production equation system.	The authors find no empirical evidence for differences in the (overall technical) efficiency levels of private and public water supply utilities. The allocative efficiency of public firms, however, seems to be higher than the one of private firms.
Garcia-Sanchez (2006)	DEA	24 Spanish municipalities.	*Inputs:* total staff, number of treatment plants, length of pipes, total expenses. *Outputs:* water supplied, index for differences in production characteristics and quality controls.	Population density, average number of persons per house, municipal area. *Embedding:* included in DEA via a second-stage tobit regression (three-stage approach).	The mean efficiency scores range from 0.86 to 0.95 depending on the specification used. The authors find no evidence for differences in efficiency between public and private water supply utilities.
Garcia-Valinas and Muniz (2007)	DEA	3 Spanish municipalities, 1985-2000.	*Inputs:* operational costs. *Outputs:* water delivered, number of inhabitants, length of pipes.	Density of rainfall. *Embedding:* included in production frontier.	The mean efficiency scores of the water supply utilities range from 0.81 to 0.94 depending on the specification used.
Haug (2008)	DEA	37 Eastern German municipal water supply utilities, 2002.	*Inputs:* number of employees, current book value of property, plant and equipment, expenses for materials and purchased services. *Outputs:* volume of billed water.	Dummies for company type and outsourcing, population density, imported drinking water, hardness of water, age of the distribution system, portion of distribution system 1960-1989. *Embedding:* second-stage OLS and Tobit regression.	The mean efficiency score of the utilities is approximately 0.73. Most of the exogenous variables have no significant effect on (technical) efficiency.

Name	**Method**	**Sample**	**Inputs and Outputs**	**Exogenous Variables**	**Main Findings**
Hirsch (1965)	Cost function	24 municipalities in St. Louis, USA, 1960.	*Inputs:* average annual residential waste collection and disposal cost per pickup. *Outputs:* number of pickup units, weekly collection frequency.	Pickup density, dummies for pickup location, nature of contractual arrangements and type of financing. *Embedding:* included in the cost function.	The authors find no empirical evidence for significant economies of scale in the provision of waste collection for St. Louis.
Kumbhakar and Hjalmarsson (1995)	SFA	380 Swedish social insurance offices, 1974-1984.	*Inputs:* number of working days. *Outputs:* income evaluation assessments, sickness reports and control, minor reimbursements of personal outlays for travel expenses, evaluation of pension and social insurance payments.	-	The mean labour-use efficiency ranges from 0.77 to 0.83. Moreover, the authors find evidence for a slight decrease in labour productivity from 1974 to 1984.
Stevens (1978)	Cost function	340 firms producing waste collection services, USA, 1974-1975.	*Inputs:* total expenditure of waste collection; input price: wages paid to a waste collector. *Outputs:* total quantity of waste collected.	Dummy for market structure, number of collections, waste collected each year, household density, percentage of households serviced, index for temperature. *Embedding:* included in the cost function.	For cities with more than 50,000 inhabitants, total expenditure of waste collection is significantly less when service is provided by a private monopolist rather than a public monopolist.
Woodbury and Dollery (2004)	DEA	73 water supply utilities in New South Wales, Australia, 1999-2000.	*Inputs:* management costs, maintenance and operation costs, energy and chemical costs, capital replacement costs. *Outputs:* number of assessments (services and properties), annual water consumption; quality: water quality and service index.	Population size, properties per km of pipe, location, amount of rainfall, percentage of residential assessment, dummy for type of water. *Embedding:* second-stage Tobit regression.	The mean (overall technical) efficiency scores range from 0.77 to 0.93 depending on the specification used. The exogenous variables used in the second-stage Tobit regression mostly have no significant impact on efficiency.

