Empirical analyses of public service productivity and an experimental investigation of norm violations

Inauguraldissertation

zur Erlangung des akademischen Grades
doctor rerum politicarum

eingereicht an der

Wirtschaftswissenschaftlichen Fakultät
der Heinrich-Heine-Universität Düsseldorf

von
Maria FRIESE, M.Sc.
geboren am 03. Dezember 1989 in Berlin

Erster Gutachter:
Univ.-Prof. Dr. Justus HAUCAP

Zweiter Gutachter:
Univ.-Prof. Dr. Florian BAUMANN

Rektorin der Heinrich-Heine-Universität Düsseldorf:
Univ.-Prof. Dr. Anja STEINBECK

Dekan der Wirtschaftswissenschaftlichen Fakultät:
Univ.-Prof. Dr. Justus HAUCAP

September 2017

Acknowledgements

There are several people without whom the completion
of this thesis would not have been possible.

I want to thank my first supervisor, Justus Haucap,
for providing input at several stages of my dissertation and

my second supervisor, Florian Baumann,
for broadening my research interests through our collaboration.

My gratitude also goes to my coauthors
Volker Benndorf, Ulrich Heimeshoff and Gordon Klein.

I am thankful to my friends and colleagues
Andrea, Hamid, and Ismael for continuous support.

Finally, I always knew I could count on my family and my friends,
Hannah and Ida, which made this task much easier.

Thanks also to Stefan Seitz and Kristin Nowak at the Research Data Centre (FDZ) of the Statistical Office in Stuttgart for data provision and technical support. Funding from DICE (GRK 1974) is gratefully acknowledged.

Contents

Acknowledgements **iii**

1 Introduction **1**

2 Task bundling, ownership and efficiency **5**
2.1 Introduction 6
2.2 Efficiency of incineration plants 9
2.2.1 Related literature 9
2.2.2 Industry background 10
2.3 Data 12
2.4 Data Envelopment Analysis 16
2.4.1 General methodology 16
2.4.2 Empirical implementation 18
2.5 Results 20
2.5.1 Efficiency scores 20
2.5.2 Regression of efficiency scores 20
2.6 Robustness checks 24
2.6.1 Accounting for secondary outputs 24
2.6.2 Stochastic frontier analysis 25
2.7 Conclusion 27
2.A Data appendix 29
2.A.1 Sources 29
2.A.2 Definition 30
2.B Bootstrap procedure 31
2.C Efficiency scores 31

3 Ownership and organization in German public service provision **33**
3.1 Introduction 34
3.2 Productivity of public services 37
3.2.1 Institutional background 37
3.2.2 Empirical studies on public vs. private provision 39
3.2.3 Organizational structure and productivity 40

3.3 Empirical strategy and data 42
3.3.1 Production function 43
3.3.2 Effect of organizational structure 45
3.3.3 Data and summary statistics 47
3.4 Estimating equations and results 50
3.4.1 Production function 50
3.4.2 Total factor productivity 50
3.4.3 Robustness check: addressing potential price bias 54
3.5 Conclusion 55
3.A Data sources – overview 57
3.B Legal forms 58
3.C Tabulation of the organizational structure 58
3.D Individual data sources 59

4 Do frustration and anger promote criminal behavior? 69
4.1 Introduction 70
4.2 The experiment 71
4.2.1 Design and treatments 71
4.2.2 Procedures 72
4.2.3 Hypotheses 73
4.3 Results 74
4.4 Conclusion 77
4.A Experimental instructions 79

5 Conclusion 85

Bibliography 87

Declaration of Authorship 95

List of Figures

2.1 Input-oriented DEA, two inputs and one output 17

4.1 Share of subjects who try to take money from the charity by frame and gender 74
4.2 Predicted taking probabilities and 95% confidence interval of the taking decision 76

List of Tables

2.1 Modes of provision 11
2.2 Summary statistics 15
2.3 DEA scores using operational costs; and labor 19
2.4 DEA scores using operational costs and capital expenditures; and labor 20
2.5 Regression of DEA scores using operational costs; and labor . . . 21
2.6 Regression of DEA scores using operational costs and capital expenditure; and labor 23
2.7 Regression of DEA scores using revenue as output 25
2.8 Stochastic frontier estimation 27
2.9 DEA scores using revenue as output 31

3.1 Summary statistics by organizational structure 49
3.2 Production function estimates 50
3.3 TFP regressions 53
3.4 Relation between prices and organizational structure 55

4.1 OLS estimations for emotions 73
4.2 Probit estimations of the taking decision 75

Chapter 1

Introduction

This thesis, entitled "Empirical analyses of public service productivity and an experimental investigation of norm violations", has been written while I was a doctoral researcher at the Düsseldorf Institute for Competition Economics at Heinrich-Heine-Universität Düsseldorf. It considers two different areas of economics. The first part empirically studies the productivity of public services in a very particular industry, the garbage sector. Another strand of my research considers human behavior in the area of Law & Economics and tries to explain what factors might lead people to revert to crime. Specifically, we conduct a lab experiment to study if frustration and anger resulting from losses make people more likely to commit a norm violation.

There is a long academic discussion about whether public services should be provided by the government or if it is better to outsource them to private firms (Grossman and Hart, 1986; Hart et al., 1997; Williamson, 1993). The debate has given rise to a number of studies aiming to test if public firms are more productive than private ones. Often, the results are not clear-cut, and the conclusion depends on regulatory characteristics, the industry studied, technological considerations, and many other aspects (Villalonga, 2000). Furthermore, many determinants other than ownership have proven influential for productivity.

The market that we study is the one for garbage, an industry that has rarely been examined empirically, especially for Germany.[1] We analyze two unique sectors, which involve different firms and have each a distinct production technology. Chapter 2 deals with garbage incineration, which can be regarded as the last part of the value chain, disposing of the garbage by burning it. In Chapter 3, we focus on garbage collection, which involves transportation from where the waste is produced to incineration or recycling plants.

[1] This is despite of the fact that garbage fees are an important component of consumers' expenditures for utilities and have been shown to diverge widely between municipalities (Bund der Steuerzahler NRW, 2017; Verivox, 2008).

However, there are also interconnections between the components of the garbage sector, such that better cost performance in one part can influence others. For example, the amount a household pays for the collection of garbage highly depends on how much the municipalities themselves must spend for its incineration. Therefore, the question how and why firms in the garbage sector differ with respect to their efficiency has gained interest among political decision makers, even though economic considerations rarely affect the waste management concept (Bilitewski and Härdtle, 2013). One reason may be that there is little through analysis of efficiency-affecting factors in this area and our research contributes to filling this gap.

The factors that we study are not limited to public vs. private provision, but encompass other aspects of the organization. Chapter 2 entitled "Task bundling, ownership and efficiency: An application to garbage incineration" deals with the efficiency of incineration plants. Here, we study the role of ownership and *task bundling*, i.e. managing the plant with one firm instead of having several entities involved in production. The role of task bundling in the form of public-private partnerships has been recently studied theoretically (Bennett and Iossa, 2006; Martimort and Pouyet, 2008), but has not received much attention in empirical works. Besides from this, we include local concentration of incineration capacities to determine whether competition increases technical efficiency. We use Data Envelopment Analysis (DEA) to derive efficiency scores using a unique data set of 34 incineration plants between 2006 and 2014. The influence of environmental variables is analyzed in a second stage where inference is made using a recent technique by Simar and Wilson, (2007).

We find that private shareholding affects efficiency positively across all specifications. With a 10 percentage point higher share of private ownership, technical efficiency is estimated to increase by around 3%. Bundling is found to have a negative efficiency effect: both the operation of incineration with a separate plant manager or with another firm owning the assets go along with lower efficiency. The impact of local competition does not have a statistically strong effect, but tends to affect efficiency negatively. This could be attributed to non-optimal development of capacities given current incineration demand.

In Chapter 3 with the title "Property rights and transaction costs - The role of ownership and organization in German public service provision" on garbage collection, we additionally consider a firm's legal structure, which determines transactional costs and information asymmetries between the firm and the municipality as organizer of the service. Using a sample of 84 firms during the years 2000-2012, we estimate a production function using a recent technique

introduced by Ackerberg et al., (2015) to obtain estimates of total factor productivity. These estimates are then projected onto ownership, legal status and a set of control variables. We find that private firms are clearly more productive than public ones, while semipublic firms, in which public and private partners jointly hold stakes, are less productive than their public counterpart.

The second part of this thesis tries to answer the question whether people will violate norms when they feel that the status quo is threatened because of externally caused losses. The experimental study is motivated by the observation that the existence of crime may not solely be attributable to the decision of rational agents. Whereas Becker, (1968) argues that persons will make a simple cost-benefit analysis when deciding whether to commit a crime, other strands of literature both inside and outside economics offer alternative interpretations.

In economics, the prospect theory by Kahneman and Tversky, (1979) suggests that people care more about changes in payoffs from an activity relative to a reference point than about absolute ex-post levels. In the criminological literature, the general strain theory (Agnew, 1992) hypothesizes that crimes are committed because individuals respond to the loss of income, status, or other values with negative feelings, which in turn increase the propensity to behave criminally.

Chapter 4 titled "Do frustration and anger promote criminal behavior? Experimental evidence on the role of gender" reports the results of our lab experiment. Motivated by the arguments mentioned above, we analyze the influence of experiencing losses on the decision to commit a gainful norm violation. Here, losses are invoked by framing the income of a real-effort task in such a way that participants get money subtracted from their budget over the course of the experiment. The norm violation is modeled by allowing participants to take away money from a donation intended for charity. We specifically explore the emotional channels through which the loss treatment affects the norm violation, as these are considered a main driver of crime in the criminology literature.

We find that only men react to loss framing with an increased propensity to take away the donation. Women, on the other hand, tend to take more often in the gain frame, so that there is a significant gender effect. This difference is not explained by the loss treatment affecting the genders aversely: in fact, both males and females react with increased frustration and anger to the loss experience. However, it seems that both genders deal differently with emotions. Whereas men tend to take the donation the more frustrated and angry they are, we do not find such an effect for females.

Chapter 2

Task bundling, ownership and efficiency: An application to garbage incineration

Summary of the chapter

I analyze the role of task bundling, ownership and competition in explaining efficiency of refuse incineration plants. Efficiency scores are derived from Data Envelopment Analysis for a unique sample of German incineration plants between 2006 and 2014. Private ownership is associated with higher efficiency, while managing production with several firms (task unbundling) is found to hamper efficiency. Local competition from other incineration plants does not have a statistically significant effect.

2.1 Introduction

A widely discussed topic among economic scholars is how the government should organize the provision of public tasks. One example of a service that governments must fulfill is offering citizens opportunities for disposing of garbage. On average, every person in the European Union produces 1.3 kg of waste per day (Eurostat, 2015). The state, in most cases the local government, must find adequate means to dispose of waste, while complying with environmental laws and social norms. Incineration of waste is one possible option that has been used in Germany since the 1970's.

These plants have the reduction of the waste in volume and weight through incineration as primary objective and usually produce energy as a by-product. Building and operation of plants requires large investments over long planning horizons, so that strategies for incineration influence municipal budgets and, ultimately, the citizens (Rand et al., 2000). Therefore, the analysis of technical performance and costs of incineration plants has gained interests among local decision makers, although such considerations rarely affect actual political decisions (Bilitewski and Härdtle, 2013). Furthermore, recent investments into new capacities in Germany led to increased competition and raise the question how such a change in the operating environment affects an individual plant and the sector as a whole.[1]

The goal of this chapter is to analyze the productive efficiency of incineration plants in Germany, particularly regarding the impact of various efficiency determinants raised in the literature. Analyzing productivity differences between firms has been of interest to economists for a long time (for a survey, see Syverson, 2011). One type of studies concerns analyzing factors influencing efficiency of public utilities. An often-considered determinant of empirical studies on efficiency dispersion is ownership, which has its foundation in several strands of theoretical literature (Boycko et al., 1996; Hart et al., 1997; Laffont and Tirole, 1993). A common consensus is that the influence of ownership is heterogeneous (Villalonga, 2000), which implies that analyses looking at specific industries and countries are important. The impact of private ownership is therefore included in this empirical analysis, as plants differ largely in the degree of private involvement.

[1] A prohibition of landfills in 2005 led to increased demand for capacity, which made it lucrative to invest into building new incineration plants. This development led to the existence of overcapacities around the year 2010 (Rau, 2010). Political decisions clearly affected the market environment and it is therefore interesting to analyze if this translates into measurable efficiency effects.

Apart from ownership, the degree of competition in an industry is known to influence firm performance. Replacing regulation with market mechanisms in formerly state-dominated sectors between the 1970's and 1990's has shown to improve efficiency in various industries (Fabrizio et al., 2007, for electricity generation; Galdon-Sanchez and Schmitz, 2002, for production of iron ore; Olley and Pakes, 1996, for the telecommunications sector). Given that competition has proven influential to improve efficiency in these other sectors, this chapter investigates whether this is also the case for incineration. Competition is particularly relevant in our setting because the plants are not pure local monopolies. Most actors wanting to incinerate their garbage can chose the cheapest plant around based on per-ton incineration prices and transportation costs.[2]

A claim from recent theoretical work, which has rarely been studied empirically, is that the structure of organization within a public service can further influence its cost (Martimort and Pouyet, 2008). The emerging literature on public-private-partnerships (PPPs) deals with the question whether provision of a public task should be carried out by several firms, or by a single one if service delivery entails different tasks (Hart, 2003). Combining two tasks – termed *bundling* – is found to lead to lower costs if better performance in the first task positively affects the second, for example by decreasing costs or increasing productivity.[3] A related intuition can also be found in the literature on vertical relations, where integration can avoid duplication efforts or exploit existing technological externalities among vertical structures (Grossman and Hart, 1986; Williams, 1985).

In the German industry for garbage incineration, operation and technical management are either done within the same firm, or performed by two separate entities. Operation includes strategic planning (acquisition of garbage, managing capacity utilization) and investment into assets (renovating and building infrastructure). The technical manager is mostly responsible for ensuring smooth production (interfering at production stoppage, managing energy transmission). If performing day-to-day production also led to better long-run management decisions, this would translate into lower costs and there would be benefits of integrating these tasks within one firm. Similarly, there exist plants where asset ownership is outsourced, which could further affect performance. Such forms

[2]This goes for private actors (companies) and municipalities that have not tied themselves contractually to using only one plant. Both of these actors are important.

[3]Martimort and Pouyet, (2008) use a multi-task principal agent environment with sequentiality to show that bundling is optimal if performance in the first decreases the cost of the second. Bennett and Iossa, (2006) and Hart, (2003), who base their analysis on the theory of property rights, find a similar result.

of organization are denoted bundling in this chapter and their influence will be examined in the empirical analysis.

Overall, I test the effect of competition, ownership, and bundling on performance by relating them to efficiency scores derived from the non-parametric tool of Data Envelopment Analysis (DEA). I use a unique, self-composed data set of 37 German incineration plants between the years 2006 and 2014. The method employed has the advantages of allowing multiple outputs and inputs, while making no assumptions of the underlying technology. Efficiency is computed from a production frontier with variable returns to scale, known as the BCC model (Cooper et al., 2007). The efficiency score is then projected onto the factors described above and control variables using a procedure advanced by Simar and Wilson, (2007).

The data set created combines data administered and provided by the Statistical Office of Germany for output with publicly available financial and operating data from incineration plants for the inputs. For unbundled structures, cost data are available for all stages of the production process. To address efficiency-influencing factors, further control variables are added from various sources.

I find that a higher degree of private ownership is associated with plants being more technically efficient. Conversely, efficiency is decreased if more than one firm is involved in running the plant. Outsourcing day-to-day business to a firm is found to decrease efficiency. The same effect is found for firms that rent their machinery: here, efficiency is significantly lower than for plants owning their own assets. Local competition does not have a pronounced effect on efficiency, but some evidence points to its effect being negative. All results are similar when considering the energy production of incineration plants in the definition of output. Furthermore, the effects can be reproduced in a robustness check using the parametric technique of estimating a stochastic frontier, which is a complementary way of examining efficiency.

The chapter proceeds as follows. Section 2.2 summarizes the relevant literature and gives some industry background. The data is described in Section 2.3. Section 2.4 discusses the empirical approach used. Section 2.5 presents the main results and Section 2.6 shows several robustness checks. Section 2.7 concludes.

2.2 Efficiency of incineration plants

2.2.1 Related literature

The effect of bundling in the sense of integrating horizontally related tasks has rarely been considered in empirical work. One analysis, even though methodologically different from this study, is done by Takahashi, (2011). He estimates a production function exploiting a reduction of job classifications that led to a broader range of tasks for workers in Australian coal mines. Takahashi, (2011) finds that using the same workforce for production and maintenance increases productivity. The benefit is attributed to reducing duplication effort and waiting time for the maintenance and operation of coal mine machinery. An analysis of combining tasks in the form of horizontal integration is also done by Lu and Wedig, (2013). Using a sample of nursing homes, the authors argue that monitoring possibilities from regional clustering can be one way to solve increasing agency costs of horizontal integration.

In the empirical literature, it is more common to consider the benefits of vertical integration, which follows a similar intuition as task bundling. Even though differences exist in the theoretical modeling, the practical insight is that tasks should be carried out jointly if positive spillovers exist. As an example, Nemoto and Goto, (2004) or Kwoka, (2002) examine the effect of integrating the generation and distribution stages in the electricity sector by estimating cost differences between the two structures using parametric cost functions. Both studies find that integration leads to considerable cost savings. Conversely, Garcia et al., (2007) find that economies of vertical integration do not exist in the water sector.

In contrast to bundling, ownership and competition are considered in many studies, independent of the precise method to estimate efficiency. In the context of Data Envelopment Analysis, relevant contributions include Su and He, (2012) and Sueyoshi and Goto, (2012).[4] Su and He, (2012) study a sample of Chinese manufacturing firms and show that enterprises owned directly by the Central State are less efficient than other forms of public ownership. A similar result is found by Lam and Shiu, (2004) who study Chinese thermal power plants. In the context of Swedish retail stores, Maican and Orth, (2015) demonstrate that more local competition in the form of flexible policies for new market entrants increases productivity.

[4] A meta study on DEA for electricity and environment is provided by Sueyoshi et al., (2017).

2.2.2 Industry background

Incineration plants burn different types of garbage at high temperatures and produce electricity, heat or steam, or a combination of them, as a by-product. In this chapter, I focus on plants burning conventional household garbage and exclude those that treat other forms, such as hazardous waste or sewage sludge. Since 2005, all garbage in Germany needs to be incinerated or recycled, after a regulation prohibited the use of landfills (Umweltbundesamt, 2016). As a result of the prohibition, there was a short-term spike in demand for capacities, while the market is exhibiting local overcapacities in recent years (Wilts, 2012).

Two main factors led to this trend. First, capacities had been quickly built after fearing that current installations would not suffice after the prohibition of landfills. Second, a new type of plants using refuse-derived fuel (RDF) appeared in the market and started to compete with conventional incineration plants on the acquisition of domestic garbage (Thiel, 2013). RDF plants burn waste that has a higher calorific value on average than conventional household garbage, e.g. plastic and industrial wastes (Wilts, 2012). However, some proportion of waste can be burned in both types of plants and this is the fraction that the different plants compete upon.[5] These market developments will be considered in the empirical analysis later.

The decision to construct an incineration plant is made by local governments as a means to fulfill their obligation of handling waste. The local government can decide on management style and ownership structure (Claus, 2000). In practice, the engagement of private firms differs considerably among the plants. Besides from purely public and purely private ownership, intermediate regimes of semipublic ownership of the operator exist.

Another aspect of the management strategy is deciding how many firms carry out the tasks of a particular plant. This bundling (one firm only), or unbundling (several firms), of tasks will be analyzed in this chapter. On a practical basis, tasks can be divided into three broad categories. First, an administrative one that involves dealing with customers, setting incineration fees and managing the broad organization of the plant. Second, day-to-day operation is related to insuring smooth production, interfering at complications (often incidents of fire), and managing small-scale technical maintenance. Third, developing a long-run perspective of the plant, which includes planning renovations, plant

[5] Refused-derived fuel is produced by transforming high-caloric refuse of different types into other forms, such as flock or pallets (Buekens, 2013). Therefore, RDF plants can burn RDF produced from household waste that could have been burned in a conventional incineration plant.

TABLE 2.1: Modes of provision

	bundling status	firms involved (tasks)	% firms	N
B	bundled	**operator** (strategy, investment, plant management, maintenance)	79.4	209
PM	tasks unbundled	**operator** (strategy, investment) **plant manager** (plant management, maintenance)	5.9	7
AO	ow'sh unbundled	**operator** (strategy, plant management, maintenance) **asset owner** (investment)	11.8	35
PM, AO	tasks and ow'sh unbundled	**operator** (strategy) **plant manager** (plant management, maintenance) **asset owner** (investment)	2.9	8

expansion and technical improvements. These investments into plant equipment are important as regulatory constraints (mostly related to emission levels) are increasing and technological developments emerge.

For the empirical analysis, I classify all plants into one bundling regime depending on how these tasks are organized. The different structures observed in the sample are summarized in Table 2.1. Under a bundled structure (B), all categories are performed within the same firm and there is one operator (O) doing all three tasks. Under task unbundling, there is a separate plant-managing firm (PM), which may or may not be vertically related to the operator. Lastly, there exist also structures in which there is a separate company owning the tangible assets (AO) such as machines and land, which it leases to the operator. Again, those two firms may be in some way related through shareholding. The fourth scenario is the one where task and ownership unbundling occur simultaneously (last row).

There are several possibilities in which the bundling status could affect efficiency. For the case of a separate plant manager it could be, for example, that learning from day-to-day management led to better long-run business decisions. Then, benefits from bundling would stem from increased business expertise. Regarding asset leasing vs. the plant using its own infrastructure, efficiency might be fostered because firms owning assets have bigger investment incentives when this also increases operational efficiency.[6] Evidence from business

[6]The trade-off between investing into asset quality vs. regularly incurring maintenance costs for fixing equipment is also mentioned by Iossa and Martimort, (2009) in the context of the transportation sector. The fact that the integration status can affect costs has also been shown for

reports suggests that certain types of investments are likely to decrease costs in the long-run, which would make a case for integrating asset ownership and operation.[7] Such an intuition follows the main argument of the PPP literature claiming that positive externalities between stages favor task integration (Martimort and Pouyet, 2008).

2.3 Data

The data used in this chapter stem from two main sources. Input data are obtained from publicly available documents, mainly firms' annual statements, which are published in the German Federal Gazette. This data is complemented by annual statements obtained from other sources, like reports of municipalities on shareholding in companies (*Beteiligungsbericht*) and reports provided by the operators themselves. Output data (garbage incinerated) is found in the waste balance report (*Abfallbilanz*), a data set that is gathered and administered by the Federal Statistical Office Germany. Control variables are collected from several sources, see Appendix 2.A.1 for details. All variables are measured on an annual basis for the years 2006-2014.

The relevant industry that is analyzed with the data is all German incineration plants burning mainly household waste. The sample is created by excluding plants for which the required data is not available.[8] The final sample contains 37 out of 70 incineration plants, which represents around 50% of capacity installed.

As inputs, I use labor (measured as number of workers) and operational costs from the income statements. Operational costs are the sum of material costs, other operating expenses and depreciation. This is done because firms have some liberties in allocating costs into relevant categories. In order to obtain a quantity-equivalent of the cost input, it is deflated using a weighted average of appropriate cost indices taking into account the contribution of each cost category and regional price differences. The relevant deflators are described in Appendix 2.A.2.

the railway sector, where operation can be separated from managing infrastructure (Ivaldi and McCullough, 2008).