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
Security					
Barros and Alves (2005)	SFA	33 police precincts in Lisbon, Portugal, 1999-2003.	*Inputs:* operational cost; input prices: price of labour, price of capital. *Outputs:* clear-up rates of theft and burglaries, car robberies, clear-up rates of drug-related crimes and minor offences.	-	The mean efficiency score is approximately 0.54. The majority of the police precincts operate beneath the best practice frontier.
Carrington et al. (1997)	DEA	163 police patrols in New South Wales, Australia, 1994-1995.	*Inputs:* number of police officers, number of civilian employees assigned to a patrol, number of police cars. *Outputs:* number of offences, arrests, summons and major car accidents, kilometers traveled by police cars.	Proportion of young people and of government housing in a patrol, location of a patrol. *Embedding:* second-stage Tobit regression.	The results suggest that, on average, the police patrols of New South Wales could produce the same output with 13.5% less inputs. Moreover, differences in the operating environments do not have a significant influence on the efficiency of police patrols.
Davis and Hayes (1993)	SFA	Police departments in 141 cities in Illinois, USA, 1982-1986.	*Inputs:* sum of operating and capital expenditures; input prices: weighted average salary (labour), 20 year municipal bond yields (capital). *Outputs:* per capita crime rate (inverse).	Median income, percentage of minorities, high school graduates and homeowners, population, tax rate, dummies for location and mayor. *Embedding:* included in the production function and second-stage OLS regression.	The mean efficiency score is approximately 0.76. Moreover, tax rates and city size influence citizen monitoring of municipal bureaucrats.
Diez-Ticio and Mancebon (2002)	DEA	47 Spanish police forces, 1995.	*Inputs:* number of police officers, number of vehicles, population size. *Outputs:* property and violent clear-up rate.	Qualification level of police officers, proportion of sworn and non-sworn police officers. *Embedding:* second-stage OLS regression.	The mean efficiency scores range from 0.76 to 0.90 depending on the specification used. The authors find no evidence for a significant relationship between the qualification of the police officers and efficiency.
Drake and Simper (2000)	DEA	35 English and Welsh police forces, 1992-1997.	*Inputs:* total cost of the employed staff, premises-related expenses, transport related expenses, capital and other costs. *Outputs:* clear-up rate, number of traffic offences, number of breathalyser tests.	-	The smallest and largest police forces tend to produce relatively higher pure technical efficiency scores than the intermediate size forces. The authors find evidence of significant in- and decreasing returns to scale at the extremes of the size spectrum.

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
Drake and Simper (2001)	DEA	39 English and Welsh police forces, 1996-1998.	*Inputs:* total cost of the employed staff, premises-related expenses, transport related expenses, capital and other costs. *Outputs:* percentage of time officers spend patrolling, violent crime and burglary clear-up rate, percentage success rate in answering 999 calls, percentage performance in respect of target response times, number of breathalyser tests.	-	The overall (pure, scale) mean efficiency scores range from 0.69 (0.81, 0.86) to 0.72 (0.82, 0.89) depending on the year considered. Further results point to a statistically significant and negative relationship between size and pure technical efficiency.
Drake and Simper (2002)	DEA, DFA	43 English and Welsh police forces, 1992-1997.	*Inputs:* total cost of the employed staff, premises-related expenses, transport related expenses, capital and other costs. *Outputs:* clear-up rate, number of traffic offences, number of breathalyser tests.	-	The largest police size group displayed significant diseconomies of scale, based on the cost function specification, and relatively large levels of scale inefficiencies, based on the DEA analysis.
Drake and Simper (2003)	DEA, SDEA FDH, SFA	42 English and Welsh police forces, 1996-1999.	*Inputs:* total cost of the employed staff, transport related expenses, capital expenses. *Outputs:* number of cleared up crimes, Violent crime and burglary clear-up rate, number of breathalyser tests.	Population, criminal offences recorded, geographical dummies. *Embedding:* second-stage Tobit regression.	The results obtained from the four estimation approaches are strongly (positive) correlated.
Drake and Simper (2004)	DEA	41 English and Welsh police forces, 1998-2000.	*Inputs:* total cost of the employed staff, transport related expenses, capital and other costs; input prices: staff cost per member of staff, transport costs per hectare, capital per 1000 population. *Outputs:* number of complaints and days lost per officer, number of crimes solved of emergency calls to stations answered within a target time, number of breathalyser tests.	-	The estimated mean efficiency score is approximately 0.76, while the minimum level of cost efficiency was found to be only 0.56.
Drake and Simper (2005a)	DEA	41 English and Welsh police forces, 2001-2002.	*Inputs:* number of burglaries, vehicle crimes and robbery; net budget revenue (only for cost function). *Outputs:* total offences cleared, total days lost to sickness.	Daytime population, proportion of lone parent households and terraced housing, dummy for sparsely populated areas. *Embedding:* two-stage DEA.	The mean efficiency scores range from 0.55 to 0.96 depending on the specification used. The results suggest that it is extremely important to adequately incorporate the impact of environmental variables.
Drake and Simper (2005b)	DEA, SFA	293 Basic Command Units, UK, 2001-2002.	*Inputs:* violent crimes against persons, sexual offences, robbery, burglary of dwelling, theft of a (motor) vehicle. *Outputs:* clear-up rates for every input.	-	The results point to substantial divergence in efficiency levels, both across police forces as a whole, and across Basic Command Units within the same force.