[7] Examples include the investment into flue gas treatment equipment, which leads to long-run decreases in energy consumption, or installations of electronic systems monitoring component deterioration that in turn foster operational availability (see, e.g., MVA Weisweiler GmbH & Co. KG, 2007; SRS Ecotherm GmbH, 2014).

[8] There are some plants that I exclude because they perform other activities, such as collecting domestic garbage. In general, DEA accommodates multi-product firms. However, there are not enough firms also performing this activity, such that a reference group cannot be created. Concerning data unavailability, not all municipal plants are obliged to publish annual statements, which leads to further exclusion of plants.

An additional input that may affect efficiency in the long run is capital. There are several ways to measure the contribution of capital, with each method having advantages and disadvantages. One measure is the historical cost of invested capital. However, this measure is not sensible if investment is lumpy (Coelli et al., 2003), as it is likely to be the case for incineration plants. Any imprecise measurement of these costs would be exacerbated by the fact that this input would quantitatively exceed the other inputs by a large amount. Given that I only observe a limited time period and that capital in this industry is very long-lived, I follow Kwoka and Pollitt, (2010) and use a capital expenditure measure.[9] In the second specification, this variable is added to operational costs in order to capture the effect of conserving infrastructure on efficiency.

The main output data is garbage to be incinerated, expressed in tonnes. An additional output is manure to be composted (in tonnes) for those firms that operate a composting plant. As mentioned in Section 2.2.2, plants additionally produce energy (electricity, heat or process steam), but this information is not available on the plant level. However, a robustness check uses total revenue (including income from energy generation) as an output and finds similar results (see Section 2.6.1).

Because plants use different organizational structures for the waste-burning process, some data adjustment must be made when firms are not of the bundled type. For example, a firm with a separate plant-managing firm might look like it were using fewer inputs compared to an integrated plant if only the operator were considered. In order to compare plants to each other in a valid way, the following procedure is used. For unbundled structures (PM), I sum up each input for the plant manager and the operator. Lastly, those costs are subtracted from material expenses that are incurred as compensation for the PM. This is done because internal transfers cancel out if we consider the whole production process and not adjusting the data would bias the results (Garcia et al., 2007). In cases where assets are not owned by the operator (AO), investment expenditure of the asset-owning firm are added. For the last category (unbundled operation and asset ownership), both adjustments are done simultaneously.

Besides from the DEA input and output variables, there are those that are considered outside the production process, but affecting efficiency (environmental variables). Bundling is summarized in Table 2.1 where the frequency of observed provision modes in the sample is displayed. Around 79% are integrated, whereas around 6% have an independent plant manager. In 12% of plants, asset

[9] See Fried et al., (2002), who also exclude capital stock from the inputs of DEA.

ownership is by another firm, while 3% have outsourced both plant management and asset ownership. In the empirical analysis, I include them as indicator variables, *pm* (plant manager) and *ao* (asset owner). For the last category (PM and AO), both variables take on the value of 1.

Firms also differ in the involvement of private actors. In Germany, 17% of incineration plants are privately owned, 23% have a mixed ownership, whereas 60% are fully public. Previous studies have found a positive effect of private ownership for incineration plants (Chen et al., 2014). Therefore, the variable *privshare* is included, which measures shareholding of private companies in the operator as a share.

As mentioned before, one would expect technical efficiency to be further influenced by the competition from neighboring plants. Neighboring capacity within a certain radius around the plant (*neighcap*) will measure the intensity of competition from close-by plants. Competition arises also from so-called refused-derived-fuel (RDF) plants. As described in Section 2.2.2, those plants incinerate using a slightly different technology, but compete with conventional incineration plants on refuse acquisition. I address this interdependence by adding the capacity of RDF plants within a certain radius (*neighcap_o*, with the subscript *o* denoting "other type") as another environmental variable.

In order to control for the demand for incineration which likely varies by demographic structures, both competition variables are divided by population density.[10] Both *neighcap* and *neighcap_o* should capture if plants are able to increase their efficiency when there are more other plants in proximity. In the empirical analysis, I will define three types of competition areas of 50, 100 and 150 km around the plant.[11]

It is also important to control for technical factors that determine efficiency. The first is plant capacity as a proxy for a plant's scale of operation. It is not clear which effect this will have on efficiency: it could be that capacity can lead to size advantages, but also that bigger plants are more difficult to manage (Chen et al., 2014). Second, the age of a plant is likely to be directly related to efficient operation. Because it is quite common to expand the plant by adding new lines,[12]

[10] A similar variable is used by Maican and Orth, (2015) in the context of measuring local competition in the retail market.

[11] These areas should be those that a municipality choosing an incineration plant considers reasonable options given transportation costs. The distance between a municipality and its regularly used incineration plants would be around 50 km on average, but with possibly longer distances in rural areas. In addition, prices might still be constrained by plants further away even though they are not actually chosen, which is why I include two more distance radii.

[12] Lines are sections of the incineration plant that can operate independently from each other. It is common to enlarge the plant by adding a new line.

TABLE 2.2: Summary statistics

	mean	std. dev.	5th perc.	95th perc.
Outputs				
refuse incinerated	290.91	166.63	78.94	686.32
manure composted	3.79	12.72	0.00	4.05
Inputs				
no. of workers	94.28	65.75	0.00	198.00
op. costs	30.25	19.39	9.21	74.85
op. costs plus capital exp.	34.92	21.48	10.85	86.88
Environmental Variables				
share of private ownership	0.34	0.35	0.00	1.00
plant manager $= 1$	0.06	0.23	0.00	1.00
asset owner $= 1$	0.17	0.37	0.00	1.00
neighboring capacity conv.	312.51	300.44	0.00	841.20
neighboring capacity RDF	29.51	28.05	0.00	99.25
age index	18.26	11.68	2.03	42.00
plant capacity	37.02	21.08	10.00	88.00
Other Variables				
revenue	44.66	24.10	12.30	94.57
No. of obs.	259			

Note: Outputs measured in thousands of annual tonnes. Operational costs, capital expenditure and revenue reported in millions of Euros. Neighboring capacities (conventional and RDF) computed by adding up capacity in a radius of 100 km around the plant and dividing it by population density. Age index is capacity-weighted plant age, in years. Plant capacity measured in t/h.

Source: FDZ der Statistischen Ämter des Bundes und der Länder, Statistik der Abfallentsorgung 2006-2014 (refuse incinerated). See Appendix 2.A.2 for sources of the other variables.

I construct the variable *ageindex*, which is the plant age (in years), weighted by the contribution of each line to total capacity.

Table 2.2 summarizes the input and output variables, as well as the environmental variables. The refuse incinerated has its mean at 291.000 metric tonnes per year.[13] Around 12% of plants operate a composting plant, for which the manure composted with a mean of around 3.800 annual tonnes is negligible compared to the waste incinerated. On average, firms employ 94 workers and report costs of around 30.25 mio. Euros. If one additionally considers capital expenditure, this changes to costs of 34.92 mio. Euros.

The second part of the table summarizes the environmental variables. An

[13]This is comparable in magnitude to the yearly waste produced by private consumers in the state of Bremen, which has around 670.900 inhabitants (Statistisches Bundesamt, 2017).

average plant is 18 years old and has an hourly capacity limit of 37 tonnes. The average share of private shareholding is 34%, with the 5% and 95% percentile located at 0 and 1, respectively. For completeness, the table also recalls the bundling regime (for details, see Table 2.1). A plant's competition from its own type is denoted neighboring capacity (conventional), whereas competition from plants burning refused-derived fuel is summarized as neighboring capacity (RDF). One can observe that competition from conventional plants is much stronger than the one from RDF plants.

2.4 Data Envelopment Analysis

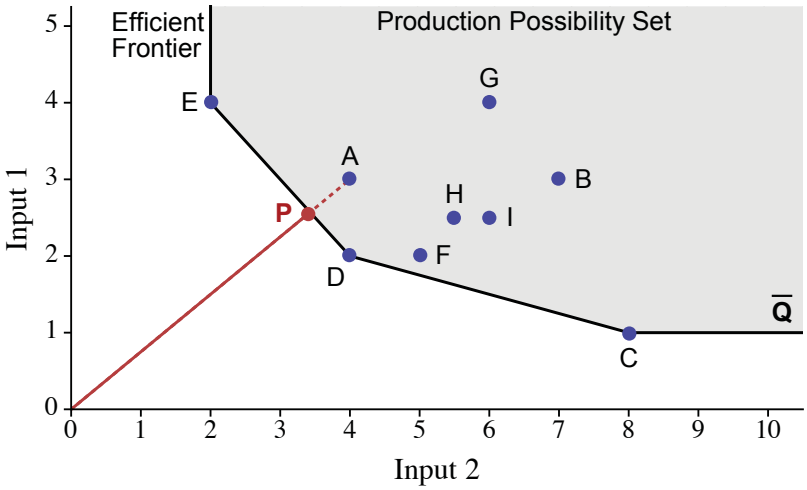
2.4.1 General methodology

Data Envelopment Analysis is one approach to analyze production behavior of decision-making units (DMUs) and associated efficiencies. It is a non-parametric technique that aims to estimate a convex frontier composed of efficient firms that closely fits the data. Away from this frontier are inefficient firms, which do not maximize their output given inputs compared to the reference group of efficient firms. Efficiency is measured by a scalar $\theta \in (0, 1]$, where a value of one signifies that the firm is fully efficient, while firms with a value less than one are considered technically inefficient. Importantly, DEA makes no assumption about the underlying production technology. It deviates from parametric approaches like estimation of a cost function, as it does not assume all firms to be cost minimizers and therefore behave efficiently (Fried et al., 2008).

The scalar θ measures technical efficiency. For example, $\theta < 1$ expresses that all inputs can be proportionately reduced by $1 - \theta$%, while still producing the same output level(s). The specific model used is the BCC model, which allows for variable returns to scale and has been applied to incineration plants in previous work on this topic (Chen et al., 2014).[14] I use an input-oriented model, which is appropriate when the output is largely exogenous to the DMU. This assumption is reasonable, as an incineration plant can influence the quantity delivered to it only to a very limited degree.

[14]One could additionally consider mix inefficiency, which can exist on top of pure technical inefficiency. Mix inefficiencies are input excesses that exist because inputs could be even further reduced after a proportionate input reduction of $1 - \theta$%. This measure is beyond the scope of this chapter.

FIGURE 2.1: Input-oriented DEA, two inputs and one output



Source: Own illustration based on Cooper et al., (2007, Fig. 1.4, p.7)

Let the linear program for the input-oriented BCC model be defined as:

$$\min_{\theta,\boldsymbol{\lambda}} \theta \text{ s.t.} \tag{2.1}$$

$$\theta \mathbf{x}_i - X\boldsymbol{\lambda} \geq 0 \tag{2.2}$$

$$Y\boldsymbol{\lambda} \geq \mathbf{y}_i \tag{2.3}$$

$$\mathbf{e}\boldsymbol{\lambda} = 1 \tag{2.4}$$

$$\boldsymbol{\lambda} \geq \mathbf{0}, \tag{2.5}$$

where θ is a scalar and denotes the efficiency score, $\boldsymbol{\lambda}$ is a $n \times 1$ vector to be optimized upon and $\mathbf{e}$ is a vector of 1's.[15] The program is run for each DMU $i = 1, \ldots, n$, which is equivalent to the plant level for my analysis. The vectors $\mathbf{x}$ ($\mathbf{y}$) contain the k (r) inputs (outputs) used by plant i. The matrices $X_{k \times n}$ and $Y_{r \times n}$ capture the inputs and outputs of all DMUs, respectively.

The logic of DEA is illustrated in Figure 2.1, where observed input usage is plotted for different DMUs given constant output $\overline{Q}$. The region containing all data points (between E and C) presents the production possibility set,

$$P = \{(\mathbf{x}, \mathbf{y}) | \, \mathbf{x} \geq X\boldsymbol{\lambda}, \mathbf{e}\boldsymbol{\lambda} = 1, \boldsymbol{\lambda} \geq 0\}, \tag{2.6}$$

i.e. where production is feasible. The points E, D and C are on the efficient frontier and therefore would have a technical efficiency (θ) of one. In contrast

[15] This model was first proposed by Banker et al., (1984).

to that, all other points represent inefficient DMUs whose performance could be improved by reducing inputs. For example, A's efficiency is measured by considering the ratio $\overline{OP}/\overline{OA}<1$, with O denoting the origin and P being the location where the line OA hits the frontier. Again for DMU A, the reference set is composed of DMUs E and D, as these are the closest observations to it that lie on the frontier.

2.4.2 Empirical implementation

For the DEA estimation to deliver sensible estimates, it is important that all data used is consistent and comparable. Because the data I employ is panel data, a pooling of all observations fails to estimate efficiency scores consistently if there is technological progress in the industry. Under such a scenario, the frontier would shift outwards as time passes and pooling all observations would unjustly treat the early years by comparing them to later data points, which could not be reached given the technological status. On the other hand, the limited sample size does not permit to estimate the frontier separately for each year. Therefore, I conduct a Window Analysis in order to address this issue. In this framework, plants from different years are pooled, but DEA is performed separately for several windows (periods). With this method, it is possible to compare the performance of DMUs over time, as well as investigate industry-wide time changes (Cooper et al., 2011).[16]

I define three windows, each three years long, i.e. 2006-2008, 2009-2011 and 2012-2014. Aside from symmetrically dividing the data period, these windows also broadly capture industry dynamics. The first window can be classified as high market expansion (growth in combined conventional and RDF capacity 10%), the second as moderate (6.0%) and the third as a stable market period (0%).

The impact of non-discretionary variables can be analyzed in several ways. One such approach is a two-step procedure in which the obtained scores from DEA are regressed on a set of covariates to analyze the influence of uncontrollable variables using methods such as OLS or Tobit (see Byrnes et al., 1988; Ray, 1991). Simar and Wilson, (2007) criticize the methodology of using these models when regressing the efficiency scores on covariates for ignoring unknown correlation patterns of the estimated technical efficiency.

[16]This implies that DEA is run using $\sum_{t=1}^{T} n_t$ independent observations, where T denotes the last year of the window and n_t the number of plants in year t.

TABLE 2.3: DEA scores using operational costs; and labor

year	$\hat{\theta}$	
	by year	by window
2006	0.6231	
2007	0.6248	0.6336
2008	0.6536	
2009	0.7230	
2010	0.7314	0.7355
2011	0.7523	
2012	0.6344	
2013	0.5944	0.6307
2014	0.6672	
mean	0.6669	

Source: FDZ der Statistischen Ämter des Bundes und der Länder, Statistik der Abfallentsorgung 2006-2014, own calculations.

Therefore, Simar and Wilson developed bootstrapping methods based on a truncated regression model that makes valid inference of parameters in a second stage possible. In this chapter, I use the first algorithm proposed, but adopted to an input-oriented DEA model.[17] Details of the bootstrap procedure can be found in Appendix 2.B. The second stage considers the relation between estimated efficiency scores and environmental variables and reads as:

$$\hat{\theta} = \beta_0 + \mathbf{Z}\boldsymbol{\beta} + \epsilon, \tag{2.7}$$

where $\hat{\theta}$ is the efficiency score computed from Data Envelopment Analysis, β_0 is the constant, $\mathbf{Z}$ includes all non-discretionary (environmental) variables, $\boldsymbol{\beta}$ is a vector of parameters to be estimated, and ϵ is a normally distributed error term, $\epsilon \sim N(0, \sigma_\epsilon^2)$, with right-truncation at $1 - \mathbf{Z}\hat{\boldsymbol{\beta}}$. The matrix $\mathbf{Z}$ includes the environmental variables as summarized in Table 2.2. These can be grouped into the effects of ownership (*privshare*), bundling (binary variables *pm* and *ao*), and competition (*neighcap* and *neighcap_o*). Additionally, all specifications include the control variables *capacity* and *ageindex*. All regressions are run using year-fixed effects, which control for time-varying factors that affect all plants equally.

[17] The DEA scores were estimated based on Ji and Lee, (2010) and the bootstrapping algorithm was implemented following Tauchmann, (2016) using 200 replications.

TABLE 2.4: DEA scores using operational costs and capital expenditures; and labor

year	$\hat{\theta}$	
	by year	by window
2006	0.7254	
2007	0.6940	0.7185
2008	0.7409	
2009	0.7536	
2010	0.7614	0.7749
2011	0.7880	
2012	0.7150	
2013	0.6999	0.7109
2014	0.7297	
mean	0.7342	

Source: FDZ der Statistischen Ämter des Bundes und der Länder, Statistik der Abfallentsorgung 2006-2014, own calculations.

2.5 Results

2.5.1 Efficiency scores

Tables 2.3 and 2.4 report the mean efficiency for the model without and with considering capital expenditure for the inputs, respectively. I report $\hat{\theta}$ for each year separately (left column) and for every window of the time period 2006-2014 (right column).

For the first model, the estimated score is 0.67 on average over all years and DMUs. Within each window, later scores are on average slightly higher than earlier ones, indicating improving technical efficiency within each window. However, these are raw rates that do not control for other factors, such that making cross comparisons is not very meaningful. Table 2.4 shows the result from the specification where capital expenditures is added to inputs. Here, the average is a score of 0.73, which is higher than the one reported in Table 2.3.

2.5.2 Regression of efficiency scores

Table 2.5 reports the results of the second stage regressions for the first input specification. Columns (1) to (5) display different specifications of environmental variables. In the table, Columns (3) to (5) only differ in that competition

TABLE 2.5: Regression of DEA scores using operational costs; and labor

	(1)	(2)	(3)	(4)	(5)
age index	0.0006	0.0010	0.0007	0.0009	0.0003
	(0.0012)	(0.0011)	(0.0011)	(0.0011)	(0.0011)
capacity	0.0012*	0.0014**	0.0014**	0.0014**	0.0013**
	(0.0007)	(0.0005)	(0.0006)	(0.0006)	(0.0006)
privshare	0.2171***	0.1750***	0.1821***	0.1667***	0.1784***
	(0.0419)	(0.0352)	(0.0397)	(0.0391)	(0.0402)
pm		–0.1661***	–0.1589***	–0.1615***	–0.1508***
		(0.0485)	(0.0487)	(0.0515)	(0.0538)
ao		–0.1143***	–0.1111***	–0.1038***	–0.0994***
		(0.0329)	(0.0315)	(0.0325)	(0.0357)
neighcap_k			–0.0704	–0.0213	–0.0433**
			(0.0460)	(0.0254)	(0.0220)
neighcap_o_k			–0.2246	0.0545	0.0749
			(0.2413)	(0.1388)	(0.0759)
N	259	259	259	259	259

Note: The variables *pm* and *ao* are indicator variables for the existence of a separate plant manager and asset owner, respectively. Columns (3) to (5) use neighboring capacity in a radius of k =50, 100, 150 km, respectively. All columns include year-fixed effects. Standard errors bootstrapped using Simar and Wilson, (2007) procedure with 200 replications.

Source: FDZ der Statistischen Ämter des Bundes und der Länder, Statistik der Abfallentsorgung 2006-2014, own calculations.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

areas of 50, 100 and 150 km are used, respectively. It can be concluded that private shareholding increases efficiency, with the estimated coefficients ranging between 0.22 and 0.17 and all of them being significant at the 1% level. In order to give a quantitative interpretation, one can consider the effect of increasing the ownership share of private firms by 0.1: the semi-elasticity calculated at the mean of $\hat{\theta}$ implies that this represents an efficiency increase of around 2.7%. This effect is quite substantial given that there are both fully public and fully private firms.

The variables indicating task unbundling are introduced in Column (2), with the reference category being one firm operating the plant. Both types of task unbundling – separate plant management and separate asset holding – are found to affect efficiency negatively. For separating plant management from general operation, the efficiency score will be 0.16 lower on average, with the effect being significant at the 1% level. For asset unbundling, the estimated coefficient of -0.11 and of the same significance shows that this structure is less efficient

than the bundled one. Importantly, this effect exists after controlling for possible superiority of private firms in provision. These results suggest that there are substantial economies of organizing incineration within one firm only.

Regarding neighboring competition, the estimated effect is not robust across the different competition areas defined. One can observe that capacity of conventional plants in the close-by area tends to affect efficiency negatively, but only in one specification. The coefficient on *neighcap* is only significant at the 5% level for a competition area of 150 km. Neighboring capacity of RDF plants does not affect efficiency; all coefficients are not significant here.

The coefficient on total plant capacity is positive throughout all specifications, indicating that plants that can process more garbage per hour seem to benefit by being able to increase efficiency. The age index does not have any direct effect on efficiency.

The results when capital expenditures are considered as another input component are reported in Table 2.6. The Specifications (1) to (5) follow the same logic as before. Again, the presence of private shareholders positively affects the estimated efficiency score and this effect is quantitatively stronger now (around 0.39). If one computes again the effect of raising private shareholding by 0.1, this implies a 5.4% higher efficiency under this model.

The negative efficiency effect of operating the plant with several firms remains significant and comparable in magnitude to the first specification where only operational cost and workers were included as inputs. Compared to the first specification, including capital expenditures in the inputs additionally controls for possible efficiency effects of preserving capital equipment. Therefore, the benefit of integration outweighs the possible one from "specialization". This would be different if, e.g., under asset unbundling, the asset holding company had superior knowledge about maintaining the infrastructure.

The neighboring capacity of conventional plants has a significantly negative effect only in Column (5), i.e. again for a radius of 150 km. The *neighcap_o* variable capturing competition from RDF plants is not significant in any specification. This might be because this type of competition is not strong compared to the one from other conventional plants.

As opposed to Model (1), plant capacity does not have a significant influence on the estimated efficiency. Differences in plant sizes seem to be already taken up by different usages of inputs for the first stage (DEA estimation) of this model.

TABLE 2.6: Regression of DEA scores using operational costs and capital expenditure; and labor

	(1)	(2)	(3)	(4)	(5)
age index	0.0013	0.0017	0.0015	0.0010	0.0003
	(0.0013)	(0.0013)	(0.0012)	(0.0013)	(0.0013)
capacity	–0.0012	–0.0009	–0.0009	–0.0010	–0.0012*
	(0.0008)	(0.0007)	(0.0007)	(0.0006)	(0.0006)
privshare	0.4352***	0.3831***	0.3861***	0.3895***	0.3950***
	(0.0598)	(0.0466)	(0.0511)	(0.0511)	(0.0457)
pm		–0.1649***	–0.1564***	–0.1512***	–0.1338**
		(0.0634)	(0.0592)	(0.0557)	(0.0538)
ao		–0.1221***	–0.1215***	–0.1195***	–0.1139***
		(0.0342)	(0.0338)	(0.0378)	(0.0337)
neighcap_k			–0.0392	–0.0244	–0.0504**
			(0.0487)	(0.0253)	(0.0238)
neighcap_o_k			–0.1114	–0.2515	–0.0456
			(0.2967)	(0.1705)	(0.1111)
N	229	229	229	229	229

Note: The variables *pm* and *ao* are indicator variables for the existence of a separate plant manager and asset owner, respectively. Columns (3) to (5) use neighboring capacity in a radius of k =50, 100, 150 km, respectively. All columns include year-fixed effects. Standard errors bootstrapped using Simar and Wilson, (2007) procedure with 200 replications.

Source: FDZ der Statistischen Ämter des Bundes und der Länder, Statistik der Abfallentsorgung 2006-2014, own calculations.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

All in all, the regressions reveal that task unbundling in the form of separating plant management or asset ownership makes plants significantly less technically efficient. There seem to be economies of horizontal integration in case of the PM regime. Unfortunately, the precise reason for this cannot be known, but the mechanism may work through benefits of joint decision-making or avoidance of duplication effort. In the AO case, the unbundling of asset ownership may lead to different investment incentives or input usage.

The positive effect of private shareholding is robust and could stem from a combination of different sources. For example, it may be that private firms have more expertise in building and designing the plant, which reduces input usage.[18] Further, private firms also tend to be active in other parts of the garbage value chain, e.g. in collection, which may make them superior in acquiring

[18]It is often the case that private firms build their own infrastructure and operate it later on (EEW Energy from Waste, 2017). This explanation is quite close to what the theoretical PPP literature has given as a primary example, i.e. the two stages of building and operating infrastructure.

garbage and therefore optimizing capacity use.

As mentioned before, the competition effect is not robust. Most likely, this is because the sample does not encompass all plants and covers a limited time period, so that any geographical interconnections between efficiency and local market concentration cannot be estimated precisely. In this way, the analysis is unfortunately limited by data constraints.

2.6 Robustness checks

2.6.1 Accounting for secondary outputs

In the process of burning the garbage, it is common that plants produce energy (electricity, heat, steam) as a by-product. It might therefore be relevant to the efficiency analysis to include them as another output of the DEA model, as has been done in Chen et al., (2014). One disadvantage of the data set is that quantity-based output of energy production is not available for all plants. A correlation analysis including those secondary outputs that *are* observed reveals, however, that the correlation with burned garbage is very strong (Spearman's correlation coefficient $\rho = 0.78, p < 0.001$).[19] Therefore, it is likely that failing to incorporate energy output in the analysis does not strongly affect the results (Dyson et al., 2001).

Still, I test the robustness of the results with regard to this issue by using total revenue as output.[20] This measure clearly incorporates both the garbage burned and any energy produced, as this is sold to outside electricity companies. The approach might have the disadvantage of failing to separate quantity from price effects if (output) prices vary locally. I mitigate this issue as much as possible by using the state-specific consumer price index to deflate revenue. The input specification is maintained as in the first approach. The first-stage results (DEA scores) of this formulation are reported in Appendix 2.C.

Table 2.7 shows the corresponding second stage using the previously computed efficiency scores. One can observe that the results of private shareholding remain, with all coefficients being significant at the 1% level and of the same magnitude as in the quantity-output specifications. Regarding bundling, the separation of asset ownership from operation also preserves its negative and significant effect. The variable *pm* denoting the separate plant manager regime

[19] These outputs are electricity, heat, and process steam, all measured in megawatt hours.

[20] As before, the second output is manure composted for plants operating a composting plant. In this case, the revenue earned with this activity is subtracted from total revenue.

TABLE 2.7: Regression of DEA scores using revenue as output

	(1)	(2)	(3)	(4)	(5)
age index	–0.0004	0.0005	–0.0000	0.0003	–0.0000
	(0.0012)	(0.0012)	(0.0011)	(0.0009)	(0.0012)
capacity	0.0015**	0.0014**	0.0012**	0.0013**	0.0012**
	(0.0006)	(0.0006)	(0.0005)	(0.0005)	(0.0006)
privshare	0.1490***	0.1336***	0.1728***	0.1445***	0.1420***
	(0.0408)	(0.0360)	(0.0432)	(0.0415)	(0.0388)
pm		–0.0253	–0.0123	–0.0267	–0.0107
		(0.0436)	(0.0469)	(0.0494)	(0.0497)
ao		–0.1806***	–0.1901***	–0.1901***	–0.1703***
		(0.0310)	(0.0334)	(0.0334)	(0.0323)
neighcap_k			–0.0323	0.0112	–0.0329
			(0.0446)	(0.0279)	(0.0215)
neighcap_o_k			–0.6028***	–0.1139	0.0329
			(0.2209)	(0.1321)	(0.0746)
N	248	248	248	248	248

Note: The variables *pm* and *ao* are indicator variables for the existence of a separate plant manager and asset owner, respectively. Columns (3) to (5) use neighboring capacity in a radius of k=50, 100, 150 km, respectively. All columns include year-fixed effects. Standard errors bootstrapped using Simar and Wilson, (2007) procedure with 200 replications. Operational costs and labor used as inputs.

Source: own calculations.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

shows a negative sign, but is not significant at the 10% level. Again, there seem to be positive efficiency effects from an increased scale of operation and a slight tendency for neighboring competition to decrease efficiency.

2.6.2 Stochastic frontier analysis

This section shows that the main results obtained in this chapter do not stem from specificities about the technique to compute efficiency, but can be reproduced using other econometric methods. While Data Envelopment Analysis is especially interesting for the study of multiple outputs and an unknown production technology, the method can be sensitive to measurement error in the frontier-defining observations. Therefore, a parametric analysis that can be interpreted straightforwardly is performed additionally. I choose here to carry out a Stochastic Frontier Analysis (SFA), which is another standard approach to analyze production behavior of firms that do not necessarily behave efficiently (Fried et al., 2008).

The log-linear production frontier is defined as

$$\ln q_i = \beta_0 + \beta_1 \ln oc_i + \beta_2 \ln lab_i + v_i - u_i, \tag{2.8}$$

where inputs and outputs are maintained as in specification 1, i.e. q is output (garbage incinerated plus manure composted), oc is operational costs and lab is number of workers. Additionally, year-fixed effects are included in order to control for frontier-shifting factors (e.g. technological change). The error term consists of two parts. First, there is random noise v_i, which is standard normally distributed. The second component is systematic plant inefficiency u_i, which is left-truncated at zero to ensure that efficiency is smaller than one.

Within this framework, there are several ways to link exogenous variable to efficiency. Here, I follow the approach by Deprins and Simar, (1989), in which the environmental variables directly influence the mode of the inefficiency distribution.[21] Formally, $u_i \sim N(\mathbf{z}_i\boldsymbol{\alpha}, \sigma^2)$, with $\boldsymbol{\alpha}$ capturing the coefficients of environmental variables and σ^2 denoting the (constant) variance of the inefficiency distribution. The vector $\mathbf{z}_i$ contains the same set of variables as before and a competition area of 150 km is used. Year-fixed effects are included to control for time-varying factors influencing the inefficiency of all plants.

The results of the SFA are displayed in Table 2.8. For simplicity, I do not report the coefficients of the frontier, but only the estimated effects of the environmental variables. The signs of the coefficients are interpreted as the direction of the marginal effect on *in*efficiency u_i, implying that one would expect the opposite signs compared to the estimations reported in Tables 2.5 and 2.6.

Overall, the results are in line with those using the DEA approach. A larger private share reduces inefficiency, with the effect being significant at the 5% level. Concerning the impact of bundling, the main results are also reproduced. The PM regime again is more inefficient than task bundling, with the effect being significant at the 1% level. This holds also for the ownership unbundling (AO) regime, at the 10% significance level. The competition variables are not influential. Interestingly, plant age has the expected negative effect on efficiency under this approach. As observed also in the equivalent specification for DEA, larger capacity increases efficiency (or, equivalently, reduces inefficiency). The conclusion from this exercise is that the results are not sensitive to the modeling approach chosen.

[21] There are more advanced models that can explicitly take into account the panel data structure of the model (e.g. Greene, 2005), but the size of the data set unfortunately does not permit their usage.

TABLE 2.8: Stochastic frontier estimation

Effect on u_i	
age index	0.0107**
	(0.0053)
capacity	–0.0234***
	(0.0035)
privshare	–0.3349**
	(0.1546)
pm	0.7119***
	(0.2039)
ao	0.2642*
	(0.1447)
neighcap_k	0.1514
	(0.0923)
$\text{neighcap\_o}_\text{k}$	0.0364
	(0.2943)
N	259

Note: The variables *pm* and *ao* are indicator variables for the existence of a separate plant manager and asset owner, respectively. Neighboring capacity computed for k=150 km. Year-fixed effects included.

Source: FDZ der Statistischen Ämter des Bundes und der Länder, Statistik der Abfallentsorgung 2006-2014, own calculations.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

2.7 Conclusion

This chapter has analyzed the efficiency of refuse incineration plants in Germany in the period of 2006-2014 using the non-parametric tool of Data Envelopment Analysis. The focus was on efficiency-affecting factors that have been raised in the economic literature as important organizational determinants. After a first stage was performed to compute technical efficiency, these estimates were projected on environmental variables in a second stage procedure. In order to achieve inference, a bootstrap procedure first proposed by Simar and Wilson, (2007) was used.

The regressions show that private ownership unambiguously affects efficiency positively. The estimated effect of increasing private shareholding by 0.1 is found to increase θ in a range of 2.7-5.4%, depending on the precise specification used. Operating plants with private shareholders might therefore be beneficial for consumers by reducing the cost for incineration and, ultimately,

the fees charged for garbage collection. This result implies also that one should treat with caution the recent trend of municipalities buying back private shares in order to make utilities fully public again (Bataille and Steinmetz, 2015).

This chapter also delivers preliminary evidence on the role of task bundling, specifically on hiring separate plant-managing or asset-owning firms. Both variants are found to decrease efficiency, with the effect being significant in a majority of the empirical specifications. The results are in line with the existence of positive externalities between the tasks, i.e., bundling goes along with lower costs because of spillovers.

It was also hypothesized that local competition – the concentration of incineration capacities in the neighboring regions – will affect efficiency. Here, the results are not clear-cut. There is a slight tendency for competition to decrease efficiency, perhaps counter-intuitively. This relation might point to the fact that overcapacities do exist in this market, so that expensive investments into assets cannot be recovered given current demand status. This issue should be investigated further and taken into account for national garbage policy.

Lastly, this paper points to several directions in which the research could be expanded. One drawback of this data set is that the cases in which plant management is outsourced are relatively few. Given that there are not so many plants, a data set for other countries or industries that is larger in the number of observations might make it possible to estimate in a more direct way the connection between task integration and total costs of the service. Furthermore, one difference between this paper and the theoretical contributions on PPPs is that timing cannot be explicitly incorporated, because the data does not go back that long. If one could obtain historical information of the firms constructing the plant and corresponding costs, it might be possible to assess the role of task bundling in more detail and find an estimation strategy closer to the theoretical foundations. This research should provide a first stepping-stone to expand the empirical literature on this topic.

2.A Data appendix

2.A.1 Sources

1. *Financial Data (balance sheet, income statement) and workers.* Federal Gazette (Bundesanzeiger Verlag GmbH, online publisher of yearly accounts); reports on shareholding ("Beteiligungsberichte") of the municipalities.

2. *Quantity data:* Garbage to be incinerated: Research Data Centre of the Federal Statistical Office and the Statistical Offices of the Länder (FDZ der Statistischen Ämter des Bundes und der Länder), Statistik der Abfallentsorgung, 2006-2014. Mixed manure to be composted: own research.

3. *Ownership information:* firm database Hoppenstedt, own research.

4. *Technical information (conventional incineration plant capacities, year of construction):* Umweltbundesamt; Interessengemeinschaft der thermischen Abfallbehandlungsanlagen in Deutschland e.V.; International Solid Waste Association (ISWA), Waste-to-Energy State-of-the-Art Report, 5th edition (2006), 6th edition (2012) [revision 11/2013].

5. *Capacities of RDF plants:* Thiel, (2013, Table 2, pp. 841-842).

6. *Geographical location (latitude, longitude):* OpenStreetMap contributors.

7. *Deflators:* Buildings and equipment price index, producer price indices, consumer price index: Federal Statistical Office Germany (Statistisches Bundesamt), DESTATIS. Intermediate inputs index: Eurostat (STAN database, ISIC Rev. 4).

8. *Population density:* Federal Statistical Office Germany (Statistisches Bundesamt), DESTATIS.

2.A.2 Definition

Variable	Definition
quantity incinerated	garbage to be incinerated, in tonnes
quantity mixed manure	mixed manure to be composted, in tonnes
labor	number of workers
operational costs	sum of raw materials; purchased goods and services; depreciation; other operating expenses
capital expenditure	net investment into tangible assets
raw material deflator[a]	weighted average of producer price index for lime[b]; intermediate inputs deflator
purchased goods and services deflator	average of indices for engineering services; technical, physical and chemical analysis; machine examination; chemical analysis; machine cleaning; consumer price index[c]
depreciation deflator	consumer price index[c]
other operating expenses deflator	average of indices for auditing, tax services and accounting; telecommunications services; consumer price index[c]
capital expenditure deflator	deflator for machinery and equipment and other tangible assets
revenue deflator	consumer price index[c]
capacity	plant capacity in t/h
privshare	share of private shareholding in the operator
ageindex	weighted age of the plant[d]
neighcap_k	sum of neighboring capacity of other conventional incineration plants in a radius of k km, divided by population density of the plant's district (Kreis)[e]
neighcap_o_k	sum of neighboring capacity of RDF incineration plants in a radius of k km, divided by population density of the plant's district (Kreis)[e]

[a] The share for the weighted average is computed according to the proportions of value reported by the firm.

[b] Lime is used in flue gas treatment, its share in raw materials expenses is computed according to available information from input-output analysis.

[c] The state-specific CPI is used to control for regional price differences.

[d] The index is computed by weighting the age of each line by its share of capacity in total plant capacity.

[e] Computed using the STATA module *nearstat* (Jeanty, 2010).

2.B Bootstrap procedure

The bootstrap procedure follows Simar and Wilson, (2007) and is formulated for an input-oriented model as described in the steps below.

1. Compute $\hat{\theta}_i$ from the data $\{\mathbf{x}_i, \mathbf{y}_i\} \; \forall \; i = 1, \ldots, n$.

2. Use maximum likelihood for obtaining an estimate $\hat{\boldsymbol{\beta}}$ of $\boldsymbol{\beta}$ and an estimate $\hat{\sigma}_\epsilon$ of σ_ϵ for the truncated regression of $\hat{\theta}_i$ on $\mathbf{z}_i$ (Equation 2.7), using all $m < n$ observations where $\hat{\theta} < 1$.

3. Loop over the next three steps L times to obtain a set of bootstrap estimates $\mathcal{B} = \{\hat{\boldsymbol{\beta}}^*, \hat{\theta}^*_\epsilon\}$.

   (a) For each $i = 1, \ldots, m$, draw ϵ_i from the $N(0, \hat{\sigma}^2_\epsilon)$ with right-truncation at $1 - \mathbf{z}_i\hat{\boldsymbol{\beta}}$.

   (b) For each $i = 1, \ldots, m$, compute $\theta^*_i = \mathbf{z}_i\hat{\boldsymbol{\beta}} + \epsilon_i$.

   (c) Use the maximum likelihood method to estimate the truncated regression of θ^*_i on $\mathbf{z}_i$, yielding estimates $(\hat{\boldsymbol{\beta}}^*, \hat{\sigma}^*_\epsilon)$.

4. Use the bootstrap values $\mathcal{B}$ and the original estimates $(\hat{\boldsymbol{\beta}}, \hat{\sigma}_\epsilon)$ to derive a confidence interval for each element of $\boldsymbol{\beta}$ and for σ_ϵ.

2.C Efficiency scores

TABLE 2.9: DEA scores using revenue as output

year	$\hat{\theta}$	
	by year	by window
2006	0.7239	
2007	0.7546	0.7469
2008	0.7626	
2009	0.6774	
2010	0.6791	0.6849
2011	0.6980	
2012	0.7486	
2013	0.7346	0.7474
2014	0.7600	
mean	0.7268	

Source: own calculations.
Note: Labor and operational costs used as inputs.

Chapter 3

Property rights and transaction costs - The role of ownership and organization in German public service provision

Co-authored with Ulrich Heimeshoff and Gordon Klein

Summary of the chapter

This chapter provides evidence that ownership and organization matters for the efficiency of provision of public services. In particular, we find that pure private ownership is more efficient than pure public ownership, and public ownership is more efficient than mixed ownership. The delegation of management in different legal forms also has an impact, highlighting the importance of the design of the government-operator relationship. We apply a structural approach of production function estimation ensuring precise determination of total factor productivity for a panel of German refuse collection firms between 2000-2012. We project total factor productivity estimates on ownership and organization. Our results are in line with the trade-offs implied by the property rights literature and provide important policy implications regarding the organization of public service provision.

3.1 Introduction

For many decades, there has been an extensive public debate on the optimal provision of utility services and infrastructure, which are mostly acknowledged as basic tasks to be provided by the government. While in the 1990's many privatizations were observed, for instance in the European telecommunications sector, there are plenty of current examples where the opposite, a renationalization of utilities and infrastructure has taken place. An example is New Zealand's railway, which was first privatized in the 1980's and 1990's and was then renationalized in 2004.[1] In Germany, the City of Hamburg's formerly privately owned electricity network was renationalized following a public referendum.[2] Aside from policy debates of pure public or private ownership, there are persistent discussions on mixed ownership, such as public-private partnerships, which are aimed at balancing the advantages of private and public ownership.[3]

An extensive debate about these issues exists not only within the policy-making context, but also in the academic literature. While the traditional view of economists generally favors private provision of services and utilities (Bennett and Johnson, 1979), there are influential papers showing that public provision of goods and services may lead to positive or negative outcomes depending on the characteristics of the service considered (Hart et al., 1997). Likewise, the empirical literature shows that, depending on the circumstances, private or public provision may be the most efficient (for a survey, see Villalonga, 2000).

Our chapter adds to this literature by analyzing the efficiency of basic public services in Germany, considering the role of ownership as one important determinant. Several theories have been advanced to delineate in which situations private or public provision of services is optimal. These works are closely related to literature on factors that determine the size of the firm (the classic make-or-buy decision). The property rights literature advanced by Grossman and Hart, (1986), argues that when *specific rights* cannot be fully specified due to transaction costs, *residual rights* – i.e. ownership of vertically dependent layers – can serve to influence decisions in cases where all actions cannot be laid out ex-ante. The importance of relationship-specific investments in production then determines the optimal organization of firms along the value chain.

[1] http://www.kiwirail.co.nz/about-us/history-of-kiwirail.html

[2] http://www.hamburg.de/energiewende/4110666/ergebnis-volksentscheid/

[3] For instance, there is a long tradition of Private-Public-Partnerships in the British health service, see https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/266818/07_PPP_28.11.13.pdf.

The logic of the property rights literature has been used to analyze whether public services should be provided by the government or a private firm (Hart et al., 1997). Taking into account that real-world contracts are incomplete due to transaction costs, the authors derive scenarios under which either publicly or privately provided service is optimal. This is mainly determined by the underlying trade-off between the potential for cost reduction on the one hand and a possible deterioration in quality that may go along with this on the other hand. If quality may be harmed by an excessive incentive of cost reduction, public provision is optimal. On the other hand, if quality is contractible or its deterioration is not a big concern,[4] the case for private provision is higher since agency problems in public firms may be tackled.

Our study goes beyond purely looking at ownership by also taking into account additional aspects of productivity. An important determinant for productivity besides from ownership lies in the relationship between the government as the organizer and the firm. This may include, for example, how detailed service requirements are given to the firm, the precise role of the government and the firm in terms of control, organization and management, or the freedom with which a firm can make business decisions. We include these factors in the analysis by considering the legal status as an efficiency driver in addition to ownership, since legal form impacts government-firm relations in our setting. These are effects beyond those from pure ownership, such as corporate governance (Hart, 1995).[5] If we find productivity differences within publicly-owned firms, we may attribute this to the degree of contractual completeness or the informational "closeness" between firm and government, which are both influenced by legal status. We explain this in more detail in section 3.2.1.

We estimate a production function in value added using the technique introduced by Ackerberg et al., (2015) and project total factor productivity (TFP) derived from this function on ownership and legal status. This approach overcomes the classical endogeneity problem that exists when unobserved productivity is correlated with input choice by using moment conditions that are exogenous to the stochastic element of productivity. This is an advantage of our estimation procedure in comparison to former studies analyzing the public-private dichotomy. In our productivity equation, we control for factors that might be

[4] If quality is contractible, private firms have a strictly stronger incentive for cost reduction, as they have a profit motive and do not require the approval of the government. The same will hold if quality is not too important. Quality in this context refers to what is demanded by the government (for example that all students receive a good level of education), not necessarily what consumers prefer.

[5] We will use the term *institutional setting* to refer to those factors that are determined by the legal status.

potentially correlated with ownership in order to obtain an unbiased estimate. Lastly, we perform a robustness check to make sure that our results are not driven by heterogeneity in output prices.

We utilize a unique self-created dataset for the German market for public services, which includes refuse collection and related services.[6] This sector is likely to have the outstanding feature mentioned by Hart et al., (1997, p. 1154), namely that the quality dimension seems to be less important than the reduction of costs. Therefore, the working hypothesis that pure cost efficiency (or its mirror, technical productivity) should be one of the main goals in the provision of these services is naturally justified. The dataset consists of firm-level information from 2000 to 2012 including 865 city-year observations from municipal firms operating in large German cities. The data allow us to analyze differences between public and private companies and hybrid forms where public and private partners jointly hold shares in the refuse collector. Moreover, we can distinguish between three different types of institutions (having different legal statuses) offering garbage collection. The first type is refuse collection under a government contract (contracting out), the second type is refuse collection by an independent municipal firm (delegation), and the third is refuse collection by the municipality itself (government provision). This particular setting allows us to separate the impact of the two different layers of agency costs on efficiency.

Many empirical studies have considered the role of ownership for different sectors. Considering the waste sector, recent meta studies include Bel et al., (2010) and Simões and Marques, (2012). However, there is little empirical work directly focusing on several layers of agency costs, i.e. the combination of ownership and organization jointly. Cullmann et al., (2016) include legal status in an efficiency analysis of energy supply companies and do not find any significant differences between them. In the context of waste disposal, Dijkgraaf and Gradus, (2015) include measures that go beyond pure ownership by distinguishing between one-municipality firms and a number of municipalities jointly forming an entity and do not find an effect on efficiency.

Our research provides us with two main results. First, private firms are unambiguously more efficient in operation. Maintaining that there is large potential for cost reduction in this sector,[7] this result confirms the claim made by Hart et al., (1997) who predict private provision to be superior because ownership

[6]The data consists of information gathered directly from German cities combined with data from the AMADEUS database.

[7]For example, cost savings can be obtained by optimizing the route of collection vehicles, which leads to a decrease in fuel costs. Such an implementation would not affect the quality of collection for the consumer and might even lead to less disturbance by trucks in city traffic.

leads the private manager to perform more cost reduction than a government employee. Further, we show that the same does not hold in situations where private ownership is only partial. Mixed firms in our sample perform worse in terms of efficiency compared to fully public firms, and even more so compared to private ones. The often-advocated advantage of semipublic firms, i.e. that they combine efficiency-enhancing motives of the private sector with the role of the government to prevent quality losses, may therefore not materialize.

Our second result concerns the importance of the organizational setting in which a firm operates. Here, we find that contracting out per se – discounting the ownership effect – and government provision perform equally well in terms of efficiency, while delegation to an independent municipal firm brings with lower efficiency. Further, we find that the degree of specialization negatively affects productivity, while population size has a positive effect. Our findings speak directly to how public services should be organized, which in turn may have important implications for consumer welfare.

The chapter is structured as follows: The next section discusses the background of the German refuse collection market with emphasis on regulatory issues and structures ideas around TFP in public utilities. Section 3.3 presents our empirical strategy. In Section 3.4 we present and discuss the results and address their robustness. Section 3.5 concludes and presents some directions for future research.