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
Ganley and Cubbin (1987)	DEA	25 prisons, England, 1984-1985.	*Inputs:* man hours, materials, energy consumption. *Outputs:* prisoner days, unit of security (=number of punished offences committed by inmates).	-	15 out of 25 prisons were found to be efficient.
Grosskopf and Yaisawarng (1990)	DEA	49 municipalities in California, USA, 1982.	*Inputs:* aggregate total cost, variable cost (total cost minus capital outlays). *Outputs:* full time equivalent employment in police and fire services.	-	The authors find evidence of economies of scope (in the provision of police and fire services) when total cost is used as the cost variable.
Grosskopf et al. (1995)	Shepard-type distance function	Police department in Dallas (Texas), USA, 1977-87.	*Inputs:* variable inputs: number of police officers, sergeants and civilians; fixed inputs: number of reported auto thefts and murders. *Outputs:* arrest rates for auto theft and murder.	-	The results suggest that the Dallas Police Department performed quite well in the face of exponential crime growth and an increasingly tight budgetary situation.
Sun (2002)	DEA	14 police precincts in Taipei, Taiwan, 1994-1996.	*Inputs:* number of police officers employed, number of burglaries, offences and other crimes recorded. *Outputs:* clear-up rates for burglaries, offences and other crimes recorded.	Location, jurisdiction area, population size, proportion of young people. *Embedding:* second-stage OLS regression.	The overall (pure, scale) mean efficiency scores is 0.87 (0.93, 0.94). Moreover, the results suggest that the efficiency of the police precincts is not influenced by the exogenous variables.
Thanassoulis (1995)	DEA	41 English and Welsh police forces, 1991.	*Inputs:* number of police officers employed, number of violent crimes, burglary and other crimes recorded. *Outputs:* clear-up rates for violent crimes, burglaries and other crimes recorded.	-	Out of the 41 police forces, 13 were found to be (fully) efficient.
Transportation					
Caves and Christensen (1980)	Index of total factor productivity	Canadian National and Pacific Railways, 1956, 1963 and 1974.	*Inputs:* labour, structures (including right-of-way), equipment (including rolling stock), fuel, materials. *Outputs:* freight ton-miles and passenger-miles.	-	The principal conclusion is that public ownership is not inherently less efficient than private ownership.
Chang and Kao (1992)	DEA	5 bus firms in Taipei, Taiwan, 1956-1988.	*Inputs:* labour: number of full-time employees, capital: number of buses in operations, diesel fuel. *Outputs:* vehicle kilometres, revenue, number of bus traffic trips on routes.	-	In general, the results suggest that public bus firms are less efficient than private ones in the period considered.

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
Chicoine et al. (1989)	Cost function	Mail survey of 650 road officials, USA, 1982.	*Inputs:* total road costs; input prices: hourly wage rate paid to employees, replacement costs for road graders and single-axle trucks, price of road material, cost-of-living index. *Outputs:* gravel-road equivalent mileage, average daily traffic loads.	-	For low-volume rural roads, substantial size inefficiencies were identified.
Chu et al. (1992)	DEA	Bus transit agencies, USA, 1985 and 1986.	*Inputs:* vehicle operating, maintenance, general/administrative and other expenses, revenue vehicle hours, population density, proportion of households without automobile, financial assistance per passenger. *Outputs:* revenue vehicle hours, unlinked passenger trips.	-	The results of the Data Envelopment Analysis point to substantial divergence in efficiency among the transit agencies.
Coelli and Perelman (1999)	DEA, PLP, COLS	17 European railway companies, 1988-1993.	*Inputs:* labour: annual mean of monthly data on staff levels, capital: total length of lines, equipment: rolling stock. *Outputs:* sum of distances traveled by each passenger and tonne of freight.	-	The mean efficiency scores range from 0.79 (DEA) to 0.93 (PLP). The correlations between the various sets of technical efficiency predictions are all positive and significant.
Cook et al. (1991)	DEA	62 highway maintenance patrols in Ontario, Canada.	*Inputs:* maintenance and capital expenditures, climatic factors. *Outputs:* assignment size factor, averge traffic served, pavement rating change factor, accident prevention factor.	Percentage of privatisation, traffic level. *Embedding:* descriptive analysis.	In general, privatisation impacts are different from district to district. Overall, the authors find no evidence that privatization increases efficiency.
Cowie and Asenova (1999)	DEA	Bus companies, UK, 1995/1996.	*Inputs:* number of staff employed in both managerial and operational positions, fleet size. *Outputs:* operating revenue.	-	The results point to substantial inefficiencies among the bus companies. Private bus companies are found to have the highest level of technical efficiency.
Cowie and Riddington (1996)	Deterministic frontier techniques	13 European railway companies, 1992.	*Inputs:* population density, number of state railway related employees, state rail capital per capita. *Outputs:* passenger train kilometres, service provision index.	-	The mean efficiency scores range from 0.70 to 0.89 depending on the estimation method and specification used.
Deller (1992)	SFA (production function)	Mail survey of 1319 road officials, USA, 1982	*Inputs:* number of full-time and part-time employees, flow of services from motorised graders, single-axle trucks, loaders, average daily traffic loads for a typical mile of road. *Outputs:* gravel-equivalent index.	-	The estimates suggest that costs may be 14% higher than necessary due to production inefficiencies.

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
Deller et al. (1988)	Cost function	Mail survey of 1799 road officials, USA, 1982.	*Inputs:* total road costs; input prices: hourly wage rate paid to employees, prices for materials and operations required to maintain the roads, prices for earth graders and trucks, cost-of-living index. *Outputs:* miles of paved and loose aggregated surfaced roads, miles of roads with bituminous surface.	Utilization measure, intergovernmental road aid *Embedding:* included in the cost function.	The authors find evidence for size economies; the cost of maintenance could be reduced by 50% if some jurisdictions would merge.
Deller and Halstead (1994)	SFA (cost function)	Mail survey of 104 road officials, USA, 1987.	*Inputs:* total road costs; input prices: hourly wage rate paid to employees, prices for motorised and single-axle dump trucks. *Outputs:* miles of roads under town jurisdiction.	-	The results suggest that road maintenance costs are slightly more than 40% higher than necessary due to managerial inefficiencies.
Deller and Nelson (1991)	Farrell-measure	Mail survey of 446 road officials, USA, 1982.	*Inputs:* number of full-time-equivalent employees, road graders, single-axle trucks, surfacing material; input prices: average annual salary, replacement cost, material requirements for resurfacing projects, cost-of-living index. *Outputs:* miles of gravel, low and high bituminous roads.	-	The results suggest that larger townships are more efficient than smaller ones.
Deller et al. (1992)	SFA (cost function)	Mail survey of 435 road officials, USA, 1982.	*Inputs:* see Deller and Nelson (1991). *Outputs:* see Deller and Nelson (1991).	-	The results suggest that costs could be reduced, on average, to 45% of current levels. Larger townships seems to be more efficient than smaller ones.
Farsi et al. (2005a)	SFA (several variants)	50 railway companies, Switzerland, 1985-1997.	*Inputs:* total annual costs; input prices: labour and energy expenses, residual expenses per seat (capital). *Outputs:* number of passenger- and ton-kilometres, network length.	-	The results suggest that the inefficiency estimates for the railway companies are very sensitive to the adopted specification.
Farsi et al. (2006b)	SFA (several variants)	94 bus companies, Switzerland, 1986-1997.	*Inputs:* total annual costs; input prices: labour expenses, residual expenses per seat (capital). *Outputs:* number of seat-kilometres, network length.	-	The comparison of the different estimation methods shows that models which do not distinguish between unobserved network effects and inefficiency can overestimate the inefficiency scores.
Førsund (1992)	DEA, PLP	23 Norwegian ferry companies, 1984-1988.	*Inputs:* total wages, fuel, maintenance and repair cost. *Outputs:* total length run in 1988 multiplied with the capacity of the ferry in (standardised) cars.	-	The results indicate a substantial variation in the level of efficiency across ferries with a potential for input saving of approximately 30%.