3.2 Productivity of public services

3.2.1 Institutional background

Our study focuses on evaluating the performance of firms offering public services, with waste collection being a major business activity that all firms fulfill. Waste collection means picking up waste from households or firms and disposing of it, either by incineration or recycling. Most of the firms also fulfill other tasks relevant for the public infrastructure, for example city cleaning, drainage, (green) surface maintenance and management of cemeteries. The firms are effectively regional monopolies, as state-level laws prevent the presence of several operators. They do face competition on some segments of their activities, however.[8]

[8]Regulation applies to the provision of tasks used implicitly or explicitly by private consumers. This includes, for example, refuse collection from private households, who are obliged to dispose of their garbage by using the service provided, but not from private firms, which can choose among several suppliers, so that the collector can freely charge prices.

Public services in Germany are administered by municipalities or cities, which enjoy considerable autonomy in the way of organizing them. A city may choose, amongst others, the mode of execution (own provision/delegation), the involvement of private firms and the legal form of the operator. They may also influence the financing mix, e.g. by forming a semipublic company in which both parties invest a share of capital. In practice, we can observe much heterogeneity in the way public services are organized. The principal is thus the local authority (town hall) initiating the service, whereas the agent is the hired firm in charge of the actual provision. The actual remuneration of the firm depends on the organizational form it has. When final consumers can be identified (e.g., with refuse collection), individual consumer prices are indirectly set by the authority using a type of cost-of-service regulation and laws prescribe "cost-based prices" on the basis of past accounting costs (Klusemann, 1998). For tasks related to public infrastructure common to all citizens, the community sets an (internal) price, which is passed on to the firm. For all services provided to private firms, prices can be set freely.

There are three basic organizational models, which we call contracting out, delegation and government provision.[9] Under contracting out, the municipality assigns all execution to a private law (limited liability) firm, which can have public, private or semipublic ownership. The reason we classify it as contracting out is that the relationship between the city and the firm is formalized in a long-term contract (usually around 20 years). This contract includes the remuneration of the firm, defines the business relation and the service characteristics.[10] The reimbursement for all services provided to the public must legally be closely related to its costs. Contracts may be renegotiated, but are usually fixed for some time, in which payments are adjusted to a general price index.

The second mode, delegation, occurs when a city founds a public-law municipal firm. In this case, the firm is not only operator, but also organizer: it sets fees, employs its own workers and may make independent business decisions. These organizational tasks are normally fulfilled by the city under contracting out and government provision. The precise division of responsibilities between firm and city is not as formalized as in the case of contracting out. Rather, the municipality intends to retain supervision by appointing local government members to the advisory board.

[9]The legal implications of delegation are based on an overview provided by Institut für Fortbildung und Verwaltungs-Modernisierung, (2016).

[10]The description of the institutional framework is based on the works by Hövelborn, (2014) and Schulze Wehninck, (2008), as well as a selection of publicly available contracts.

Third, government provision occurs when the firm is directly associated with the municipality and has the legal status of an owner-operated municipal enterprise. This implies that the firm's action is judicially not separable from it.[11] Importantly though, the firm has defined boundaries in terms of bookkeeping and may hire its own workers. The same accounting rules apply to all types of firms so that data is comparable. Therefore, it is distinct from a public agency.[12]

There are thus some differences here with respect to the classical "make or buy" decision of the government that is analyzed in Hart et al., (1997). First, contracting out can also occur to a firm under public (or semipublic) ownership. Second, we distinguish between two different types of public provision, delegation and government provision, which differ in their managerial "closeness" to the city. In the former case, management and operation are outsourced to another public entity (even though the city has some final control rights), while in the latter, we can speak of classical in-house-provision as it has been used in the theoretical literature.

3.2.2 Empirical studies on public vs. private provision

The role of ownership for public services is studied extensively in the literature (for a survey, see Megginson and Netter, 2001). Also, municipal waste collection has been considered in the literature as one example of a public service. Typically, the empirical studies estimate a cost function and analyze cost difference between private and public provision. Ownership as one determinant of production costs is generally treated as a binary variable, i.e. *private* includes all types of contracting-out agreement, whereas *public* provision occurs when the service provider is a municipality.

This type of analysis has been performed for several countries. Dijkgraaf and Gradus, (2003) study the Netherlands using data from 1996 to 2007 and report cost savings of 15-20% from contracting out, and later reproduce the general finding using different data (Dijkgraaf and Gradus, 2007). Reeves and Barrow, (2000) consider Ireland and likewise find significant cost savings from private provision (around 45%). Using Swedish data on 115 municipalities, Ohlsson, (2003) finds no direct effect of public vs. private provision on production costs. An empirical study on Norwegian refuse collectors by Sørensen, (2007) analyzes ownership effects between regular public companies and those jointly

[11] For example, any contract the firm enters into is made in the name of the municipality.

[12] A "classic" public agency in Germany uses staff of the municipality and its financial planning is done within the city's overall budget. Further, accounting rules differ from the ones prescribed for other firms.

held by *several* municipalities and finds that the latter are less cost efficient than their one-municipality counterpart. He attributes this to the existence of higher agency costs for firms with several (municipal) shareholders.

Overall, a meta study on the difference between public and private provision conducted by Bel et al., (2010) for solid waste collection shows mixed results, with a slight tendency towards the superiority of private provision. However, many of the studies are characterized by small sample sizes and use estimation procedures that do not reflect the recent progress made in the estimation of total factor productivity (TFP).

We contribute to and improve this literature in several ways. First, we take into account the classic bias that occurs when efficiency is related to factor use by estimating TFP as the residual from the production using the procedure developed by Ackerberg, Caves & Frazer (2006), which the previous studies estimating cost functions do not do. Second, we dig deeper into the role of ownership by analyzing the case of semipublic firms. Furthermore, we also address some productivity effects that may occur independent of ownership, but that are rather due to the precise organization of the firm. Lastly, we are analyzing unique panel data from Germany that has not been used in previous research. The results are also likely to apply in the context of other developed countries.

3.2.3 Organizational structure and productivity

We proceed by summarizing theoretical arguments on the provision of public services. To do this, we draw on aspects that have been (explicitly or implicitly) discussed in the property rights literature by Grossman and Hart, (1986) and applied to the public-private context by Hart et al., (1997). We complement the literature review by discussing the potential role of mixed firms for technical efficiency. When *organizational structure* that the utilities display – of which ownership is one component – has an influence on production costs, such an effect will be mirrored in total factor productivity because of the duality between cost and production functions.

At the heart of the discussion about the provision of public services is the recognition that the delegation of a task invokes a relationship during which the goals of the principal (in this case the government) may not align with those of the hired agent. Classical agency literature is concerned with motivating the provider of a task in order to overcome problems of moral hazard and/or asymmetric information. From a pure incentives viewpoint, ownership plays no role, as both government officials and private firms need to be motivated to perform

(Hart et al., 1997). This result rests on the assumption that contracts are complete and enforceable.

Considering the organizational forms discussed in section 3.2.1, the (local) government a) contracts out the service to a limited-liability company of public, mixed, or private ownership, b) transfers production and organization to another public institution, c) produces the service in-house by transferring the task to a municipal enterprise. It is reasonable to assume that all organizational modes will exhibit some agency cost, whether the hired manager is a public official or represents a private firm.[13] Yet, private firms may perform better because they extenuate the agency problem, e.g. through threat of takeover, bankruptcy or the market for ownership rights (Villalonga, 2000). Ownership best serves to control managers if it is concentrated and direct, which is a main result of corporate governance theory (Fama and Jensen, 1983). Private firms in our sample generally have more concentrated ownership, whereas publicly-owned firms ultimately have citizens as their final owner.

An additional occurrence of the superiority of private provision is when public services have high cost-saving potential and quality is not too important. In a seminal paper, Hart et al., (1997) analyze government make or buy decisions using a theoretical model to study privatization. The basic trade-off between public and private provision of a service hinges on a comparison of investments in quality and cost savings of the potential operator. Private companies tend to underinvest in quality, but are generally more cost efficient than public agencies. Government agencies invest more into higher quality than private companies, but fail to provide enough cost innovations.

Arriving at this conclusion rests on the assumption that contracts are incomplete, i.e., that neither quality- nor cost innovations can be contracted upon ex-ante. In the case of government provision, the public manager is not being rewarded with the full benefits of cost and quality improvements. Under private provision, the firm is the residual claimant of cost-reducing effort because it owns the assets. Beyond that, Hart, (2003) argues that cost advantages of private firms are further enhanced through lower costs of contracting. Interestingly, the case of garbage collection is mentioned explicitly by Hart et al., (1997, p. 1154), who argue that "the damage to quality resulting from the private contractor [...] is probably trivial", reaching the conclusion that private provision would be superior.

[13]For the case of a public firm, the key point here is that the hired (government) manager cannot be fully controlled by the (local) government. Even though politicians hold board positions at the municipal enterprise, they are not involved in day-to-day business operations, so that managers have discrepancy in their decision-making.

In this literature, joint ownership is not discussed very frequently. In reality, the mixed enterprise, where public and private partners jointly own and operate a company through a consortium, is observed often.[14] Such a form has been advocated by practitioners for relieving fiscal distress and improving operational expertise, while at the same time mitigating the risk of quality deterioration created by private ownership (Bennett et al., 2000). However, some theoretical contributions have alluded to potential problems between partners of a consortium arising from imperfect monitoring capabilities, essentially an agency conflict within a firm (Martimort and Pouyet, 2008, p.400).[15] With respect to the role of ownership in our empirical analysis, we might expect a positive effect of private ownership, supported by the theoretical and empirical literature presented here. There is no such predisposition towards mixed firms, because they are rarely considered as their own category in empirical studies. Any potential effect on their role is highly policy relevant because the costs and benefits of private involvement in public firms is a frequent point of debates. Further, our analysis will later reveal whether there are productivity differences *within* publicly-owned firms due to their precise legal form and corresponding internal organization.

Our brief survey of the theoretical and empirical literature on public versus private ownership and managerial practices shows that both matter. The literature is still ambiguous as to whether public or private provision is more efficient, but there is a tendency towards superior efficiency of the private offering. Gains in efficiency are generally not solely related to privatization, but also to changes in organizational structure and management practices, which often differ significantly between public and privately organized organizations. Frequently, empirical studies only consider one of these determinants with respect to its effect on efficiency. However, we can test both aspects by including institutional setting separately from ownership.

3.3 Empirical strategy and data

We consider that in the long run, firms' objective is profit maximization, given the required service provision by the municipality. Therefore, we estimate a production function where the obtained residuals measure deviations from optimal

[14]Such mixed enterprises (also called institutional PPP), have a dominant share of public ownership in our sample and are characterized by the sharing of risk and profit.

[15]See also Schmitz, (2001), who analyzes partial privatization and finds that it may the optimal mode of provision in some cases.

behavior, i.e. the firm's technical efficiency. The impact of firm characteristics, legal status and ownership, on efficiency is examined by regressing predicted efficiency scores on the organizational structure and a set of firm covariates.

3.3.1 Production function

We follow the general strand of the literature that uses structural estimation to obtain unbiased coefficients of the production function as pioneered by Olley and Pakes, (1996) (referred to from now on as OP) and extended by Levinsohn and Petrin, (2003) (referred to from now on as LP). The key component of both approaches is the approximation of unobservable productivity through observed choices: OP use investment levels, whereas LP propose a flexible input (e.g. material costs). Both approaches, however, have some associated weaknesses. The OP approach leads to much data loss if there are many statistical units with negative or zero investment. On the other hand, the LP approach suffers from the more fundamental critique that it does not identify the labor coefficient in the first stage if labor and materials are flexible inputs and chosen simultaneously. This criticism stems from Ackerberg et al., (2015) (ACF from now on) who have subsequently developed a closely related estimation method that mitigates this problem. Therefore, we employ one variant of the estimation strategy suggested by ACF in response to the LP procedure. The ACF methodology has been used extensively in applied work (see, e.g., Lee et al., 2013; Parrotta and Pozzoli, 2012).[16]

When considering productive efficiency, a regulated firm must have sufficient organizational freedom over the usage of inputs (hire workers, buy intermediate products) and the determinants for production (capital structure, schedule of operation) in order to benefit from improvements in technological efficiency. We therefore consider briefly the production process of communal services. After receiving the planning for the next period (generally a year) from the municipality, an operator's manager may adjust its labor force and/or capital according to the production requirements. Note that the firm also owns the capital and that it consists mainly of trucks and other vehicles. Most material costs are incurred at the time production occurs. For waste collection, for instance, material costs are mostly composed of incineration fees for collected garbage that are incurred at the time of disposal).

[16]See http://webuser.bus.umich.edu/jagadees/other/acf_code.html for details on the technical implementation.

We assume that different municipal tasks can be represented by the same technological relationship requiring the same inputs.[17] Output for operator i in period t is measured by real value added Y (revenue minus cost of material) produced by combining labor L and capital input K according to the Cobb-Douglas production function

$$y_{it} = \beta_l l_{it} + \beta_k k_{it} + u_{it}, \tag{3.1}$$

where lower-case letters denote the logarithm.[18] From our estimation, we have excluded firms that were active also in the electricity, gas and water distribution industry and only reported global financial figures. For those, it is unlikely that a common production technology exists among tasks.

The unobserved part of the production function can be split into two components according to $u_{it} = \omega_{it} + \varepsilon_{it}$, where ω includes a constant. The first term ω_{it} is productivity observable to the firm, whereas ε_{it} is an idiosyncratic, unanticipated shock. Importantly, management may decide to adjust the firm's input levels after the firm has been affected by a productivity shock. An estimation that does not take this into account suffers from the well-documented simultaneity bias, as first suggested by Mundlak, (1961).[19] Using OLS on Equation (3.1) would thus produce biased results, because unobserved productivity would be correlated with input choice.[20] A fixed-effects estimation would solve the problem only if the productivity were time-invariant, which is unlikely to be the case.

In order to take these well-known problems into account, we implement the semiparametric approach by ACF whose main idea is that a firm's material input demand is invertible and can be used as a proxy for productivity. Productivity is assumed to evolve as a first-order Markov process: $\mathrm{p}(\omega_{it}|I_{it}) = \mathrm{p}(\omega_{it}|\omega_{it-1})$, where I_{it} is the firm's current information set. As described previously, labor is chosen before t so a firm's material demand contains current labor and can be expressed as $m_{it} = f(l_{it}, k_{it}, \omega_{it})$. If it is strictly increasing in ω, it can be inverted and substituted into (3.1) which results in

$$y_{it} = \beta_l l_{it} + \beta_k k_{it} + f^{-1}(l_{it}, k_{it}, \omega_{it}) + \varepsilon_{it}. \tag{3.2}$$

[17] Recall from section 3.2.1 that firms can perform several public service tasks.

[18] We prefer the estimation of a value added production function in order to aggregate products within a firm as well as to compare firms with different products (Lee et al., 2013).

[19] Notice that we do not face selection bias, as the firms in our sample do not face the risk of bankruptcy (at least on a practical level).

[20] In our estimation, we use OLS estimation as a benchmark and find no outstanding differences compared to the preferred estimation procedure.

The function $f^{-1}(\cdot)$ is proxied with a third order polynomial in labor, capital and materials and estimation of (3.2) constitutes the first stage necessary to net out unexpected production shocks.

The expected productivity can be expressed as $\mathrm{E}[\omega_{it}|I_{it}] + \xi_{it} = \mathrm{E}[\omega_{it}|\omega_{it-1}] + \xi_{it}$. In our application, we approximate this process with a third order polynomial. To identify the coefficients of the production function, it is necessary to find a choice variable orthogonal to the innovation in productivity ξ_{it}. Specifically, we use the moment condition that

$$\mathrm{E}\left[\xi_{it} \middle| \begin{array}{c} l_{it} \\ k_{it} \end{array}\right] = 0, \tag{3.3}$$

which implies that labor and capital were chosen in $t-1$. Ackerberg et al., (2015) stress that this moment condition is valid if there are, for example, slacks in hiring and firing. For the case of the municipal services, staffing decisions must be made well in advance and approved by the responsible board. In addition, there are significant notice periods. Overall, we are confident that this assumption is not too restrictive.

3.3.2 Effect of organizational structure

Our primary interest lies in investigating how heterogeneity in estimated TFP scores can be explained by the firm's organizational structure. They can be recovered from the estimates of the production function as $\hat{\phi}_{it} - \hat{\beta}_k k_{it} - \hat{\beta}_l l_{it}$, where $\hat{\phi}$ is the predicted value of the first stage that serves to eliminate idiosyncratic production shocks. The equation to be estimated reads as

$$\log(TFP) = \alpha_0 + \alpha ORGSTR + \mathbf{X}\boldsymbol{\beta} + \epsilon, \tag{3.4}$$

The equation aims at estimating the effect of the organizational structure on (the log of) TFP recovered in the previous step. It contains a constant α_0. The variable $ORGSTR$ comprises the legal status and ownership structure. In particular, we consider five levels for a firm's organizational structure: $MUNI$, where the ownership is public and the management is integrated in the city government. $INST$, where the ownership is public and the management is separated from ownership in a public legal form, LIM_PUB, where the ownership is public and the management separated in a private legal form, LIM_SEMPUB where the ownership is shared public and private and the management is in a private legal form and finally LIM_PRIV, where the ownership is private and

the management is separated in a private legal form. The general problem of omitted variable bias is tackled using a set of covariates captured in $\mathbf{X}$. In particular, we control for the population of the city as a major productivity shifter because there may be returns to scale. Moreover, we take into account whether the firm observed is a specialized firm.[21] Given that there may be regional differences, for example due to economic conditions, we will control for state fixed effects. The inclusion of this is important because it is likely to be correlated to the variable of interest. The equation contains an i.i.d. error component captured in ϵ.

Still, other issues may exist. There will be a problem of reverse causality if more efficient firms are more likely to display one organizational structure than another. If, for example, bureaucrats in cities with more efficient operators are more likely to select the legal form of limited liability, the causality would be reversed and estimation of (3.4) would lead to biased results. This argument is related to a finding in the theoretical literature on contract choice, where a firm is offered a menu of different regulatory contracts and self-selects itself into one according to its efficiency type (see, e.g., Laffont and Tirole, 1993). In the context of our investigation, this would mean that in cities with more efficient operators bureaucrats would rather choose one specific legal status.

In practice, such considerations may not be a major issue, as regional characteristics seem to play an important role in explaining the chosen organizational structure. For example, 22% of operators are limited liability in Bavaria, whereas this fraction is 58% in the state of North Rhine-Westphalia. Over all the years studied, we observe that 54% of operators are a municipal enterprise, 11% are public-law institutions and 34% are limited liability companies. Changes are quite rare: three firms adopted private ownership, eight firms changed ownership from public to semipublic and two reversed ownership to fully public. Regarding changes in legal status, we observe that from the municipal enterprise, four switched to the public-law institution and two to limited liability. We are thus confident that state fixed effects capture unobserved variables correlated with organizational structure.

A second issue may be a bias due to unobserved heterogeneity. Since the data does not provide sufficient temporal variation to introduce firm-specific effects, we control for covariates driving the efficiency as the population and the degree of specialization. Still, we take into account the already mentioned state-level fixed effects that account for structural differences across the country, such as a slightly different legislative setting or general economic conditions.

[21] We define this variable in the empirical strategy.

Third, we perform a robustness check to ensure that the prices are not driving the results we observe. Since we do not have output data and cannot impose this kind of productivity measure, we correlate the ownership and organizational form on prices we have for a cross section in one year. This regression shows whether there are structural correlations between organizational structure and prices, which would affect our results.

3.3.3 Data and summary statistics

The data used in this chapter are extracted from cities' mandatory reports on their financial stakes in firms.[22] They contain financial information, along with additional details such as employment data, ownership structure and legal status of the municipal firm. Supplementary information was taken from other publicly available sources, as well as the proprietary AMADEUS database (see Appendix 3.A). This newly created data set comprises 84 different operators of large German cities through the years 2000-2012.[23] The data are restricted to the population of cities because rural areas often commission to several subcontractors. Thus, sensible data is not available and the classification into an organizational form is much less obvious (Bataille and Steinmetz, 2015).

As described in section 3.3.2, we group the legal forms into three categories: limited liability companies (LIM), public-law institutions ($INST$) and the owner-operated municipal enterprise ($MUNI$). A firm is defined as publicly owned if at least 95% of the owners are public actors (cities, institutions etc.), as semipublic if the state holds at least 50.1% and as private if the public share is less than 50.1%. Semipublic firms always have an absolute majority held by the municipality and their share of public ownership in the sample ranges from 51 to 60%. Our empirical analysis is concerned about the effects of *both* ownership and legal status. Given that firms with an amount of private shareholding must adopt the legal form LIM, we can combine this information and obtain five levels for a firm's organizational structure: $MUNI$, $INST$, LIM_PUB, LIM_SEMPUB and LIM_PRIV (see Appendix 3.C for details).

Table 3.1 summarizes input (relative to value added, aside from labor) and output variables of the production process used in this study. We report the summary statistics by organizational structure: Columns (1) and (2) contain the municipal firm and the institution, while Columns (3) to (5) summarize the

[22] These are called *Beteiligungsbericht*: the obligation to publish such a report is prescribed by state laws.

[23] "Large city" in this context means that a city does not belong to another district, i.e. that it is independent (German: *kreisfreie Stadt*).

limited-liability companies (with public, semipublic and private ownership, respectively).

As described in the previous section, we rely on value added data to characterize output. Table 3.1 includes the dependent variable value added and also reports revenue. Furthermore, we report for information purposes the yearly quantity of collected waste (measured in tonnes).[24] We have information on two inputs of the production function. The input labor measures the number of employees working in the firm, while capital is represented as the value of tangible assets (including land, motor vehicles, equipment and machinery). The proxy variable materials, used for inverting out productivity, represents expenditures for raw materials (including energy, intermediate inputs and purchased services). All monetary inputs and outputs are expressed in prices using respective deflators, with 2000 as the base year.[25]

[24]Note that we are not able to use this physical quantity measure in our estimation. First, some firms collect all types of waste (e.g., also paper, glass and plastic), whereas others do not. There is no reliable information for this allocation for most of the sample period. Second, some firms deliver other types of public services, which are relevant in terms of revenue shares, for which quantity data does not exist.

[25]Revenue: consumer price index for garbage collection fees (averaged with fees for drainage if the firm is active in this segment also). Material expenses: intermediate inputs price index. Labor expenses: consumer price index. Capital: gross fixed capital formation index. See Appendix 3.A for sources.

TABLE 3.1: Summary statistics: means (and standard deviation) by organizational structure

	Municipal firm	Public institution	Public lim.-liab.	Semipublic lim.-liab.	Private lim.-liab.	Total
Quantity of waste	48892.83	218906.41	80022.41	72607.73	41678.73	79628.18
	(54013.20)	(298230.70)	(85751.37)	(59849.13)	(9265.35)	(132407.80)
Revenue	40537.20	132030.09	40242.22	47444.84	41581.97	51901.30
	(35628.93)	(170023.23)	(28911.94)	(50224.18)	(9127.23)	(72665.08)
Value Added	23891.15	88154.02	24272.18	30392.09	20950.79	32205.92
	(21074.32)	(129720.06)	(20227.33)	(31601.79)	(5080.62)	(52532.84)
Number of workers	370.46	1457.13	394.76	473.05	145.09	511.26
	(299.57)	(2029.75)	(336.93)	(418.81)	(24.08)	(821.20)
Tangible assets / Value added	5.08	2.06	1.04	0.80	2.58	3.25
	(6.48)	(2.11)	(0.99)	(0.43)	(1.04)	(5.14)
Material expenses / Value added	0.80	0.75	0.81	0.55	1.00	0.76
	(0.51)	(0.54)	(0.82)	(0.30)	(0.23)	(0.57)
Population	212185	908511	276185	301671	158410	313871
	(209575)	(1121427)	(240418)	(215851)	(69692)	(473298)
No. of obs.	448	98	174	134	11	865
No. of firms	35.3	8.9	13.4	11.1	1.2	69.9

Note: All monetary values measured in thousands of Euros. Quantity is the collected solid waste in tonnes.

TABLE 3.2: Production function estimates

Variable	OLS	ACF
Labor	0.8321***	0.8245***
	(0.0130)	(0.0577)
Capital	0.1578***	0.1507***
	(0.0080)	(0.0345)
No. of obs.	865	865

Note: Standard errors in parentheses. Standard errors derived using block bootstrapping with 200 replications for the columns with ACF estimates.
* p $<$ 0.1, ** p $<$ 0.05, *** p $<$ 0.01.

3.4 Estimating equations and results

3.4.1 Production function

Table 3.2 provides the estimates for the production function. We report OLS first and then the results using the ACF algorithm. Given endogeneity problems when applying OLS, which are circumvented by the ACF methodology, the OLS estimates are used as a benchmark. Column (1) provides the OLS benchmark for value added. Both capital and labor are positively and significantly correlated to the outcome in value added.

The results based on the ACF algorithm are highly significant and very similar to those obtained by OLS. To examine returns to scale, we test whether the sum of labor and capital coefficient test is equal to one against the two-sided alternative. The t-test cannot reject the hypothesis of constant returns to scale ($p = 0.58$). This result is consistent with those previously obtained in the literature when one considers larger municipalities and cities, as we do in our analysis. For the estimation of a cost function, Dijkgraaf and Gradus, (2015) find an output coefficient very close to one. Similarly, Stevens, (1978) obtains constant economies of scale for cities with a population size of over 50.000 inhabitants.[26]

3.4.2 Total factor productivity

To analyze efficiency difference, we use Equation (3.4), which describes the impact of a firm's organizational structure on TFP. We run this regression with OLS

[26]The 5% percentile of the population in our sample is 49.851.

using standard errors clustered at the establishment level.[27]

The four levels of this main variable of interest are $INST$, PUB_LIM, $SEMPUB\_LIM$ and $PRIV\_LIM$: the institution and three types of limited-liability companies with varying ownership. We thus compare each organizational structure with the fifth (baseline) category $MUNI$, which we had previously defined as traditional public provision. Because each firm offers a slightly different portfolio of city services, we control for possible effects of specializing in some of them. The variable SPE takes on the value of 1 if the firm only carries out garbage collection and street cleaning services.

Our main specification uses the TFP measures from the value added production function. The results from estimating the baseline Equation (3.4) are presented in Table 3.3. Column (1) controls for our four indicators of organizational structure. Interestingly, only the effect of $PRIV\_LIM$ is highly significant at the 1% level with a coefficient of 0.2574, indicating that private firms organized in a limited-liability company are approximately 29% more efficient than the baseline group $MUNI$.[28] Given that the other categories are not significantly different from the baseline group the absolute productivity advantage is similar to the other groups.

Still, an important driver for productivity may be the population. This effect is controlled for in column (2), indicating that city population is highly significant and positively shifts productivity. While the coefficient for the $PRIV\_LIM$ remains nearly unchanged, the coefficients for $INST$ and $SEMPUB\_LIM$ become negatively significant. These coefficients indicate that these organizational structures perform less efficiently than the baseline category. One might expect that the category $SEMPUB\_LIM$ is more efficient, e.g. due to private know-how in the operation. Given the strong effect of private ownership on productivity, this seems surprising.

We can only speculate about the reason for these results. One possible explanation is that the production process is harmed if there is a strong interest divergence. While private owners will probably aim for profit maximization, the public actors may have quality objectives. This could have several effects. First, internal disputes between the partners may lead to a delays in investment

[27] There is not enough time variation in the organizational structure to identify the coefficients using a fixed-effects methods, which is why we will use OLS with controls in estimating Equation (3.4). The path dependency of the organizational structure strengthens the point that there is no strategic selection, which would lead to reverse causality.

[28] All effects are computed according to $\exp(c) - 1$, where c is the estimated coefficient.

or innovations.[29] Second, such a dichotomy may keep managers from making business decisions that satisfy both constraints.[30] If the provision is totally private, however, the incentive to appropriate rents leads to superior technical productivity, which is in line with cost efficiency in well-defined contractual arrangements (see Hart, 2003).

The effect that $INST$ performs worse than the two other public categories could be explained with the arguments given in Hart, (1995)[31] concerning the problem with the separation of ownership and management. In our setting, the owner is equivalent to the municipality, and it should have sufficient control mechanisms for management, similarly to the supervisory board in publicly-traded firms. Because the firm is relatively independent in its decision-making, there may not be sufficient supervision. This is different for the other two types of public firms: PUB_LIM have discretion over *how* the task is performed, but control is executed by monitoring contract compliance and by organization of firms with private legal status.[32] For municipal provision, such formal contracts do not exist, but since they are integrated into the government, informal control can be easily achieved since there are few informational barriers. This point relates to an analysis done by Amaral, (2008), who considers the relation between the government's capacity for expertise and control and the autonomy margin of the firm in addition to ownership. He postulates that they should go hand in hand: higher autonomy, which will increase innovation incentives should be accompanied by corresponding control mechanisms preventing opportunistic behavior.

Controlling for firms that only offer the garbage services (column 3), one can see that specialized firms are less productive, indicating some form of economies of scope between tasks. Also, the productivity effect of semipublic firms decreases and loses significance slightly below the 10% threshold.

To check whether the results remain, we control for state-fixed effects in column (4). Given that state-level differences exist in the pattern of organizational structure, introducing these dummies leads to an increase in the validity of the

[29] Of course, contracting imperfections are likely to exist in the real world. The role of bargaining frictions in PPP is analyzed in a recent paper by Schmitz, (2015), thereby extending standard property rights models, which assume that ex-post bargaining is efficient.

[30] Eckel and Vining, (1985) report some evidence that managers in mixed companies receive unobtainable targets, e.g. high cost efficiency and extensive social goals, which leads to some sort of "cognitive dissonance".

[31] See also Hart et al., (1997) and Hart, (2003) for the literature on contractual efficiency.

[32] This legal form may voluntarily found a supervisory board. Further, these types of firms are often held by publicly-traded firms, which always have an advisory board.

TABLE 3.3: TFP regressions

Variable	(1)	(2)	(3)	(4)
INST	–0.0059	–0.0613***	–0.0531**	–0.0523**
	(0.0424)	(0.0232)	(0.0224)	(0.0241)
PUB_LIM	0.0178	0.0127	0.0328	0.0245
	(0.0278)	(0.0288)	(0.0268)	(0.0334)
SEMPUB_LIM	–0.0404	–0.0472*	–0.0395	–0.0539**
	(0.0288)	(0.0278)	(0.0282)	(0.0254)
PRIV_LIM	0.2574***	0.2656***	0.2475***	0.2834***
	(0.0363)	(0.0362)	(0.0385)	(0.0373)
pop 10^{-7}		0.8006***	0.9394***	0.9998***
		(0.1177)	(0.1318)	(0.2019)
specialized			–0.0489**	–0.0589***
			(0.0228)	(0.0222)
Constant	3.5745***	3.5571***	3.5736***	3.6006***
	(0.0179)	(0.0185)	(0.0224)	(0.0570)
State-fixed effects	No	No	No	Yes
R^2	0.08	0.15	0.18	0.27
No. of obs.	865	865	865	865

Note: Dependent variable is $\log(TFP)$. Standard errors clustered at the firm level in parentheses. All states that consist only of one city have been assigned to the geographical neighbor region (Berlin=Brandenburg, Bremerhaven and Bremen=Lower Saxony, Hamburg=Schleswig-Holstein).

* p $<$ 0.1, ** p $<$ 0.05, *** p $<$ 0.01.

effects explained previously. We again find a significant negative impact on productivity for $SEMPUB\_LIM$ (around 5%). The category $INST$ has a negative productivity effect of equal magnitude (5%), while there is no difference between $SEMPUB\_LIM$ and the baseline group. Most importantly, we still observe a highly significant effect of private firms of around 32%. Population and degree of specialization also impact productivity. Interestingly, we see that it is not only ownership that matters, but also the particular institutional setting. Taking into account the whole table, we conclude that the importance of ownership is complemented by the relation between the principal and the operator of the service, which in our analysis has been mirrored by the legal status.

The main results of column (4) are robust to the inclusion of other variables that could shift productivity. Further, when we introduce year dummies, we cannot reject the hypothesis that they are jointly equal to zero, indicating that there is no clear time pattern in the evolution of productivity.

3.4.3 Robustness check: addressing potential price bias

A potential caveat in the usage of industry deflators is when output or input prices are heterogeneous, because measured TFP would contain price and "true" efficiency effects. This occurs, for example, when large firms have market power in the product market (Klette, Griliches, et al., 1996). In our analysis, the existence of a price bias would prove most problematic when differences are structural in the sense that they were correlated with the organizational structure whose impact on productivity we are analyzing. If, for example, firms of one organizational form were charging consistently higher prices for their output, one would overestimate true productivity because part of it would be solely due to prices.

We address this question by studying the association between organizational structure and output prices using garbage collection fees gathered and provided by SPIEGEL ONLINE, (2008) and Verivox, (2008). This data is available for a cross section of the year 2008 and covers 62 of 84 firms in our sample. For the subsequent analysis, we use these fees to compute an average price per liter of waste.[33] These fees only serve as a rough proxy for output prices because they comprise only one business line (garbage collection) that the firm is in involved in. However, this is not too problematic since this line is most important in terms of revenue shares. They are the best available measures of prices at the individual firm level and their usage can serve to alleviate concerns one could have with using general price deflators in our empirical analysis.

To this end, we run a simple OLS regression of average price on the categories of organizational structure. The results are presented in Table 3.4. There seems to be a positive association between PUB_LIM and output prices, significant at the 1% level, while all other structures do not show any association. The results do not change when we include potential cost shifters.[34] We should therefore address what this finding implies for the robustness of the analysis of technical efficiency provided in the previous section.

Given the insignificant coefficients on semipublic and private ownership, this robustness check refutes the suspicion that the superiority of private firms and the inferiority of semipublic firms in terms of technical efficiency could be due to higher or lower prices, respectively. Concerning the PUB_LIM category,

[33] Reported are the fees charged for weekly collection of residual waste, calculated based on a four-person household. The four pricing categories are: 60l, 120l, 240l and 1.100l. We compute per liter prices and then take the unweighted average over the four categories.

[34] If we include average wage in the equation, for example, results and associated significance levels do not change.

TABLE 3.4: Relation between prices and organizational structure

Variable	
INST	–0.5736
	(0.3661)
PUB_LIM	1.1615***
	(0.3040)
SEMPUB_LIM	–0.0601
	(0.2925)
PRIV_LIM	–0.7710
	(0.8497)
Constant	2.7465***
	(0.1594)
R^2	0.30
No. of obs.	62

Note: Dependent variable is average fee per liter, baseline category =$MUNI$ (public provision). Population size (POP) included as control.
* p $<$ 0.1, ** p $<$ 0.05, *** p $<$ 0.01.

this analysis would tend to suggest that we may be *overestimating* their productivity effect, i.e. this type could be less efficient than the baseline category $MUNI$ (classical public provision). On the other hand, it is possible that the same pattern, i.e. higher prices, exists with respect to input prices, which would cancel out a potential bias and speak against overestimation of the effect. Unfortunately, neither data on material prices nor better output price data is available, so that we cannot further investigate this question. Most importantly, though, this analysis does not provide evidence that heterogeneity in output prices drive the results obtained for semipublic and private ownership.

3.5 Conclusion

Our chapter analyzed the productive efficiency of public services using a newly-created data set from Germany. Productivity estimates have been obtained by employing the well-established ACF procedure and projecting the obtained residuals on the firm's organizational structure. This method circumvents the endogeneity problem of the production function that arose in previous studies examining the productivity effects of private provision of refuse collection services.

Our analysis shows that not only ownership, but also legal status and the

accompanying contractual practices influence the way in which inputs are converted to output. We find that the private provision of refuse collection is most efficient. Comparing this with other forms of ownership, we find a non-linear relationship in the degree of private ownership. That is, mixed-ownership models such as public-private partnerships are less efficient than pure public entities.

Moreover, we see that the contractual arrangement is important in the way of how to organize a public company. Legal forms that separate ownership and management seem to have a lower efficiency, which may be explained by typical principal-agent problems. These results are generally in line with the intuitive examples provided by the property rights literature and provide evidence that transaction cost arguments are highly relevant for organizing public utilities.

The results found are important for policy debates worldwide regarding the most appropriate organization of public utilities. If utilities are organized in a contracting-out arrangement, the results propose a superiority over pure public or private service provisions. A combination of semipublic entities like public-private partnerships seems to bring together more the disadvantages from both private and public worlds than their advantages. In public entities the organizational form matters. If there is a separation of management and ownership, private legal forms are more able to reap efficiency benefits than public legal forms including the separation.

3.A Data sources – overview

This is an overview of the different sources used. For a complete overview of individual sources, see the online appendix.

1. *Firm characteristics.* Reports on shareholding ("Beteiligungsberichte") of the city, provided by the cities themselves or public libraries and archives. Employee data supplemented by usage of the Amadeus database of Bureau van Dijk and direct information from the firms. Ownership information supplemented by firm database Hoppenstedt.

2. *Financial Data (balance sheet, income statement).* Reports on shareholding ("Beteiligungsberichte") of the city, provided by the cities themselves or electronic information systems of city councils. Supplemented by annual statements from electronic information systems of city councils or official homepage of the firm. Supplemented by usage of Bundesanzeiger (online publisher of yearly accounts), Bundesanzeiger Verlag GmbH.

3. *Quantity data.* Federal Statistical Office Germany (Statistisches Bundesamt), DESTATIS.

4. *Deflators.* Consumer price index, producer price index: Federal Statistical Office Germany (Statistisches Bundesamt), DESTATIS. Intermediate inputs price, Gross Fixed Capital Formation price series: EU Klems.

5. *Lines of business.* Derived from the reports-on stakeholding ("Beteiligungsberichte") and own research (using the firms' homepages).

6. *Regional characteristics.* Surface area, population of the city: Federal Statistical Office Germany (Statistisches Bundesamt), DESTATIS.

7. *Output prices.* Study of garbage collection fees, SPIEGEL ONLINE and Verivox (2008).

3.B Legal forms

Law system	Contractual freedom	Legal form
public law	tied	Eigenbetrieb, eigenbetriebsähnliche Einrichtung
public law	free	Körperschaft des öffentlichen Rechts, Anstalt des öffentlichen Rechts
private law	free	GmbH, GmbH & Co. KG

3.C Tabulation of variable $ORGSTR$

Legal Status	Contractual freedom	Ownership		
		Public ($> 95\%$)	Semipublic ($60 - 51\%$)	Private ($< 50\%$)
public law	tied	$MUNI$		
public law	free	$INST$		
private law	free	LIM_PUB	LIM_SEMPUB	LIM_PRIV

3.D Individual data sources

city	area code	sources
Aachen	5334002	2009: JA 2010[b]; 2010: JA 2010[b]; 2011: JA 2011[b]; 2012: JA 2012[b]
Augsburg	9761	2002: BB 2004; 2003: BB 2005; 2004: BB 2005; 2005: BB 2006; 2006: BB 2007; 2007: BB 2008; 2008: BB 2009; 2009: BB 2010; 2010: BB 2011; 2011: BB 2012
Baden-Baden	8211	2006: BB 2006; 2007: BB 2007; 2008: BB 2008; 2009: BB 2009; 2010: BB 2010; 2011: BB 2011; 2012: BB 2012
Bamberg[b]	9461	2000: JB 2000; 2001: JB 2001; 2002: JB 2002; 2003: JB 2003; 2004: JB 2004; 2005: JB 2005; 2006: JB 2006; 2007: JB 2007; 2008: JB 2008; 2009: JB 2009; 2010: JB 2010; 2011: JB 2011; 2012: JB 2012
Berlin	11	2000: BB 2001; 2001: BB 2002; 2002: BB 2004 - Bd. I; 2003: BB 2004 - Bd. I; 2004: BB 2005 - Bd. I; 2005: BB 2006 - Bd. I; 2006: BB 2007 - Bd. I; 2007: BB 2008 - Bd. I; 2008: BB 2009 - Bd. I; 2009: BB 2010 - Bd. I; 2010: BB 2011 - Bd. I; 2011: BB 2012 - Bd. I; 2012: BB 2013 - Bd. I
Bielefeld	5711	2000: 10. BB; 2001: 11. BB; 2002: 12. BB; 2003: 13. BB; 2004: 14. BB; 2005: 15. BB; 2006: 16. BB; 2007: 17. BB; 2008: 18. BB; 2009: 19. BB; 2010: 20. BB; 2011: 21. BB; 2012: 22. BB
Bochum	5911	2000: BB 2005/2006; 2001: BB 2005/2006; 2002: BB 2005/2006; 2003: BB 2005/2006; 2004: BB 2005/2006; 2005: BB 2005/2006; 2006: BB 2006/2007; 2007: BB 2007/2008; 2008: BB 2008/2009; 2009: BB 2009/2010; 2010: BB 2009/2010; 2011: BB 2011; 2012: BB 2012
Bottrop	5512	2003: BB 2008; 2004: BB 2008; 2005: BB 2008; 2006: BB 2008; 2007: BB 2008; 2008: BB 2009; 2009: BB 2010; 2010: BB 2011; 2011: BB 2012; 2012: BB 2013
Brandenburg	12051	2003: 8. BB (2003-2005); 2004: 8. BB (2003-2005); 2005: 8. BB (2003-2005); 2006: 9. BB 2006; 2007: 10. BB 2007; 2008: 11. BB 2008; 2009: 12. BB 2009; 2010: 13. BB 2010; 2011: 14. BB 2011; 2012: 15. BB 2012
Braunschweig	3101	2001: VI. BB; 2002: VII. BB

Bremerhaven	4012	2000: HP 2002/2003, WP 2002, HP 2000/2001, Bd. I, WP 2000; 2001: BA 2001; 2002: BA 2002; 2004: BA 2005; 2005: BA 2005; 2006: BA 2006; 2007: BA 2007; 2008: BA 2008; 2009: BA 2009; 2010: BA 2010; 2011: BA 2011; 2012: BA 2012
Chemnitz	14511	2002: 11. BB; 2003: 11. BB; 2004: 11. BB; 2005: 12. BB; 2006: 13. BB; 2007: 14. BB; 2008: 15. BB; 2009: 16. BB; 2010: 17. BB; 2011: 18. BB; 2012: 19. BB
Coburg	9463	2005: BB 2005; 2006: BB 2006; 2007: BB 2007; 2008: BB 2008; 2009: BB 2009; 2010: BB 2010; 2011: BB 2011; 2012: BB 2012
Cottbus	12052	2000: BB 2003; 2001: BB 2003; 2002: BB 2003; 2003: BB 2003; 2004: BB 2004; 2005: BB 2005
Darmstadt	6411	2006: BB 2007; 2007: BB 2008; 2008: BB GJ 2008; 2009: BB GJ 2009; 2010: BB GJ 2010; 2011: BB GJ 2011; 2012: BB GJ 2012
Delmenhorst	3401	2003: BB Stand 31.12.2005; 2004: BB Stand 31.12.2005; 2005: BB Stand 31.12.2005; 2006: GB 2007; 2007: GB 2007; 2008: GB 2008; 2009: GB 2009; 2010: GB 2010; 2011: GB 2011; 2012: GB 2012
Dessau	15101	2000: BB 2000; 2001: BB 2001; 2002: BB 2002; 2003: BB 2003; 2004: BB 2004; 2005: BB 2005; 2006: BB 2006
Dessau-Roßlau	15001	2007: 2. BB; 2008: 3. BB; 2009: 4. BB; 2010: 5. BB; 2011: 6. BB; 2012: 7. BB
Dortmund	5913	2000: BB 2000/2001; 2001: BB 2001/2002; 2002: BB 2002/2003; 2003: BB 2003/2004; 2004: BB 2004/2005; 2005: BB 2005/2006; 2006: BB 2006/2007; 2007: BB 2007/2008; 2008: BB 2008/2009; 2009: BB 2009/2010; 2010: BB 2010/2011; 2011: BB 2011/2012; 2012: BB 2013/2012
Dresden	14612	2000: BA 2000; 2001: BB 2002; 2002: BB 2002; 2003: BB 2003; 2004: BB 2004; 2005: BB 2005; 2006: BB 2006; 2007: BB 2007; 2008: BB 2008; 2009: BB 2009; 2010: BB 2010; 2011: BB 2011; 2012: BB 2012
Duisburg	5112	2010: BB 2010; 2011: BB 2011; 2012: BB 2012
Düsseldorf	5111	2000: BB 2000; 2001: BB 2001; 2002: BB 2002; 2003: BB 2003; 2004: BB 2004; 2005: BB 2005; 2006: BB 2006; 2007: BB 2007; 2008: BB 2008; 2009: BB 2009; 2010: BB 2010; 2011: GB 2011; 2012: GB 2012

Eisenach	16056	2005: BA 2006; 2006: BA 2006; 2007: BA 2007; 2008: BA 2008; 2009: BA 2009; 2010: BA 2010; 2011: BA 2011; 2012: BA 2012
Emden	3402	2004: WP 2007[b]; 2005: WP 2007[b]; 2006: BB 2011, WP 2007[b]; 2007: BB 2011, WP 2008[b]; 2008: BB 2011, WP 2009[b]; 2009: BB 2011, WP 2010[b]; 2010: BB 2012, WP 2011[b]; 2011: JA 2012, WP 2012[b]; 2012: JA 2012, WP 2013[b]
Erfurt	16051	2000: BB 2001[d]; 2001: BB 2002[d]; 2002: BB 2003[d]; 2003: BB 2004; 2004: BB 2005; 2005: BB 2006; 2006: BB 2007; 2007: BB 2008; 2008: BB 2009; 2009: BB 2010; 2010: BB 2011; 2011: BB 2012; 2012: BB 2013
Essen	5113	2000: BA 2000; 2001: BB 2004; 2002: BB 2005; 2003: BB 2006; 2004: BB 2007; 2005: BB 2008; 2006: BB 2009; 2007: BB 2010; 2008: BB 2011; 2009: BB 2012; 2010: BB 2013; 2011: BB 2014; 2012: BB 2015
Flensburg	1001	2000: BB 2001; 2001: BB 2002; 2002: BB 2003; 2003: BB 2004; 2004: BB 2005; 2005: BB 2006; 2006: BB 2007; 2007: BB 2008; 2008: BB 2009; 2009: BB 2010; 2010: BB 2011; 2011: BB 2012; 2012: BB 2013
Frankenthal	7311	2010: HP 2013[b]; 2011: HP 2013[b]; 2012: HP 2014[b]
Frankfurt a.M.	6412	2001: BB 2002; 2002: BB 2002; 2003: BB 2003; 2004: BB 2004; 2005: BB 2005; 2006: BB 2006; 2007: BB 2007; 2008: BB 2008; 2009: BB 2009; 2010: BB 2010; 2011: BB 2011; 2012: BB 2012
Freiburg	8311	2005: BA 2006; 2006: BA 2006; 2007: BB 2008; 2008: BB 2009; 2009: BB 2010; 2010: BB 2011; 2011: BB 2012; 2012: BB 2013
Gelsenkirchen	5513	2000: BB 2000[e]; 2001: BB 2001[e]; 2002: BB 2002[e]; 2003: BB 2003[e]; 2004: BB 2004[e]; 2005: BB 2005[e]; 2006: BB 2006[e]; 2007: BB 2007; 2008: BB 2008; 2009: BB 2009; 2010: BB 2010; 2011: BB 2011; 2012: BB 2012
Gera	16052	2000: BB 2004; 2001: BB 2004; 2002: BB 2004; 2003: BB 2004; 2004: BB 2004; 2005: BA 2005; 2006: BA 2006; 2007: BA 2007; 2008: BA 2008; 2009: BA 2009; 2010: BA 2010; 2011: BA 2011; 2012: BA 2012
Göttingen	3152	2000: BB 2005; 2001: BB 2005; 2002: BB 2005; 2003: BB 2005; 2004: BB 2005; 2005: BB 2006; 2006: BB 2007; 2007: BB 2008; 2008: BB 2009; 2009: BB 2010; 2010: BB 2011; 2011: BB 2012; 2012: BB 2013
Hagen	5914	2000: BA 2001; 2001: BA 2001; 2002: BA 2003; 2003: BA 2003; 2004: BA 2004; 2005: BB 2007; 2006: BB 2007; 2007: BB 2007; 2008: BB 2008; 2009: BB 2009; 2010: BB 2010; 2011: BB 2011; 2012: BB 2012