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
Gathon and Perelman (1992)	SFA	19 European railway companies, 1961-1988.	*Inputs:* labour units. *Outputs:* passenger- and freight-kilometres, length of the network, density of the network, percentage of the electrified network.	Index for regulatory and institutional environment. *Embedding:* included in the production function.	The results point to a negative correlation between institutional managerial autonomy and technical inefficiency.
Gathon and Pestieau (1995)	Parametric approach	19 European railway companies, 1961-1988.	*Inputs:* total number of engines and railcars, railway staff assigned to the rail operation, length of electrified and not electrified rail lines. *Outputs:* gross hauled ton-kilometers by freight and passengers trains.	Index of institutional autonomy. *Embedding:* second-stage OLS regression.	The mean efficiency scores (over the last three years range from 0.74 (Norway) to 0.95 (Netherlands). Efficiency increases with institutional autonomy.
Hjalmarsson and Odeck (1996)	DEA	72 trucks operated by the Norwegian Public Roads Administration, 1983-1985.	*Inputs:* driver's wage, fuel, rubber accessories, maintenance cost. *Outputs:* total transport distance, effetive hours in production.	Brand type and age of the trucks, regional variable. *Embedding:* Mann-Whitney test.	The mean efficiency scores range from 0.76 to 0.88 depending on the specification used. Neither the age nor the brand of the trucks influence efficiency.
Jorgensen et al. (1997)	SFA	170 bus companies, Norway 1991.	*Inputs:* total costs per vehicle kilometres. *Outputs:* number of vehicle kilometres, average bus size of the company, number of passengers boarding the buses, dummy variables for the type of bus operator and region.	Dummies for the ownership structure and subsidy system. *Embedding:* second-stage OLS regression.	The authors find no evidence for significant relationships between ownership (private or public) and efficiency.
Oum and Yu (1994)	DEA	19 railway companies in OECD countries, 1978-1989.	*Inputs:* number of employees, energy consumption (in BTUs), ways and structures, expenditures on services provided by third parties and purchased materials, number of locomotives, passenger cars and freight wagons. *Outputs:* passenger-kilometres and freight-tonne-kilometres, Passenger train kilometers and freight-train-kilometers.	Passenger-and freight-tonne-km per route-km, passenger train and freight train density, percentage of passenger train-km, average length of passenger trip and haul of freight traffic, passenger and freight load, subsidies, electrified route miles, degree of managerial autonomy. *Embedding:* second-stage Tobit regression.	UK, Sweden, Japan, Ireland, Finland and the Netherlands are close to the best practice frontier. Efficiency increases with the managerial autonomy and decreases with the dependence on public subsidies.
Perelman and Pestieau (1988)	COLS	19 European railway companies, 1970-1983.	*Inputs:* labour, energy consumption, rolling and fixed stock. *Outputs:* index of aggregate output (passengers and freight).	Lines-kms per square km, percentage of electrified lines, track-km per line-km, average passenger journey, length of haul of one ton. *Embedding:* included in the production function.	The results show that there are substantial differences in productive efficiency among the countries. Moreover, the ranking of the efficiency scores slightly changes when exogenous factors are introduced.

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
Rouse et al. (1997)	DEA	Highway maintenance in 73 territorial local authorities, New Zealand, 1993-1994.	*Inputs:* total expenditure on reseals, rehabilitation and general maintenance. *Outputs:* kilometers of road resealed and rehabilitated, index of highway surface defects.	Vehicle kilometers, roughness index for urban and rural roads, environmental index. *Embedding:* included as output variables and two-stage DEA.	The average scores of efficiency, effectiveness and economy are 0.89, 0.69 and 0.63, respectively.
Silkman and Young (1982)	Quasi-Minimum Total Cost Frontier	School bus transportation in 1575 school districts, USA, 1977-1978.	*Inputs:* total operating expenditures. *Outputs:* number of students transported to and from school, transported density.	Locally raised revenue, median family income, population (of different ages), percentage of handicapped students, fraction of district-owned transportation system, grants. *Embedding:* second-stage OLS regression.	The main result suggest that inefficiency increases with the (local) share of grant-dependence - suggesting the presence of fiscal illusion and/or collective incentive accountability effects.
Thiry and Tulkens (1992)	FDH variant	3 urban transit firms, Belgium, 1977-1985.	*Inputs:* number of hours worked per month, energy consumption, number of seat-vehicles in the company's fleet. *Outputs:* number of seat kilometers monthly supplied.	-	The urban transit firms show varying degrees of efficiency over time and across firms as well as little technical progress.
Viton (1992)	SFA	289 transit firms, USA, 1984-1986.	*Inputs:* total operating expenses; input price: (average) hourly wage rates. *Outputs:* vehicle-miles (motor-bus, rail, streetcar, trolley bus).	Measure of system-wide peaking, speed of transport, dummy variable for transport-type. *Embedding:* included in the cost frontier.	The author finds evidence for economies of scope for all modes except for motor-buses.
Administrative Units: Local Governments					
Afonso and Fernandes (2006)	DEA	51 Portuguese municipalities, 2001.	*Inputs:* total per-capita expenditures. *Outputs:* calculation of a single municipal performance indicator from several municipal services.	-	The mean efficiency scores range from 0.57 to 0.99 depending on the specification used.
Afonso and Fernandes (2008)	DEA	278 Portuguese municipalities, 2001.	*Inputs:* total per-capita expenditures. *Outputs:* calculation of a single municipal performance indicator from several municipal services.	Geographical distance to the capital of the district, municipal per capita purchasing power, population density, education level. *Embedding:* second-stage Tobit analysis.	The results suggest that efficiency increases with the level of education, municipal per capita purchasing power and the geographical distance of the municipalities (to the capital of the district).

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
Athanassopoulos and Triantis (1998)	DEA, SFA	172 Greek municipalities, 1986.	*Inputs:* operating costs (expenditures on services, salaries, maintenance and material). *Outputs:* actual households, average house area, heavy industrial use area, tourist areas.	Service expenditures, income from fees and charges, grants, infrastructure investments, incumbent party, population density, index for fees and charges. *Embedding:* second-stage fuzzy k-means cluster analysis and Tobit regression.	The mean efficiency scores range from 0.60 (DEA) to 0.85 (SFA). The technical efficiency decreases with the amount of grants received by the municipalities.
Balaguer-Coll et al. (2007)	DEA, FDH	414 Spanish local governments, 1995.	*Inputs:* wages and salaries, expenditure on goods and services, capital expenditure, current transfers, capital transfers. *Outputs:* number of lighting points, total population, waste collected, surface area of street infrastructure and public parks, quality indicator.	Tax revenue, grants, self-generated revenue, income generated by issuing debt and making loans, deficit, votes held by the governing party. *Embedding:* second-stage nonparametric regression and density estimation.	The results suggest that self-generated revenues, grants, deficit and votes held by the governing party have a negative impact on (technical) efficiency.
Borge et al. (2008)	Ratio of aggregate output to local government revenue	362-384 Norwegian local governments, 2001-2005.	*Input:* local government revenue. *Output:* aggregated indicator which is based on 17 sub-indicators of public services.	Local government revenue, indicator for democratic participation, Herfindahl-Hirschman index, political variables *Embedding:* second-stage OLS regression.	The results suggest that efficiency decreases with the fiscal capacity and the degree of party fragmentation, while efficiency increases with democratic participation. Moreover, a centralised top-down budgetary procedure is associated with low efficiency.
De Borger and Kerstens (1996a)	DEA, FDH, COLS, SFA	589 Belgian local governments, 1985.	*Inputs:* total expenditures. *Outputs:* number of beneficiaries of minimal subsistence grants and students enlisted in local primary schools, surface area of public recreation facilities, total population, fraction of population older than 65.	Per capita income, tax rate, per capita block grants, number of coalition parties, dummies for liberal and socialist ruling party, education level, population density. *Embedding:* second-stage Tobit and OLS regressions.	The mean efficiency scores range from 0.57 (COLS) to 0.94 (FDH). Technical efficiency increases with the local tax rate and the education level and decreases with per capita grants and income.
De Borger and Kerstens (1996b)	FDH	589 Belgian local governments, 1985.	*Inputs:* total expenditures. *Outputs:* surface of municipal roads + outputs of De Borger and Kerstens (1996a).	See De Borger and Kerstens (1996a) without population density. *Embedding:* second-stage Tobit regression.	The mean efficiency scores range from 0.81 to 0.97 depending on the specification used. The fiscal revenue capacity as well as the per capita block grants are important determinants of technical efficiency.

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
De Borger et al. (1994)	FDH	589 Belgian local governments, 1985.	*Inputs:* number of white-collar and blue-collar municipal employees, capital stock. *Outputs:* municipal road surface, number of beneficiaries of minimal subsistence grants and students enrolled in local primary schools, surface of public recreational facilities, ratio of non-residents to residents in municipality.	Total population, income, block grants, number of coalition parties, dummies for liberal and socialist ruling party, education level. *Embedding:* second-stage Tobit regression.	The mean efficiency scores range from 0.86 to 0.95 depending on the specification used. The scale and fiscal revenue capacity are important determinants of efficiency.
Geys (2006)	SFA	300 Flemish municipalities, Belgium, 2000.	*Inputs:* total current expenditures. *Outputs:* number of subsistence grants beneficiaries, number of students in local primary schools, surface of public recreational facilities, total length of municipal roads.	Income, share of homeowners, population density, municipal amalgamation, public debt, surplus, grants, governmental and ideological fragmentation, government's ideological position. *Embedding:* second-stage ML spatial lag model.	The results suggest that municipalities with more efficient neighbours tend to be more efficient themselves. Moreover, a high share of homeowners has a positive impact on government efficiency.
Geys and Moesen (2009a)	SFA	300 Flemish municipalities, Belgium, 2000.	*Inputs:* total current expenditures. *Outputs:* number of subsistence grants beneficiaries and students in local primary schools, surface of public recreational facilities, total length of municipal roads, share of municipal waste collected through door-to-door collections.	Income (inequality), unemployment rate, education level, total population, share of homeowners, population density, municipal amalgamation, public debt, surplus, grants, government's ideological position, dummies for type of municipality. *Embedding:* one-step approach.	The results suggest that larger and more densely populated municipalities tend be less efficient, whereas efficiency increases with the amount of grants received by the municipalities.
Geys and Moesen (2009b)	DEA, FDH, SFA	304 Flemish municipalities, Belgium, 2000.	*Inputs:* total current expenditures. *Outputs:* number of subsistence grants and students in local primary schools, surface of public recreational facilities, total length of municipal roads, share of municipal waste collected.	-	The mean efficiency scores range from 0.50 (DEA) to 0.95 (FDH).