Halle	15002	2000: BA 2001; 2001: BA 2001; 2002: BA 2002; 2003: BB 2005; 2004: BB 2005; 2005: BB 2005; 2006: BB 2006; 2007: BB 2007; 2008: BB 2008
Hamburg	2	2000: 4. BB 2000; 2001: 5. BB 2001; 2002: 6. BB 2002; 2003: 7. BB 2003; 2004: 8. BB 2004; 2005: 9. BB 2005; 2006: 10. BB 2006; 2007: 11. BB 2007; 2008: 12. BB 2008; 2009: 13. BB 2009; 2010: 14. BB 2010; 2011: 15. BB 2011; 2012: 16. BB 2012
Hamm	5915	2000: BB 2002/03; 2001: BB 2002/03; 2002: BB 2002/03; 2003: BB 2003/04; 2004: BB 2003/04; 2005: BB 2003/04; 2006: BB 2003/04; 2007: BB 2009/10; 2008: BB 2010/11; 2009: BB 2010/11; 2010: BB 2010/11; 2011: BB 2011/12; 2012: BB 2012/13
Hannover	3241	2003: BB 2008; 2004: BB 2008; 2005: BB 2008; 2006: BB 2008; 2007: BB 2008; 2008: BB 2009; 2009: BB 2010; 2010: BB 2011; 2011: BB 2012; 2012: BB 2013
Heilbronn	8121	2002: BB 2005; 2003: BB 2005; 2004: BB 2005; 2005: BB 2005; 2006: BB 2006; 2007: BB 2007; 2008: BB 2008; 2009: BB 2009; 2010: BB 2010; 2011: BB 2011; 2012: BB 2012
Herne	5916	2003: JA 2003[b]; 2004: JA 2004[b]; 2005: BB '08; 2006: BB '08; 2007: BB '08; 2008: BB '09; 2009: BB '10; 2010: BB '11; 2011: BB '12; 2012: BB '13
Jena	16053	2004: BB 2005; 2005: BB 2005; 2006: BB 2006; 2007: BB 2007; 2008: BB 2008; 2009: BB 2009; 2010: BB 2010; 2011: BB 2011; 2012: BB 2012
Kaiserslautern	7312	2007: BB 2009; 2008: BB 2010; 2009: BB 2010; 2010: BB 2011; 2011: BB 2012; 2012: BB 2013
Kiel	1002	2004: BB 2005; 2005: BB 2006; 2006: BB 2007; 2007: BB 2008; 2008: BB 2009; 2009: BB 2010; 2010: BB 2011; 2011: BB 2012; 2012: BB 2013
Koblenz	7111	2004: JA 2005[b]; 2005: JA 2005[b]; 2007: HP 2009; 2008: HP 2010; 2011: HP 2013; 2012: HP 2014
Krefeld	5114	2003: BB 2004; 2004: BB 2004; 2005: BB 2005; 2006: BB 2006; 2007: BB 2007; 2008: BB 2008; 2009: BB 2009; 2010: BB 2010; 2011: BB 2011; 2012: BB 2012

Köln[c]	5315	2005: BB 2009; 2006: BB 2009; 2007: BB 2009; 2008: BB 2009; 2009: BB 2009; 2010: BB 2010; 2011: BB 2011; 2012: BB 2012
Landau	7313	2008: JA 2009; 2009: JA 2010; 2010: JA 2011; 2011: JA 2012; 2012: BB 2003
Leipzig	14713	2001: BB 2003; 2002: BB 2004; 2003: BB 2005; 2004: BB 2006; 2005: BB 2007; 2006: BB 2008; 2007: BB 2009; 2008: BB 2010; 2009: BB 2011; 2010: BB 2012; 2011: BB 2013; 2012: BB 2014
Leverkusen	5316	2004: Amad; 2005: BA 2006; 2006: BA 2006; 2007: BA 2007; 2008: BA 2008; 2009: BA 2009; 2010: BA 2010; 2011: XIX. BB; 2012: XX. BB
Ludwigshafen	7314	2000: 7. BB; 2001: 8. BB; 2002: 9. BB; 2003: 10. BB; 2004: 11. BB; 2005: 12. BB; 2006: 13. BB; 2007: 14. BB; 2008: 15. BB; 2009: 16. BB; 2010: 17. BB; 2011: 18. BB; 2012: 19. BB
Lübeck	1003	2000: WP 2000; 2001: BB 2003; 2002: BB 2004; 2003: BB 2005; 2004: BB 2006; 2005: BB 2007; 2006: BB 2008; 2007: BB 2009; 2008: BB 2010; 2009: BB 2011; 2010: BB 2012; 2011: BB 2013; 2012: BB 2014
Magdeburg	15003	2002: BB 2007, JA 2003[b]; 2003: BB 2007, JA 2003[b]; 2004: BB 2007, JA 2004[b]; 2005: BB 2007, JA 2005[b]; 2006: BB 2007; 2007: BB 2008; 2008: BB 2009; 2009: BB 2010; 2010: BB 2011; 2011: BB 2012; 2012: BB 2013
Mainz	7315	2000: BB 2002, Bd. II; 2001: BB 2002, Bd. II; 2002: BB 2003, Bd. II; 2003: BB 2004, Bd. II; 2004: BB 2007, Bd. II; 2005: BB 2007, Bd. II; 2006: BB 2007, Bd. II; 2007: BB 2009, Bd. II; 2008: BB 2009, Bd. II; 2009: BB 2010, Bd. II; 2010: BB 2011, Bd. II; 2011: BB 2012, Bd. II; 2012: BB 2013, Bd. II
Mannheim	8222	2000: BB 2001; 2001: BB 2001; 2002: BB 2002; 2003: BB 2003; 2004: BB 2004; 2005: BB 2005; 2006: BB 2006; 2007: BB 2007; 2008: BB 2008; 2009: BB 2009; 2010: BB 2010; 2011: BB 2011; 2012: BB 2012
Mönchengladbach	5116	2000: BB 2001; 2001: BB 2002; 2002: BB 2003; 2003: BB 2004; 2004: BB 2005; 2005: BB 2006; 2006: BB 2007; 2007: BB 2008; 2008: BB 2009; 2009: BB 2010; 2010: BB 2011; 2011: BB 2012; 2012: BB 2013
Mülheim an der Ruhr	5117	2000: BB 2001; 2001: BB 2001; 2002: BB 2002; 2003: BB 2003; 2004: BB 2004; 2005: BB 2005; 2006: BB 2006; 2007: BB 2007; 2008: BB 2008; 2009: BB 2009; 2010: BB 2010/11; 2011: BB 2011/11; 2012: BB 2012

München	9162	2002: BB 2002; 2003: BB 2003; 2004: BB 2004; 2005: BB 2005; 2006: BB 2006; 2007: BB 2007; 2008: BB 2008; 2009: BB 2009; 2010: BB 2010; 2011: BB 2011; 2012: BB 2012
Münster	5515	2000: BB 2001/2002; 2001: BB 2001/2002; 2002: BB 2006; 2003: BB 2006; 2004: BB 2006; 2005: BB 2006; 2006: BB 2006; 2007: BB 2007; 2008: BB 2008; 2009: BB 2009; 2010: BB 2010; 2011: BB 2011; 2012: BB 2012
Neustadt[b]	7316	2000: JA 2000; 2001: JA 2001; 2002: JA 2002; 2003: JA 2003; 2004: JA 2004; 2005: JA 2005; 2006: JA 2006; 2007: JA 2007; 2008: JA 2008; 2009: JA 2009; 2010: JA 2010; 2011: JA 2011; 2012: JA 2012
Nürnberg	9564	2001: JA 2002[b]; 2002: JA 2002[b]; 2004: JA 2005[b]; 2005: JA 2005[b]; 2006: JA 2006[b]; 2007: JA 2008[b]; 2008: JA 2008[b]; 2009: JA 2009[b]; 2010: JA 2010[b]; 2011: JA 2012[b]; 2012: JA 2012[b]
Oberhausen	5119	2010: BB 2010; 2011: BB 2011; 2012: BB 2012
Offenbach[b]	6413	2000: JA 2000; 2001: JA 2001; 2002: JA 2002; 2003: JA 2003; 2004: JA 2004; 2005: BB 2005; 2006: BB 2006; 2007: BB 2007; 2008: BB 2008; 2009: BB 2009; 2010: BB 2010; 2011: BB 2011; 2012: BB 2012
Oldenburg	3403	2003: BB 2003; 2004: BB 2004; 2005: BB 2005; 2006: BB 2006; 2007: BB 2007; 2008: BB 2008; 2009: BB 2009; 2010: BB 2010; 2011: BB 2011; 2012: BB 2012
Osnabrück	3404	2000: BB 2001; 2001: BB 2002; 2002: BB 2003; 2003: BB 2004; 2004: BB 2005; 2005: BB 2006; 2006: BB 2007; 2007: BB 2008; 2008: BB 2009; 2009: BB 2010; 2010: BB 2011; 2011: BB 2012; 2012: BB 2013
Passau[b]	9262	2000: GB 2000; 2001: GB 2001; 2002: GB 2002; 2003: GB 2003; 2004: GB 2004; 2005: GB 2005; 2006: GB 2006; 2007: GB 2007; 2008: GB 2008; 2009: GB 2009; 2010: GB 2010; 2011: GB 2011; 2012: GB 2012
Pirmasens[b]	7317	2007: JA 2008, HP 2009; 2008: JA 2008, HP 2010; 2009: JA 2009, HP 2011; 2010: JA 2010, HP 2012; 2011: JA 2011, HP 2013; 2012: JA 2012, HP 2014
Potsdam	12054	2000: BA 2000/6. BB; 2001: 8. BB; 2002: 8. BB; 2003: 9. BB; 2004: 10. BB; 2005: 11. BB; 2006: 12. BB; 2007: 13. BB; 2008: 14. BB; 2009: 15. BB; 2010: 16. BB; 2011: 17. BB; 2012: 18. BB
Remscheid	5120	2000: BB 2002; 2001: BB 2002; 2002: BB 2002; 2003: BB 2003; 2004: BB 2004; 2005: BB 2005; 2006: BB 2006; 2007: BB 2007; 2008: BB 2008; 2009: BB 2009; 2010: BB 2010; 2011: BB 2011; 2012: BB 2012

Rosenheim	9163	2000: BB 2002; 2001: BB 2002; 2002: BB 2002; 2003: BB 2003; 2004: BB 2004; 2005: BB 2005; 2006: BB 2006; 2007: BB 2007; 2008: BB 2008; 2009: BB 2009; 2010: BB 2010; 2011: BB 2011; 2012: BB 2012
Rostock	13003	2000: BB 2000; 2001: BB 2001; 2002: BB 2002; 2003: BB 2003; 2004: BB 2004; 2005: BB 2005; 2006: BB 2006; 2007: BB 2007; 2008: BB 2008; 2009: BB 2009; 2010: BB 2010; 2011: BB 2011; 2012: BB 2012
Salzgitter	3102	2001: BB, HP 2004, Bd. II; 2002: BB, HP 2004, Bd. II; 2003: BB, HP 2005, Bd. II; 2004: BB, HP 2006, Bd. II; 2005: BB, HP 2007, Bd. II; 2006: BB, HP 2008, Bd. II; 2007: BB, HP 2009, Bd. II; 2008: BB, HP 2010, Bd. II; 2009: BB, HP 2011, Bd. II; 2010: BB, HP 2012, Bd. II; 2011: BB, HP 2013, Bd. II; 2012: BB,HP 2014, Bd. II
Schwerin	13004	2000: 4. BB; 2001: 5. BB; 2002: 6. BB[c]; 2003: 7. BB[c]; 2004: 8. BB[c]; 2005: 9. BB; 2006: 10. BB; 2007: 11. BB; 2008: 12. BB; 2009: 13. BB; 2010: 14. BB; 2011: 15. BB; 2012: 16. BB
Solingen	5122	2000: BB 2002; 2001: BB 2002; 2002: BB 2002; 2003: BB 2003; 2004: BB 2004; 2005: BB 2005; 2006: BB 2006; 2007: BB 2007; 2008: BB 2008; 2009: BB 2009; 2010: BB 2010
Speyer[b]	7318	2000: JA 2000; 2001: JA 2001; 2002: JA 2002; 2003: JA 2003; 2004: JA 2004; 2005: JA 2005; 2006: JA 2006; 2007: JA 2007; 2008: JA 2008; 2009: JA 2009; 2010: JA 2010; 2011: JA 2011; 2012: JA 2012
Stuttgart	8111	2001: BB 2001; 2002: BB 2002; 2003: BB 2003; 2004: BB 2004; 2005: BB 2005; 2006: BB 2006; 2007: BB 2007; 2008: BB 2008; 2009: BB 2009; 2010: BB 2010; 2011: BB 2011; 2012: BB 2012
Suhl	16054	2002: BB 2003; 2003: BB 2004; 2004: BB 2005; 2005: BB 2006; 2006: BB 2007; 2007: BB 2008; 2008: BB 2009; 2009: BB 2010; 2010: BB 2011; 2011: BB 2012; 2012: BB 2013
Trier	7211	2001: BB 2001-2002; 2002: BB 2001-2002; 2003: BB 2003; 2004: BB 2004; 2005: BB 2005; 2006: BB 2006; 2007: BB 2007; 2008: BB 2008; 2009: BB 2009; 2010: BB 2010; 2011: BB 2011; 2012: BB 2012
Ulm	8421	2000: 6. BB 2000; 2001: 7. BB 2000; 2002: 8. BB 2000; 2003: 9. BB 2000; 2004: 10. BB 2000; 2005: 11. BB 2000; 2006: 12. BB 2000; 2007: 13. BB 2000; 2008: 14. BB 2000; 2009: 15. BB 2000; 2010: 16. BB 2000; 2011: 17. BB 2000; 2012: 18. BB 2000
Weimar	16055	2001: BB 2003; 2002: BB 2004; 2003: BB 2005

Wiesbaden	6414	2000: BB 2000; 2001: BB 2001; 2002: BB 2002; 2003: BB 2003; 2004: BB 2004; 2005: BB 2005; 2006: BB 2006; 2007: BB 2007; 2008: BB 2008; 2009: BB 2009; 2010: BB 2010; 2011: BB 2011; 2012: BB 2012
Wilhelmshaven	3405	2000: BB 2003, BB 2001; 2001: BB 2004, BB 2001; 2002: BB 2004, BB 2003; 2003: BB 2004; 2004: BB 2007; 2005: BB 2007; 2006: BB 2007, SP 2006; 2007: BB 2010, SP 2007; 2008: BB 2010; 2009: BB 2010; 2010: BB 2011, SP 2010; 2011: BB 2013; 2012: BB 2013
Wolfsburg	3103	2005: BB 2005; 2006: BB 2006; 2007: BB 2007; 2008: BB 2008; 2009: BB 2009; 2010: BB 2010; 2011: BB 2011; 2012: BB 2012
Worms	7319	2005: JA 2006[b]; 2006: JA 2006[b]; 2007: JA 2008[b]; 2008: JA 2008[b]; 2009: JA 2009[b]; 2010: JA 2010[b]; 2011: JA 2011[b]
Wuppertal	5124	2000: BB 2000; 2001: BB 2002; 2002: BB 2002; 2003: BB 2005; 2004: BB 2005; 2005: BB 2005; 2006: BB 2005; 2007: BB 2007/2008; 2008: BB 2007/2008; 2009: BB 2009; 2010: BB 2010; 2011: BB 2011; 2012: BB 2012
Würzburg	9663	2001: JA 2001[b]; 2002: JA 2002[b]; 2003: JA 2003[b]; 2004: JA 2004[b]; 2005: JA 2005[b]; 2006: JA 2006[b]; 2007: JA 2007[b]; 2008: JA 2008[b]; 2009: BB 2009; 2010: BB 2010; 2011: BB 2011; 2012: BB 2012

[a] Taken from electronic database of the city council (Ratsinformationssystem).

[b] Information provided or supplemented by the city.

[c] Supplemented using the operator's homepage.

[d] Information provided by Stadtarchiv, Erfurt.

[e] Information provided by Institut für Stadtgeschichte, Gelsenkirchen.

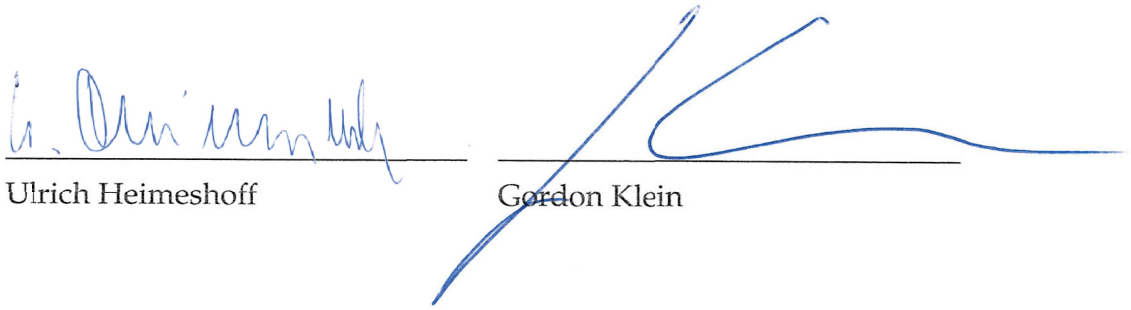
Note: Sources for financial data by fiscal year, the name is the one chosen by the respective data provider, e.g. *2005: BB 2006* indicates that information f or the year 2005 is taken from the document named *Beteiligungsbericht 2006*. Amad=AMADEUS, BB=Beteiligungsbericht, GB=Geschäftsbericht, HP=Haushaltsplan, JA=Jahresabschluss, JB=Jahresbericht, SP= Stellenplan, WP=Wirtschaftsplan. Area code identifies the city (*Amtlicher Gemeindeschlüssel*). For Aachen and Hannover, the consortium of cities and districts has been chosen (Städteregion Aachen and Region Hannnover) that also constitutes the market size of the provider.

Declaration of contribution

Hereby I, Maria FRIESE, declare that this chapter, entitled "Property rights and transaction costs - The role of ownership and organization in German public service provision" is co-authored with Ulrich HEIMESHOFF and Gordon KLEIN.

I have contributed substantially to the development of the research questions, the collection of data, the empirical analysis and the preparation of the final manuscript.

Signatures of the coauthors:



Ulrich Heimeshoff

Gordon Klein

Chapter 4

Do frustration and anger promote criminal behavior? Experimental evidence on the role of gender

Co-authored with Florian Baumann and Volker Benndorf

Summary of the chapter

We analyze the influence of frustration and anger resulting from loss experiences on the decision to commit a norm violation. In a lab experiment, subjects first complete a real-effort task where compensation is framed as a gain or a loss. Subsequently, they can increase their own income by taking away money designated for donation to charity. Whereas both males and females experience higher levels of negative emotions in the loss frame than in the gain frame, only men are more likely to take away money in the loss scenario.

4.1 Introduction

According to standard economic theory, decisions involving norm violations like property crimes do not differ much from other decisions and can be analyzed using the same methods (Becker, 1968). This implies that decision makers will weigh the possible final outcomes of a criminal activity with the corresponding probabilities. Apart from comparing expected gains and punishment, such decisions may also include non-monetary aspects such as moral costs from violating social norms (see, e.g., Polinsky and Shavell, 2007).

Behavioral economics suggests further mechanisms involved in individual decision-making. The seminal prospect theory (PT) by Kahneman and Tversky, (1979) proposes that risk-taking behavior is more sensitive to the changes in payoffs relative to a reference point than to the ex-post absolute levels. Hence, the perception of outcomes as gains or losses may affect a potential violator's decision-making (Lattimore and Witte, 1986). Also, experiencing gains or losses upfront may alter the reference point or the relevance of moral costs from norm violations (for lying, see Grolleau et al., 2016).

In the criminological literature the general strain theory (GST) has been developed, which shares some insights with behavioral economics. GST states that "strains" can lead people to committing norm violations, including crime (Agnew, 1992). A strain could be a failure to achieve positively valued goals or losing achievements (e.g. job, status) that one appreciates. It is hypothesized that such experiences trigger negative emotions, which may in turn favor crime. Thus, the motivation for norm violations is explained by relative instead of absolute perceptions of one's own situation (Agnew, 1992), relating the theory to the basic motivation of PT.

The propensity to breach social norms or to engage in criminal activities is likely to differ across genders. Data from the field suggests that men are far more likely to engage in criminal activities than women.[1] Behavioral economics has documented gender effects in many related domains. For instance, Dohmen et al., (2011) report that women are less likely to take risks, which may reduce their propensity to behave criminally. There is also evidence that men are more prone to overconfidence than women (e.g., Barber and Odean, 2001). As a consequence, men might overestimate the probability of success of a crime. Gottfredson and Hirschi, (1990) argue that a lack of self-control is a crucial driver of

[1] In the US in 2014, nearly 80% of the violent crimes and about 62% of the property crimes were committed by men (source: Federal Bureau of Investigation, 2014).

criminal behavior. This is tested by Burton Jr et al., (1998), who report that differences in self-control explain a large share of the gender gap in committing crime. Finally, men and women might deal differently with emotions. Later contributions to GST suggest that males might rather react to strain with outrage and crime, while women might respond with self-deprecating emotions (see the theoretical work of Broidy and Agnew, 1997 and some empirical evidence provided in Broidy, 2001).

In this chapter, we analyze the results of a controlled lab experiment in which we study the effects of subjects' emotions on committing a gainful norm violation that may be likened to property crime. In light of the literature, we also test whether this relation is gender-specific. We use loss framing of the payment scheme in a real-effort task to induce emotional responses compared to a benchmark case where payoffs are perceived as gains. After the task, we elicit subjects' positive and negative emotional states to measure how framing affects reported feelings. Finally, we present subjects with the possibility to take money that is intended for a well-known charity in order to connect emotions to norm violations.