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
Gimenez and Prior (2007)	Non-convex frontier methods	258 local governments in Catalonia, Spain, 1996.	*Inputs:* materials consumption and service acquisition, current transfers to decentralised organizations, total labour cost. *Outputs:* urban area, total population, number of cars, number of buildings, ordinary refuse.	Dummies for income, industry and libraries, index for commerce and tourism, total population, population density, number of inhabitants aged under 14 and over 65, police force. *Embedding:* second-stage Tobit regression.	The cost level of inefficient municipalities is on average 25% higher than the efficient level. Efficiency increases with commercial activity, tourism as well as population size and decreases with income.
Grosskopf and Hayes (1993)	Shepard-type distance function	154 municipalities in Illinois, USA, 1982-1986.	*Inputs:* weighted average salary for all uniformed employees (labour input), average yielded rates for the bond rating reported for the municipality (capital price). *Outputs:* ratio of population to crimes committed, median housing value in each municipality.	-	The average levels of technical inefficiency suggest that inputs could be reduced by over 10%.
Grossman et al. (1999)	SFA (production function)	49 U.S. central cities, 1967, 1973, 1977 and 1982.	*Inputs:* market value of property tax base, property tax system, personal property in city's residential and business property base, municipal expenditures, total expenditures on education, homes built in last decade, area, employment, African American population, median income, intergovernmental revenue, non-property tax plus sales tax revenues, overlapping state/county taxes, local fee revenue, number of homes. *Outputs:* aggregate market value of residential and business property.	Number and average population of cities, number of cities in the city's census population grouping, local income tax, state and federal grants, years for mayor's term of office, mayor-council form of government, mayor elected. *Embedding:* included in the production function.	The results suggest that large cities in the United States are operating at different levels of technical efficiency.
Loikkanen and Susiluoto (2005)	DEA	353 Finish municipalities, 1994-2002.	*Inputs:* sum of the net operating costs of providing health and social services, culture and education. *Outputs:* children's day care centres, children's family day care, open basic health care, dental care, bed wards in basic health care, institutional care of the elderly and handicapped, comprehensive schools, senior secondary schools, municipal libraries.	Size-related factors, location and physical structure, producer of services, age of employees, unemployment rate, grants. *Embedding:* second-stage OLS regression.	The averages of the annual median efficiency scores range from 0.86 to 0.90 depending on the specification used. Efficiency decreases with income, population size, unemployment rate and grants. High education levels, in contrast, were found to increase efficiency.
Sampaio De Sousa and Ramos (1999)	DEA, FDH	3756 Brazilian municipalities, 1991	*Inputs:* current spending. *Outputs:* total resident population, domiciles with access to safe water, domiciles served by garbage collection, illiterate population, enrolment in primary and secondary municipal schools.	-	The results suggest that smaller municipalities are less efficient in the provision of public goods and services than bigger municipalities.

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
Sampaio De Sousa and Stosic (2005)	DEA with "jack-strap", FDH	4796 Brazilian municipalities, 2001	*Inputs:* current spending, number of teachers, rate on infant mortality, hospital and health services. *Outputs:* enrolment, student attendance, students who get promoted to the next grade, students in the right grade (all per school), total and literate population, households with access to safe water, sewage system and garbage collection.	-	The mean efficiency scores range from 0.52 (DEA) to 0.92 (FDH)
Sung (2007)	DEA	222 Korean local governments, 1999-2001.	*Inputs:* local servants per 100 persons, annual constant expenditures per capita. *Outputs:* penetration rate of water supply, area of urban parks, ratio of road length to area, registered motor vehicles, sewage and refuse disposal, seating capacity of social welfare institutions, basic livelihood security recipients, building construction permits, civil affair and petition cases.	Number of local residents, population density, area, establishments, service related establishments, workers per person, collected local tax per person. *Embedding:* second-stage Tobit regression.	The mean efficiency scores range from 0.57 to 0.99 depending on the specification used. Moreover, the empirical findings strongly confirm the positive role of IT in improving (technical) efficiency and accelerating productivity growth.
Vanden Eeckaut et al. (1993)	DEA, FDH	235 Walloon municipalities, Belgium, 1986.	*Inputs:* total expenditures. *Outputs:* length of municipal roads, Number of subsistence grants and students in local primary schools, total population, number of persons aged 65 and more, number of crimes registered.	-	80% (20%) of the municipalities are efficient under FDH (DEA). Moreover, the results suggest that local governments with multiple-party coalitions are more efficient than municipalities governed by a single party.
Worthington (2000)	DEA, SFA	177 local governments in New South Wales, Australia, 1993	*Inputs:* number of full-time equivalent employees, other physical expenses, financial expenses; input prices: average municipal salary, physical expenditures divided by current assets, average interest rate paid on borrowed funds. *Outputs:* population, properties receiving domestic waste management services, sewerage services and water services, length of urban and rural roads.	Grants, debt service ratio, level of current assets, firm's current ratio, number of staff per 1000 capita, average rate per residential assessment. *Embedding:* second-stage Tobit regression.	The mean efficiency scores range from 0.70 (DEA) to 0.87 (SFA). The second-stage Tobit regressions show that the use of the different reference technologies has a crucial influence on the signs of the coefficients of the independent variables.