For both genders, loss framing instills negative emotions like anger and frustration, whereas it reduces the reported levels of the positive emotions of satisfaction and happiness. However, loss-induced frustration and anger only leads to more norm violations for men, while women tend to take less often in the loss frame. For both men and women, experienced levels of the positive emotions happiness and satisfaction have no explanatory power in our experiment.

4.2 The experiment

4.2.1 Design and treatments

The experiment consists of three parts. The first is a repeated real-effort task where subjects earn money by solving puzzles for ten periods. In the second part, subjects self-assess their level of frustration, anger, satisfaction and happiness on a scale from one to seven. The last part addresses the norm violation decision. Here, subjects decide whether and to what degree they would like to take money from a budget intended for a well-known charity. This way of modeling crime in the lab follows Feess et al., (2015).

We consider two treatments, which only differ in the framing of the real-effort task. In both treatments, subjects begin with an initial endowment and are paid according to their performance in the task. In the *gain treatment* subjects

start with €2 and receive an additional €0.06 for up to 15 puzzles in each period. In contrast, subjects in the *loss treatment* start with €11 and lose €0.06 for each puzzle they fall short of 15 puzzles solved.[2] These payment schemes are mathematically equivalent,[3] but subjects in the gain frame see their total profits increase over time, while subjects in the loss frame face a decline in payoffs. The development of the total profits was displayed prominently on the subjects' computer screens after each period of the real-effort task.

The real-effort task is an encryption task where subjects translate a combination of letters ("puzzles" or "words") into numbers using a randomly generated legend (Benndorf et al., 2014). We use a repeated version in which subjects have ten two-minute periods to solve as many puzzles as possible. Subjects were familiarized with this task using an unincentivized trial period where 10 puzzles had to be solved correctly.

The possible norm violation in part three was introduced as follows. At the beginning of the experiment, the participants were informed that an additional €5 were available per subject, which were intended as a donation to the "German Red Cross" charity.[4] Participants were presented with the option to take some (or all) of this money for themselves. First, they had to indicate whether they wanted to take any money at all; if yes, they could afterwards state the amount (using 2-ct. increments) $x \in [0.02, 5.00]$ they wanted to take away. Taking was successful with probability 85%, in which case the money was added to the participants' earnings (and subtracted from the potential donation). With the remaining probability of 15%, the participant's taking was unsuccessful. In this case, the attempted taking amount was returned to the charity donation and the participant additionally had to pay a fine, also equal to x, from his/her cumulated earnings. This fine was not donated but returned to the experimenters' budget. By introducing the probabilistic fine, we align the subjects' decision problem to how crime is depicted in standard economic models.

4.2.2 Procedures

The experiment took place between October 2016 and February 2017 at the DICE Laboratory at Düsseldorf University. Participants were invited using ORSEE

[2] This threshold was identical in both treatments. It was chosen as an unrealistic goal such that subjects in the loss frame would actually face losses. The average number of solved puzzles per period in our experiment was 9.61 with a median and mode of 10. There was a single subject who managed to reach the threshold of 15 puzzles and did so in every period.

[3] $2 + 0.06 \sum_{t=1}^{10} \min\{e_t, 15\} = 11 - 0.06 \sum_{t=1}^{10} (15 - \min\{e_t, 15\})$

[4] The German Red Cross (DRK e.V.) is a secular non-profit organization that seeks to help vulnerable people in case of disasters and health emergencies.

TABLE 4.1: OLS estimations for emotions

	Dependent variable			
	frustration	anger	satisfaction	happiness
loss	0.745**	0.638*	–0.554**	–0.849***
	(0.370)	(0.371)	(0.275)	(0.301)
female	0.044	–0.232	0.563*	0.230
	(0.386)	(0.361)	(0.326)	(0.314)
loss × female	0.558	0.888	–0.861**	–0.403
	(0.549)	(0.553)	(0.426)	(0.420)
age	–0.028	–0.041**	0.007	–0.008
	(0.023)	(0.019)	(0.015)	(0.014)
taskcorrect	–0.262***	–0.195**	0.283***	0.254***
	(0.087)	(0.081)	(0.077)	(0.086)
constant	6.814***	5.709***	0.398	1.078
	(1.242)	(1.080)	(1.004)	(1.063)
R^2	0.13	0.14	0.22	0.22
No of obs.	161	161	161	161

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors in parentheses. The variable *taskcorrect* denotes the average number of solved puzzles per round.

(Greiner, 2015). We conducted 8 sessions with a total of 161 subjects (80 females, 81 males). Each session lasted around 60 minutes and the participants earned 9.57 Euros on average. The experiment was programmed using the software z-Tree (Fischbacher, 2007).

4.2.3 Hypotheses

While subjects in the loss treatment repeatedly face losses during the real-effort task, subjects in the gain treatment see their profits increase over time. We thus argue that:

Hypothesis 1. *The degree of self-assessed negative (positive) emotions in the loss frame will be higher (lower) compared to the gain frame.*

Following standard GST, we anticipate that negative emotions lead to a higher inclination to commit norm violations. In the context of our experiment, this implies:

Hypothesis 2. *Subjects in the loss frame will be more prone to take money from the charity.*

Finally, following the debate in criminology and experimental evidence on gender differences in related fields, we hypothesize:

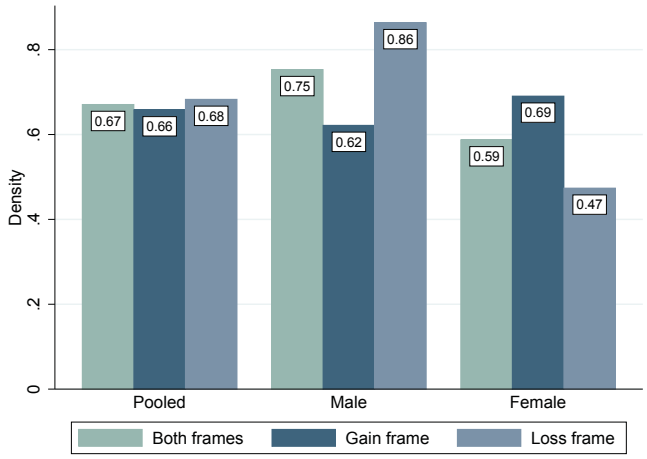


FIGURE 4.1: Share of subjects who try to take money from the charity by frame and gender

Hypothesis 3. *The number of norm violations and the correlation with reported emotions will differ across gender.*

4.3 Results

We first consider how framing affects subjects' emotional state as suggested by Hypothesis 1. Table 4.1 reports OLS regressions where the dependent variable is the self-assessed emotional state from the second part of the experiment.[5] The loss frame significantly increases negative emotions (anger and frustration), while it decreases positive ones (happiness and satisfaction). The effect generally does not differ by gender, besides from weakly significant differences in satisfaction levels. The regressions also document that higher performance in the real-effort tasks leads to lower negative and higher positive feelings.[6]

Result 1. *The degree of frustration and anger (satisfaction and happiness) are significantly higher (lower) in the loss frame compared to the gain frame, confirming Hypothesis 1.*

Next, we consider the relation between norm violations and framing. The data for the binary taking decision is summarized in Figure 4.1. There are virtually no differences between the gain and loss frame when we do not condition on gender (two-sided Fisher's exact test, $p = 0.867$). This changes when we distinguish between male and female subjects. First, men try to take money from the

[5] Running ordered probit models yields very similar results.

[6] Note that we do not find any statistically significant relation between the two treatments and the number of tasks solved.

TABLE 4.2: Probit estimations of the taking decision

	gain	loss	gain	loss	gain	loss	gain	loss
female	1.191*	0.493	0.477	–0.022	0.235	–1.467**	–0.465	–0.672
	(0.689)	(0.837)	(0.582)	(0.671)	(0.749)	(0.713)	(0.737)	(0.611)
frustration	0.054	0.334**						
	(0.133)	(0.162)						
female × frustration	–0.263	–0.417**						
	(0.171)	(0.197)						
anger			0.044	0.402**				
			(0.143)	(0.176)				
female × anger			–0.103	–0.422**				
			(0.188)	(0.205)				
satisfaction					0.033	0.057		
					(0.164)	(0.199)		
female × satisfaction					–0.012	0.125		
					(0.199)	(0.244)		
happiness							–0.036	0.041
							(0.147)	(0.174)
female × happiness							0.194	–0.218
							(0.202)	(0.227)
age	0.011	0.007	0.011	0.007	0.011	–0.005	0.011	–0.001
	(0.026)	(0.022)	(0.026)	(0.021)	(0.027)	(0.020)	(0.026)	(0.020)
taskcorrect	–0.135	0.033	–0.106	0.023	–0.104	–0.050	–0.120	0.010
	(0.112)	(0.102)	(0.112)	(0.098)	(0.115)	(0.105)	(0.116)	(0.101)
Pseudo R^2	0.05	0.21	0.02	0.21	0.02	0.16	0.03	0.16
No of obs.	79	82	79	82	79	82	79	82

Note: * p < 0.1, ** p < 0.05, *** p < 0.01. Robust standard errors in parentheses. Dependent variable $= 1$ if (part of) the donation was taken. The variable *taskcorrect* denotes the average number of solved puzzles per round.

charity more frequently than women (two-sided Fisher's exact test, $p = 0.030$). Second, while men take significantly more often in the loss frame compared to the gain frame (two-sided Fisher's exact test, $p = 0.019$), the opposite is true for women (two-sided Fisher's exact test, $p = 0.069$). The overall gender effect reported above is driven by the behavior in the loss frame. Men take significantly more often than women in the loss frame (two-sided Fisher's exact test, $p < 0.001$), but there is no such effect in the gain frame (two-sided Fisher's exact test, $p = 0.636$).[7]

Result 2. *Men are more prone to take money from the charity in the loss frame compared to the gain frame, but the opposite is true for women. We thus find mixed evidence for Hypothesis 2.*

Lastly, we analyze the relation between reported emotions and the norm violation. The results from different probit models explaining the taking decision

[7]Qualitatively similar results can be found when we consider the amounts people try to take.

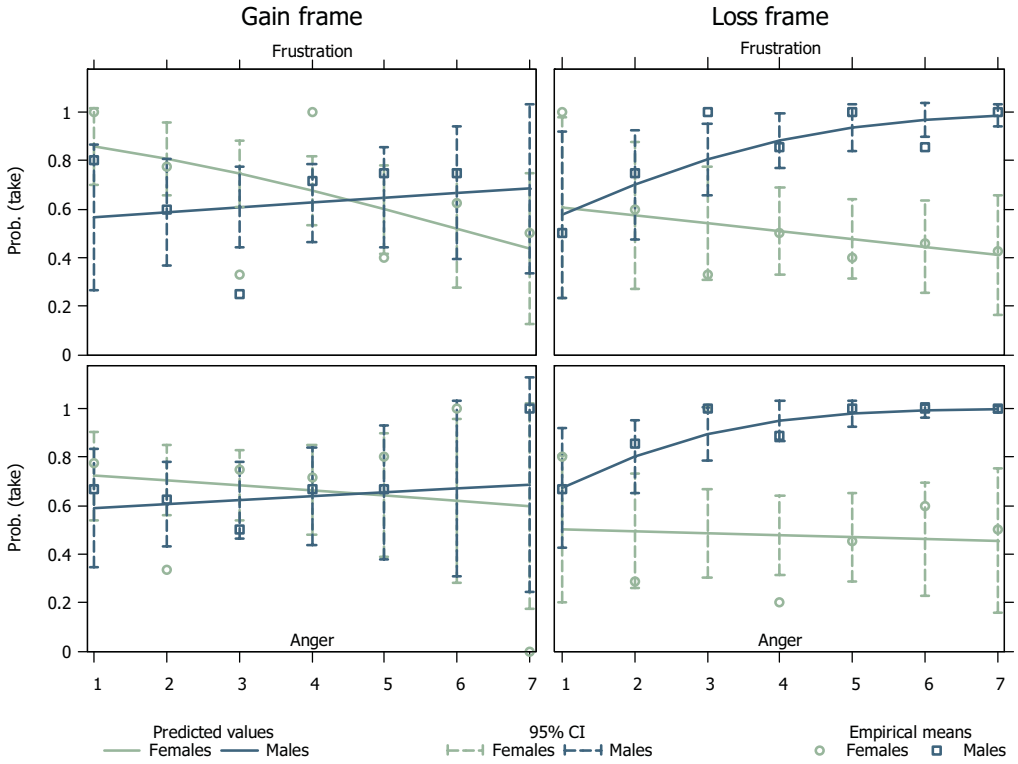


FIGURE 4.2: Predicted taking probabilities and 95% confidence interval of the taking decision (Table 4.2, Cols. 1-2), displayed at different levels of frustration and anger, by gender and frame.

are presented in Table 4.2. The emotions frustration, anger, satisfaction, and happiness are considered separately.[8] Moreover, each regression is run separately for the gain and the loss frame and a *female* indicator and its interaction with the feelings category are included. This allows emotions to have heterogeneous effects across the two treatments, as well as by gender, as the GST and the non-parametric analysis described above suggest. We include *age* and *taskcorrect* as additional control variables, but both are not significant in any specification.

We find that feelings never impact taking behavior in the gain frame. Furthermore, positive feelings do not affect the behavior in any frame, which is consistent with GST. The corresponding coefficients are all insignificant. The finding that feelings do not affect behavior in the gain frame is consistent with the notion that the gain frame serves as a reference where the emotional state of the subjects is normal.

In the loss frame, the effect of the negative emotions frustration and anger for the taking decision depends on gender: higher reported frustration and anger

[8] We do not run a model including all emotions at the same time, as there are problems of multicollinearity in such a model (several Variance Inflation Factors of this model are well above 10).

increase taking for men, but not for women.[9] We further investigate these effects in Figure 4.2 where we plot the predicted probabilities for taking at all possible emotion levels by gender as they result from the regressions reported in Columns (1) and (2). The left panels depict the results for the gain frame. They show that there are no significant differences across genders (confidence intervals) and that the taking probabilities are rather insensitive to the feelings (slopes). The right panels of the figure display these relations in the loss frame. The taking probability is increasing in frustration and anger for men and this marginal effect is significant. For women, a negative, but insignificant relation results.[10]

Result 3. *Higher degrees of frustration and anger induced by the loss frame translate into more norm violations committed by men, but not by women. Thus, we confirm Hypothesis 3.*

4.4 Conclusion

We investigated how experiencing an outcome as a loss affects the inclination for committing a gainful norm violation using a lab experiment. We framed income of a real-effort task as gains or losses and gave subjects the option to take away money designated for a charity. Collecting self-assessed emotions, we are able to link losses, induced feelings, and norm violations. We find that only men react to anger and frustration by being more likely to take the donation. Women do not seem to respond to the loss experience by committing the norm violation.

Our results are related to the findings in Grolleau et al., (2016), who allow participants to cheat by self-reporting their success in an effort task and find that subjects in the loss frame claim significantly higher performance than those in the gain frame. As in our study, men react very strongly to loss framing by committing norm violations. Our experiment suggests that the findings for lying in Grolleau et al., (2016) can be extended to other forms of norm violation that may include harm to third parties.

The idea of experiences causing emotional reactions, which affect future decisions, is also present in Beisswingert et al., (2015). They show that the experience of losing control causes anger and leads to less risk-aversion in a subsequent task, which generally is in line with what we find for men in our loss

[9] In (1) and (2) the sum of the coefficient of the feeling and its interaction with *female* is not statistically different from zero.

[10] For frustration, the predicted difference between the genders is significant at the 1% level for values 4-7 and at the 10% level for a value of 3. For anger, the difference is significant at the 1% level for values 3-7 and at the 5% level for a value of 2.

scenario. Buser, (2016) also finds a gender effect in the context of a competition. In the experiment, men react to the experience of losing by selecting higher goals for themselves, while women rather choose lower goals as a reaction. Related to that, it is a long-established idea in psychology that frustration may lead to either aggression or to resignation, see Shorkey and Crocker, (1981).

Our findings contribute to the understanding of the economic theory of norm violations and crime. The experimental evidence documents important gender effects that cannot be derived from standard economic theory. Furthermore, the results are broadly in line with the criminological general strain theory.

4.A Experimental instructions

In the following experiment, you can earn money depending on your behavior.

Please turn off your mobile telephone and do not talk to the other participants. It is very important that you comply with these rules. Should you have any questions during the experiment, please raise your hand. We will come to you immediately and answer your questions individually.

During the experiment, you can earn Taler according to your decisions. At the end of the experiment, the Taler earned will be exchanged to Euro at a rate of

50 Taler = 1 EURO

and will be paid out to you in cash.

Today's experiment consists of two phases. First, there is a task, which you will have to work on. This will be described in more detail below. The more successful you are in this part, the higher your income is. After that, you will make a one-time decision that can further influence your income.

Working phase

A practice phase will take place as a first part of the experiment, so that you can get acquainted with the task at hand. In a next step, the actual working phase will take place.

In the practice phase, all participants have to solve 10 puzzles correctly. Please note that solving the puzzles correctly in the practice phase does not lead to earnings.

The working phase lasts **10 periods, and every period takes two minutes**. Your task is solving puzzles correctly, which is explained in more detail in the next paragraph. Solving a puzzle consists of correctly encrypting one word.

*As mentioned before, your performance in the working phase influences your income. You start with an initial budget of **100 Taler** that you have for participating in the experiment. You can influence your total income by solving puzzles.*

*The compensation scheme for this is as follows: if you correctly code 15 words or less in this period, you gain **3 Taler** for every word up to this threshold. If you solve 15 words*

or more, these additional words do not influence your payment and you will receive the same payment as if you had only coded 15 words correctly.[11]

In addition, and independent of your performance in this task, an amount of **250 Taler** per participant is planned as a donation for the German Red Cross (GRC). In its charter, the GRC describes its goals as follows:

> The German Red Cross assumes the interests of those who are in need of help and support, in order to abolish social discrimination, hardship and degrading situations and to work toward improving the individual and social living conditions and those in the family.

The GRC is awarded the DZI seal of approval, which confirms the compliance with economic, legal and ethical criteria. All donations that are generated by this experiment are passed on 100 % to the GRC, the donation will take place live right after the experiment.

Description of the task

The task consists of encrypting combinations of letters (words) into numbers. In the task, three capital letters always yield a word. You have to allocate a number to each capital letter. The encryption code can be found in a table below the corresponding letter. For that purpose, please consider the following screenshot: In this example, the participant has already encrypted three words correctly (see centered field: above). Here, the three capital letters: **"Z"**, **"N"** and **"T"** have to be encoded. The solution follows immediately from the table:

- For "Z" applies: 684 (see the current entry of the participant)
- For "N" applies: 357
- For "T" applies: 848

To make an input please click on the blue box below the first capital letter. Furthermore, the screen (see screenshot) provides the following information:

[11] The italic part reads as follows for the loss scenario.
*As mentioned before, your performance in the working phase influences your income. You start with an initial budget of **550 Taler** that you have for participating in the experiment. You can influence your total income by solving puzzles.*
*The compensation scheme for this is as follows: if you correctly code 15 words or less in this period, you lose **3 Taler** for every word falling short of this threshold. If you solve 15 words or more, these additional words do not influence your payment and you will receive the same payment as if you had only coded 15 words correctly.*

- "Number of correct solutions" = number of correctly encrypted words.
- "Remaining time [sec]" = remaining time in the current period.
- "You currently encrypt word number" = current word to encrypt.

If all 3 numbers have been entered, please click the "OK" button.

- The computer then checks whether all capital letters haven been encoded correctly. Only then, the word is counted as correctly solved. Thereafter a new word (again consisting of three capital letters) is randomly drawn. Furthermore, a new encryption table is randomly generated in two steps:

  1. The computer program randomly selects in the table a new set of three-digit numbers to be used for the encoding of the capital letters.
  2. Additionally, the computer program shuffles the position of the capital letters in the table. Please note that the program always uses **all** 26 capital letters of the German alphabet.

Please note that if a new word appears, you have to click with your mouse on the first of the three blue boxes. Otherwise, no input is possible!

- The computer will mark (in red font) wrong inputs after pressing the "OK" button.

Bear in mind:

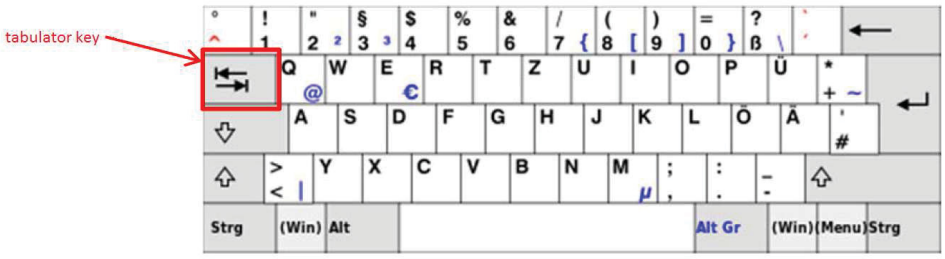
- After wrong inputs the current word to encode will not change until a correct input was made.
- However, your previous inputs (in the 3 boxes below the capital letters) will all be deleted.

- Furthermore, the table stays unaltered, meaning that the allocated numbers remain identical. Also the position of the capital letters in the table does not change.

Hints:

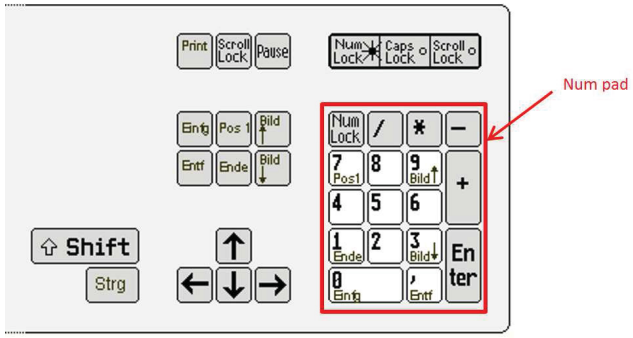
- Please note that after having entered the three-digit number you can easily switch to the next blue box by using the tabulator key on your keyboard.

  In the following picture, you can see the position of the tabulator key on your keyboard:



- The input of the numbers can be performed faster by using the numpad (on the right) of your keyboard.

  In the following picture, you can see the position of the numpad on your keyboard:



Decision phase

In this part, you can try to take away some of the 250 Taler that are designated for the German Red Cross in order to receive it for yourself.

If you would not like to do this, click "No" and your income does not change. If you do want to do this, first click "Yes". On the next screen, you can then try to take an integer amount between 1 and 250 Taler.

With a probability of 85 % taking the Taler is successful, you will receive the amount chosen and you can keep it for yourself. With probability 15 % you do not receive the amount. Instead, the amount you have chosen will be subtracted from your cumulated earnings (including your initial budget) in this case.

If you have taken an amount, but this has not been successful, the German Red Cross will receive the full 250 Taler. However, the German Red Cross will not receive the amount that gets subtracted from your income in this case.

Your decision remains secret and will not be made public at any point.

Declaration of contribution

Hereby I, Maria FRIESE, declare that this chapter, entitled "Do frustration and anger promote criminal behavior? Experimental evidence on the role of gender" is co-authored with Florian BAUMANN and Volker BENNDORF.

I have contributed substantially to the preparation and execution of the experiment, the analysis of the data, as well as the writing of the final manuscript.

Signatures of the coauthors:

Florian Baumann

Volker Benndorf

Chapter 5

Conclusion

This thesis has presented articles in two fields of economics. The first part examined production behavior in the garbage sector, whereas the second focused on the connection between norm violations and loss-invoked emotions.

In Chapter 2 with the title "Task bundling, ownership and efficiency: An application to garbage incineration", we focused on incineration plants, which is an important component of the refuse market. The focus was on important factors that do not only determine efficiency in this sector, but are also interesting from an economic perspective. The analysis is conducted using a sample of German incineration plants between the years 2006-2014. In this chapter, efficiency estimates are derived from Data Envelopment Analysis, a powerful non-parametric technique.

The main results concern the impact of task bundling, ownership and competition. We find that operating with several firms inhibits efficiency, as task bundling (one firm managing the whole plant) is clearly the most efficient structure. Further, a larger share of private stakeholding unambiguously goes along with higher efficiency: private firms seem to find a better way to convert inputs into outputs. The role of regional competition is not clear-cut, if anything, more capacity of other plants in a local area tends to affect efficiency negatively.

Chapter 3, entitled "Property rights and transaction costs - The role of ownership and organization in German public service provision" has studied the productivity of refuse collection firms in Germany in the period 2000-2012. Using a recently developed technique by Ackerberg et al., (2015), we are able to consistently estimate the production function and derive estimates of total factor productivity. The projection of productivity onto the organizational structure has revealed several interesting results. We showed that private ownership is associated with larger productivity for firms active in garbage collection.

The finding that this industry has a positive productivity effect for private firms confirms an intuition that has been raised in the theoretical literature on public vs. private ownership (Hart et al., 1997). Moreover, we do *not* find a

similar productivity effect for instances where the private firm shares ownership with the public sector, but find rather contrary evidence. This fact should let us question the often-made claim that public-private-partnerships manage to combine "the best of two worlds" by conciliating the demand for quality with efficiency incentives of the private sector.

Both of these chapters let us conclude that there are efficiency differences within public services that can be attributed to various aspects of how the service is organized. The fact that ownership, bundling, and legal status have been proven influential should call the attention of policy makers for various reasons. Foremost, one should promote the scientific study of productivity in order to learn about other industries, periods, or organizational factors. The works presented here should be a first stepping-stone in starting to consider efficiency factors in deciding on the organization of public services.

Chapter 4 called "Do frustration and anger promote criminal behavior? Experimental evidence on the role of gender" presented a different topic and investigated the connection between loss situations, invoked emotions, and the propensity to commit a norm violation. The chapter was motivated by the presumption that experiencing losses with respect to a perceived status quo will make people more likely to revert to illegal means. The General Strain Theory from criminology hypothesizes that this relation exists due to increased frustration and anger arising from those situations.

Our experiment used the payment scheme of a real-effort task to model losses and mirrored a norm violation situation by giving participants the option to take away from money intended for charity. The results show that loss framing increases frustration and anger significantly, but this translates into a higher likelihood of the norm violation only for males. Overall, we isolated one channel of criminal activity, i.e. the experience of losses. The results are broadly in line with the General Strain Theory and demonstrate a significant gender effect that cannot be derived from economic theory.

Bibliography

Ackerberg, D. A., K. Caves, and G. Frazer (2015). "Identification properties of recent production function estimators". *Econometrica* 83.6, pp. 2411–2451.

Agnew, R. (1992). "Foundation for a general strain theory of crime and delinquency". *Criminology* 30.1, pp. 47–88.

Amaral, M. (2008). "Public vs private management of public utilities-The case of urban public transport in Europe". *Research in Transportation Economics* 22.1, pp. 85–90.

Banker, R. D., A. Charnes, and W. W. Cooper (1984). "Some models for estimating technical and scale inefficiencies in data envelopment analysis". *Management Science* 30.9, pp. 1078–1092.

Barber, B. M. and T. Odean (2001). "Boys will be boys: Gender, overconfidence, and common stock investment". *The Quarterly Journal of Economics* 116.1, pp. 261–292.

Bataille, M. and A. Steinmetz (2015). "Kommunale Monopole in der Hausmüllentsorgung". *Wirtschaftsdienst* 95.1, pp. 56–62.

Becker, G. S. (1968). "Crime and punishment: An economic approach". *Journal of Political Economy* 76.2, pp. 169–217.

Beisswingert, B. M., K. Zhang, T. Goetz, P. Fang, and U. Fischbacher (2015). "The effects of subjective loss of control on risk-taking behavior: the mediating role of anger". *Frontiers in Psychology* 6, pp. 1–17.

Bel, G., X. Fageda, and M. E. Warner (2010). "Is private production of public services cheaper than public production? A meta-regression analysis of solid waste and water services". *Journal of Policy Analysis and Management* 29.3, pp. 553–577.

Benndorf, V., H. A. Rau, and C. Sölch (2014). *Minimizing learning behavior in experiments with repeated real-effort tasks*. URL: https://ssrn.com/abstract=2503029.

Bennett, E., S. James, and P. Grohmann (2000). *Joint Venture Public-Private Partnerships for Urban Environmental Services*. UNDP and Yale University. URL: http://www.ucl.ac.uk/dpu-projects/drivers_urb_change/urb_infrastructure/pdf_public_private_services/UNDP_PPPUE_Joint%20Venture_2.pdf.

Bennett, J. T. and M. H. Johnson (1979). "Public versus Private Provision of Collective Goods and Services: Garbage Collection Revisited". *Public Choice* 34.1, pp. 55–63.

Bennett, J. and E. Iossa (2006). "Building and managing facilities for public services". *Journal of Public Economics* 90.10, pp. 2143–2160.

Bilitewski, B. and G. Härdtle (2013). "Kostenbetrachtung von Abfallbehandlungsanlagen". *Abfallwirtschaft: Handbuch für Praxis und Lehre*. Berlin, Heidelberg, Germany: Springer, pp. 793–830.

Boycko, M., A. Shleifer, and R. W. Vishny (1996). "A theory of privatisation". *The Economic Journal* 106.435, pp. 309–319.

Broidy, L. and R. Agnew (1997). "Gender and crime: A general strain theory perspective". *Journal of Research in Crime and Delinquency* 34.3, pp. 275–306.

Broidy, L. M. (2001). "A test of general strain theory". *Criminology* 39.1, pp. 9–35.

Buekens, A. (2013). "Incineration technologies". New York, NY: Springer. Chap. Refuse-Derived Fuel, pp. 71–76.

Bund der Steuerzahler NRW (2017). *Vergleich der Abfall- und Abwassergebühren 2017*. URL: https://www.steuerzahler-nrw.de/Vergleich-der-Abfall-und-Abwassergebuehren-2017/85760c97552i1p352/index.html (visited on 08/12/2017).

Burton Jr, V. S., F. T. Cullen, T. D. Evans, L. F. Alarid, and R. G. Dunaway (1998). "Gender, self-control, and crime". *Journal of Research in Crime and Delinquency* 35.2, pp. 123–147.

Buser, T. (2016). "The impact of losing in a competition on the willingness to seek further challenges". *Management Science* 62.12, pp. 3439–3449.

Byrnes, P., R. Färe, S. Grosskopf, and C. Knox Lovell (1988). "The effect of unions on productivity: US surface mining of coal". *Management Science* 34.9, pp. 1037–1053.

Chen, P.-C., C.-C. Chang, and C.-L. Lai (2014). "Incentive regulation and performance measurement of Taiwan's incineration plants: an application of the four-stage DEA method". *Journal of Productivity Analysis* 41.2, pp. 277–290.

Claus, J. C. (2000). "Planung komplexer Abfallbehandlungsanlagen". Doctoral thesis. Technische Universität Berlin. URL: http://webdoc.sub.gwdg.de/ebook/diss/2003/tu-berlin/diss/2000/claus_jens.pdf.

Coelli, T., A. Estache, S. Perelman, and L. Trujillo (2003). *A primer on efficiency measurement for utilities and transport regulators*. Vol. 953. Washington, DC: World Bank.

Cooper, W. W., L. M. Seiford, and K. Tone (2007). *Introduction to Data Envelopment Analysis and Its Uses: With DEA-Solver Software and References*. 2nd ed. Luxemburg, Luxemburg: Springer Science & Business Media.

Cooper, W. W., L. M. Seiford, and J. Zhu (2011). *Handbook on Data Envelopment Analysis*. Vol. 164. Luxemburg, Luxemburg: Springer Science & Business Media.

Cullmann, A., M. Nieswand, S. Seifert, and C. Stiel (2016). "No differences in efficiency between public and private utilities". *DIW Economic Bulletin* 6.20, pp. 233–238.

Deprins, D. and L. Simar (1989). "Estimation de frontières déterministes avec facteurs exogènes d'inefficacité". *Annales d'Economie et de Statistique* 14, pp. 117–150.

Dijkgraaf, E. and R. Gradus (2015). "Efficiency effects of unit-based pricing systems and institutional choices of waste collection". *Environmental and Resource Economics* 61.4, pp. 641–658.

Dijkgraaf, E. and R. H. Gradus (2003). "Cost savings of contracting out refuse collection". *Empirica* 30.2, pp. 149–161.

Dijkgraaf, E. and R. Gradus (2007). "Fair competition in the refuse collection market?" *Applied Economics Letters* 14.10, pp. 701–704.

Dohmen, T., A. Falk, D. Huffman, U. Sunde, J. Schupp, and G. G. Wagner (2011). "Individual risk attitudes: Measurement, determinants, and behavioral consequences". *Journal of the European Economic Association* 9.3, pp. 522–550.

Dyson, R. G., R. Allen, A. S. Camanho, V. V. Podinovski, C. S. Sarrico, and E. A. Shale (2001). "Pitfalls and protocols in DEA". *European Journal of Operational Research* 132.2, pp. 245–259.

Eckel, C. C. and A. R. Vining (1985). "Elements of a theory of mixed enterprise". *Scottish Journal of Political Economy* 32.1, pp. 82–94.

EEW Energy from Waste (2017). *Our sites*. URL: https://www.eew-energyfromwaste.com/en/our-sites.html (visited on 08/28/2017).

Eurostat (2015). *Municipal waste statistics*. URL: http://ec.europa.eu/eurostat/statistics-explained/index.php/Municipal_waste_statistics (visited on 05/17/2017).

Fabrizio, K. R., N. L. Rose, and C. D. Wolfram (2007). "Do markets reduce costs? Assessing the impact of regulatory restructuring on US electric generation efficiency". *The American Economic Review* 97.4, pp. 1250–1277.

Fama, E. F. and M. C. Jensen (1983). "Separation of ownership and control". *Journal of Law and Economics* 26.2, pp. 301–325.

Federal Bureau of Investigation (2014). *Crime in the United States 2014*. Uniform Crime Reports Online. URL: https://ucr.fbi.gov/crime-in-the-u.s/2014/crime-in-the-u.s.-2014/tables/table-33 (visited on 08/17/2017).

Feess, E., H. Schildberg-Hörisch, M. Schramm, and A. Wohlschlegel (2015). *The impact of fine size and uncertainty on punishment and deterrence: Theory and evidence from the laboratory*. IZA Discussion Paper No. 9388. Institute for the Study of Labor.

Fischbacher, U. (2007). "z-Tree: Zurich toolbox for ready-made economic experiments". *Experimental Economics* 10.2, pp. 171–178.

Fried, H. O., C. K. Lovell, S. S. Schmidt, and S. Yaisawarng (2002). "Accounting for environmental effects and statistical noise in data envelopment analysis". *Journal of Productivity Analysis* 17.1, pp. 157–174.

Fried, H. O., C. K. Lovell, and S. S. Schmidt (2008). *The Measurement of Productive Efficiency and Productivity Growth*. Oxford, United Kingdom: Oxford University Press.

Galdon-Sanchez, J. E. and J. A. Schmitz (2002). "Competitive Pressure and Labor Productivity: World Iron-Ore Markets in the 1980's". *The American Economic Review* 92.4, pp. 1222–1235.

Garcia, S., M. Moreaux, and A. Reynaud (2007). "Measuring economies of vertical integration in network industries: An application to the water sector". *International Journal of Industrial Organization* 25.4, pp. 791–820.

Gottfredson, M. R. and T. Hirschi (1990). *A general theory of crime.* Stanford, CA: Stanford University Press.

Greene, W. (2005). "Fixed and random effects in stochastic frontier models". *Journal of Productivity Analysis* 23.1, pp. 7–32.

Greiner, B. (2015). "Subject pool recruitment procedures: organizing experiments with ORSEE". *Journal of the Economic Science Association* 1.1, pp. 114–125.

Grolleau, G., M. G. Kocher, and A. Sutan (2016). "Cheating and Loss Aversion: Do People Cheat More to Avoid a Loss?" *Management Science* 62.12, pp. 3428–3438.

Grossman, S. J. and O. D. Hart (1986). "The costs and benefits of ownership: A theory of vertical and lateral integration". *Journal of Political Economy* 94.4, pp. 691–719.

Hart, O. (1995). *Firms, Contracts, and Financial Structure*. OUP Catalogue. Oxford, United Kingdom: Oxford University Press.

— (2003). "Incomplete contracts and public ownership: Remarks, and an application to public-private partnerships". *The Economic Journal* 113.486, pp. C69–C76.

Hart, O., A. Shleifer, and R. Vishny (1997). "The Proper Scope of Government: Theory and an Application to Prisons". *Quarterly Journal of Economics* 112.4, pp. 1127–1161.

Hövelborn, T. (2014). "Ansatzfähigkeit eines preisrechtlich angemessenen Gewinns nach KAG". *Angemessener Gewinnaufschlag von Entsorgungsunternehmen bei öffentlichen Aufträgen zu Selbstkosten*. Wiesbaden, Germany: Springer Gabler, pp. 187–205.

Institut für Fortbildung und Verwaltungs-Modernisierung (2016). *Vergleich: Eigenbetrieb, Kommunalunternehmen, GmbH und AG*. Fachhochschule für Verwaltung und Dienstleistung. URL: `http://www.informdoku.de/themen/schwerpunkte/ausgliederung2.php` (visited on 11/10/2016).

Iossa, E. and D. Martimort (2009). *The theory of incentives applied to the transport sector*. Working Paper No. 09-13. Brunel University West London.

Ivaldi, M. and G. McCullough (2008). "Subadditivity tests for network separation with an application to US railroads". *Review of Network Economics* 7.1, pp. 159–171.

Jeanty, P. W. (2010). *NEARSTAT: Stata module to calculate distance-based variables and export distance matrix to text file*. Statistical Software Components, Boston College Department of Economics.

Ji, Y. and C. Lee (2010). "Data envelopment analysis". *Stata Journal* 10.2, pp. 267–280.

Kahneman, D. and A. Tversky (1979). "Prospect theory: An analysis of decision under risk". *Econometrica* 47.2, pp. 263–291.

Klette, T. J., Z. Griliches, et al. (1996). "The inconsistency of common scale estimators when output prices are unobserved and endogenous". *Journal of Applied Econometrics* 11.4, pp. 343–361.

Klusemann, G.-F. (1998). *Kommunalabgaben-Drama ohne Ende?: Steuern, Gebühren und Beiträge in der kommunalen Praxis*. Bonn, Germany: Friedrich Ebert Stiftung, Arbeitsgruppe Kommunalpolitik, FES Library.

Kwoka, J. and M. Pollitt (2010). "Do mergers improve efficiency? Evidence from restructuring the US electric power sector". *International Journal of Industrial Organization* 28.6, pp. 645–656.

Kwoka, J. E. (2002). "Vertical economies in electric power: evidence on integration and its alternatives". *International Journal of Industrial Organization* 20.5, pp. 653–671.

Laffont, J.-J. and J. Tirole (1993). *A theory of incentives in procurement and regulation*. Cambridge, MA: MIT press. Chap. Privatization and incentives.

Lam, P.-L. and A. Shiu (2004). "Efficiency and productivity of China's thermal power generation". *Review of Industrial Organization* 24.1, pp. 73–93.

Lattimore, P. and A. Witte (1986). "Models of decision making under uncertainty: The criminal choice". *The Reasoning Criminal*. Ed. by D. B. Cornish and

R. V. Clarke. New Brunswick, NJ and London, United Kingdom: Transaction Publishers, pp. 129–155.

Lee, J., J. S. McCullough, and R. J. Town (2013). "The impact of health information technology on hospital productivity". *RAND Journal of Economics* 44.3, pp. 545–568.

Levinsohn, J. and A. Petrin (2003). "Estimating Production Functions Using Inputs to Control for Unobservables". *Review of Economic Studies* 70.2, pp. 317–341.

Lu, S. F. and G. J. Wedig (2013). "Clustering, agency costs and operating efficiency: Evidence from nursing home chains". *Management Science* 59.3, pp. 677–694.

Maican, F. and M. Orth (2015). "A dynamic analysis of entry regulations and productivity in retail trade". *International Journal of Industrial Organization* 40, pp. 67–80.

Martimort, D. and J. Pouyet (2008). "To build or not to build: Normative and positive theories of public–private partnerships". *International Journal of Industrial Organization* 26.2, pp. 393–411.

Megginson, W. L. and J. M. Netter (2001). "From state to market: A survey of empirical studies on privatization". *Journal of Economic Literature* 39.2, pp. 321–389.

Mundlak, Y. (1961). "Empirical production function free of management bias". *Journal of Farm Economics* 43.1, pp. 44–56.

MVA Weisweiler GmbH & Co. KG (2007). *Jahresabschluss 2007*. Bundesanzeiger.

Nemoto, J. and M. Goto (2004). "Technological externalities and economies of vertical integration in the electric utility industry". *International Journal of Industrial Organization* 22.1, pp. 67–81.

Ohlsson, H. (2003). "Ownership and production costs: choosing between public production and contracting-out in the case of Swedish refuse collection". *Fiscal Studies* 24.4, pp. 451–476.

Olley, G. and A. Pakes (1996). "The Dynamics of Productivity in the Telecommunications Equipment Industry". *Econometrica* 64.6, pp. 1263–1297.

Parrotta, P. and D. Pozzoli (2012). "The effect of learning by hiring on productivity". *RAND Journal of Economics* 43.1, pp. 167–185.

Polinsky, A. M. and S. Shavell (2007). "The theory of public enforcement of law". *Handbook of Law and Economics*. Ed. by A. M. Polinsky and S. Shavell. Amsterdam, Netherlands: Elsevier, pp. 403–454.

Rand, T., J. Haukohl, U. Marxen, and W. Bank (2000). *Municipal Solid Waste Incineration: Requirements for a Successful Project*. World Bank Technical Paper 23-462. Washington, DC: World Bank.

Rau, N. (2010). *Kampf dem Abfall*. Deutschlandfunk. URL: http://www.deutschlandfunk.de/kampf-dem-abfall.697.de.html?dram:article_id=77438 (visited on 07/26/2017).

Ray, S. C. (1991). "Resource-use efficiency in public schools: A study of Connecticut data". *Management Science* 37.12, pp. 1620–1628.

Reeves, E. and M. Barrow (2000). "The impact of contracting out on the costs of refuse collection services: The case of Ireland". *Economic and Social Review* 31.2, pp. 129–150.

Schmitz, P. W. (2001). "Partial privatization and incomplete contracts: the proper scope of government reconsidered". *FinanzArchiv: Public Finance Analysis* 57.4, pp. 394–411.

— (2015). "Government versus private ownership of public goods: The role of bargaining frictions". *Journal of Public Economics* 132, pp. 23–31.

Schulze Wehninck, R. (2008). *Public Private Partnerships und Wettbewerb – Eine theoretische Analyse am Beispiel der kommunalen Abfallentsorgung*. Wiesbaden, Germany: Gabler.

Shorkey, C. T. and S. B. Crocker (1981). "Frustration theory: a source of unifying concepts for generalist practice". *Social Work* 26.5, pp. 374–379.

Simar, L. and P. W. Wilson (2007). "Estimation and inference in two-stage, semi-parametric models of production processes". *Journal of Econometrics* 136.1, pp. 31–64.

Simões, P. and R. C. Marques (2012). "On the economic performance of the waste sector. A literature review". *Journal of Environmental Management* 106, pp. 40–47.

Sørensen, R. (2007). "Does public ownership impair efficiency? The case of refuse collection in Norway". *Public Administration* 85, pp. 1045–1058.

SPIEGEL ONLINE (2008). *Von Aachen bis Zwickau: So teuer ist Müll in Deutschland*. SPIEGEL ONLINE and www.verivox.de. URL: http://www.spiegel.de/wirtschaft/von-aachen-bis-zwickau-so-teuer-ist-muell-in-deutschland-a-564920.html (visited on 07/27/2016).

SRS Ecotherm GmbH (2014). *Jahresabschluss 2014*. Bundesanzeiger.

Statistisches Bundesamt (2017). *Aufkommen an Haushaltsabfällen: Bundesländer, Jahre, 2015*. Code 32121-0002. DESTATIS.

Stevens, B. J. (1978). "Scale, Market Structure, and the Cost of Refuse Collection". *Review of Economics and Statistics* 60.3, pp. 438–448.

Su, D. and X. He (2012). "Ownership structure, corporate governance and productive efficiency in China". *Journal of Productivity Analysis* 38.3, pp. 303–318.

Sueyoshi, T. and M. Goto (2012). "Data envelopment analysis for environmental assessment: comparison between public and private ownership in petroleum industry". *European Journal of Operational Research* 216.3, pp. 668–678.

Sueyoshi, T., Y. Yuan, and M. Goto (2017). "A literature study for DEA applied to energy and environment". *Energy Economics* 62, pp. 104–124.

Syverson, C. (2011). "What determines productivity?" *Journal of Economic Literature* 49.2, pp. 326–365.

Takahashi, S. (2011). "How Multi-Tasking Job Designs Affect Productivity: Evidence from the Australian Coal Mining Industry". *Industrial and Labor Relations Review* 64.5, pp. 841–862.

Tauchmann, H. (2016). *SIMARWILSON: Stata module to perform Simar & Wilson efficiency analysis*. Statistical Software Components S458156, Boston College Department of Economics.

Thiel, S. (2013). "Energie aus Abfall". Ed. by K. J. Thomé-Kozmiensky and M. Beckmann. Band 10. Neuruppin, Germany: TK-Verlag. Chap. Ersatzbrennstoff-Kraftwerke in Deutschland und Österreich, pp. 837–852.

Umweltbundesamt (2016). *Landfill*. URL: http://www.umweltbundesamt.de/en/topics/waste-resources/waste-disposal/landfill (visited on 03/27/2017).

Verivox (2008). *Müllgebühren schwanken bundesweit über 500 Prozent*. Verivox GmbH. URL: http://www.verivox.de/presse/muellgebuehren-schwanken-bundesweit-ueber-500-prozent-37401.aspx (visited on 11/25/2016).

Villalonga, B. (2000). "Privatization and efficiency: differentiating ownership effects from political, organizational and dynamic effects". *Journal of Economic Behavior & Organization* 42, pp. 43–74.

Williams, O. E. (1985). *The Economic Institutions of Capitalism: Firms, Markets, Relational Contracting*. New York, NY: The Free Press.

Williamson, O. E. (1993). "Transaction cost economics and organization theory". *Industrial Corporate Change* 2, pp. 107–156.

Wilts, H. (2012). "Waste to Energy". Ed. by A. Karagiannidis. London, United Kingdom: Springer. Chap. The ambiguous relation between waste incineration and waste prevention.

Eidesstattliche Versicherung

Ich, Maria FRIESE, versichere an Eides statt, dass die vorliegende Dissertation von mir selbstständig und ohne unzulässige fremde Hilfe unter Beachtung der "Grundsätze zur Sicherung guter wissenschaftlicher Praxis" an der Heinrich-Heine-Universität Düsseldorf erstellt worden ist.

Düsseldorf, der 07. September 2017

_____

Unterschrift