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
Administrative Units: Countries					
Afonso et al. (2005)	FDH	23 industrialised OECD countries, 1990 and 2000.	*Inputs:* total public spending as a percentage of GDP. *Outputs:* public Sector Performance (PSP): Aggregated indicator of the performance of the public sector (PSP consists of seven sub-indicators reflecting different responsibilities of the governments).	-	Small governments tend to be more efficient than large governments. The expenditures of the EU 15 countries are, on average, 27% higher than those of the "most efficient" countries (with similar PSP indicators).
Afonso et al. (2008)	DEA	24 emerging markets, 1999-2003.	*Inputs:* total public spending as a percentage of GDP. *Outputs:* public Sector Performance (PSP): Aggregated indicator of the performance of the public sector (PSP consists of six sub-indicators reflecting different responsibilities of the governments).	Secondary school enrolment, competence of the incumbents, per capita GDP, index for property rights and political accountability, trade openness, transparency in public policy. *Embedding:* second-stage Tobit regression.	Singapore, Thailand, Cyprus, Korea, and Ireland are very close to the best practice frontier. The (technical) efficiency increases with per capita income, the education level, the competence of the incumbents and the security of property rights.
Brockett et al. (1999)	DEA	17 OECD countries, 1979-1988.	*Inputs:* labour: real GDP per worker, capital: capital stock per worker. *Outputs:* GDP	-	In the period from 1979 to 1988 productivity increased in Japan and Finland, while the productivity growth in Ireland almost strictly decreased.
Henderson and Zelenyuk (2007)	DEA	52 developed and developing countries, 1965 and 1990.	*Inputs:* physical capital: capital per worker, employment: real GDP per worker, human capital: average years of schooling. *Outputs:* real GDP per capita multiplied by population.	-	The mean efficiency scores in 1965 and 1990 are approximately 0.52, respectively. Moreover, the results suggest that developed countries are more efficient than developing countries.
Lovell (1995)	DEA, FDH	10 Asian countries, 1970-1988.	*Inputs:* country's macroeconomic decision-making apparatus (=1 for every country). *Outputs:* growth rate of GDP per captia, ratio of civilian employment to the civilian labor force above a certain age, trade balance, growth rate of the consumer price index.	-	The macroeconomic performance of Taiwan and Japan are best, whereas the Philippines and Australia are at the end of the ranking.
Lovell et al. (1995)	DEA variant	19 OECD countries, 1970-1990.	*Inputs:* country's macroeconomic decision-making apparatus (=1 for every country). *Outputs:* real GDP per capita, inflation rate, employment rate, trade balance.	Carbon and nitrogen emissions. *Embedding:* included in the production function.	The results strongly depend on the specification used (e.g. whether exogenous variables are included or not).

Name	Method	Sample	Inputs and Outputs	Exogenous Variables	Main Findings
Maudos et al. (2003)	DEA, SFA	23 OECD countries, 1965-1990.	*Inputs:* labour: real GDP per worker, capital: non-residential capital per worker, human capital: number of schooling years completed by the occupied population. *Outputs:* real GDP.	-	The SFA mean efficiency scores range from 0.81 to 0.83 depending on the specification used. Moreover, human capital seems to influence the growth of the OECD countries positively.

Note: COLS = Corrected Ordinary Least Squares, DEA = Data Envelopment Analysis, DFA = Distribution Free Approach, FDH = Free Disposal Hull, OLS = Ordinary Least Squares, PLP = Parametric Linear Programming, SDEA = Supper-Efficiency Data Envelopment Analysis, SFA = Stochastic Frontier Analysis. For an overview of the estimation approaches which are not explained in chapter 2, see e.g. Fried et al. (2008b).