Dresden University of Technology
Faculty of Business and Economics
Chair of Energy Economics and
Public Sector Management

Efficiency and Competition in Public Transport

Dissertation
Final Version
Submitted in Partial Fulfillment of the Requirements for the Degree of
Dr. rer. pol.

by

Dipl.-Wi.-Ing.
Matthias Walter
Date of Birth: 29 May 1981

Date of Submission: 23 October 2009
Date of Disputation: 2 February 2010

1. Reviewer and Supervisor: Prof. Dr. Christian von Hirschhausen
2. Reviewer: Prof. Dr. Bernhard Wieland
Acknowledgements

First and foremost I thank Christian von Hirschhausen for the opportunity to write a dissertation about public transport. I have always appreciated the working conditions laid out at the Chair of Energy Economics and Public Sector Management (EE²) and could never imagine a better setup to conduct this dissertation project in an adequate work-life balance. Needless to say that the atmosphere was also demanding and stimulating, but most importantly it was a lot of fun.

I also thank Stephan Bauer who called my attention to the Chair of Energy Economics and Public Sector Management and who facilitated a first contact. Special thanks go to Astrid Cullmann who introduced me to empirical methods in a way that made me really work with these methods. Part of the success of this thesis have also to be accredited to the congenial atmosphere at EE² with many dear colleagues and students: Anne, Borge, Fabian, Florian, Hannes, Jan, Johannes, Jonas, Juliane, Katrin, Martin, Martina, Maria, Marika, Markus, Marlen, Micha, Robert, René, Sophia, Tina, Tobias ... (those I forgot are as a matter of course included). Thanks also to Ann Stewart for language assistance. I am especially grateful for the beneficial comments received from experts such as Per Agrell, Arne Beck, Peter Bogetoft, Harold Fried, Subal Kumbhakar, David Saal, ...

I thank my parents for their unrestricted support in everything I do and Sina Gerdes for living our “Dresden adventure” together. Very special thanks go also to some of my best friends from Karlsruhe: Together we successfully mastered the transportation courses: Torsten Naue, Thomas Peschl, and Ulrich Westerkamp - funny how we’ve seem to made it!
Abstract

Bus and other road-bound services like tram and light railway are the backbone of the German local public transport sector. Based on the characterization of high deficits and fragmentation, five main research questions and hypotheses are investigated in this dissertation. First, advanced Stochastic Frontier models which account for unobserved heterogeneity and heterogeneous output variables are used to study cost efficiency and its determinants such as the vehicle utilization rate. Second, economies of scale and scope are evaluated. Third, based on the finding of substantial economies of scale, potential gains from hypothetical mergers are calculated using Data Envelopment Analysis. Fourth, I focus on competitive tendering, another option to increase efficiency in this sector. Analyzing operator changes, I find in majority regional bus services tendered out and structural conditions significantly increasing the probability for operator changes, like tendering in bigger volumes. Fifth, internal and external cost advantages for express coach services as a diversification option for public transport are confirmed. In conclusion, the results of my research are relevant to the strategic decision process of firm management as well as regulators.
Contents

List of Figures ix
List of Tables xi
List of Abbreviations xiii

I Overview 1

1 Overview 3
  1.1 The Issue ............................................. 3
  1.2 Sector Consideration .................................. 5
    1.2.1 Public Transport .................................. 5
    1.2.2 Public Road Transport in Germany ................. 6
  1.3 Modern Efficiency Analysis Applied to Local Public Transport 13
    1.3.1 Outline of Literature ................................. 13
    1.3.2 DEA Single-Product Applications .................... 15
    1.3.3 Econometric Single-Output Applications .......... 20
    1.3.4 SFA Applications with Focus on Regulatory Contracts 23
    1.3.5 Empirical Multi-Output Applications ................. 27
    1.3.6 Recommendations ................................... 29
  1.4 Structure of the Thesis ................................ 30
    1.4.1 Contribution Part II: Efficiency ................... 30
    1.4.2 Contribution Part III: Competition ................ 33
    1.4.3 Concluding Remarks ................................. 34

II Efficiency 35

2 Cost Efficiency and Some of its Determinants 37
  2.1 Introduction .......................................... 37
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.2</td>
<td>Methodology</td>
<td>38</td>
</tr>
<tr>
<td>2.2.1</td>
<td>Cost Function</td>
<td>38</td>
</tr>
<tr>
<td>2.2.2</td>
<td>Econometric Models</td>
<td>40</td>
</tr>
<tr>
<td>2.3</td>
<td>Data</td>
<td>43</td>
</tr>
<tr>
<td>2.4</td>
<td>Results and Interpretation</td>
<td>47</td>
</tr>
<tr>
<td>2.4.1</td>
<td>Regression Results</td>
<td>47</td>
</tr>
<tr>
<td>2.4.2</td>
<td>Efficiencies</td>
<td>50</td>
</tr>
<tr>
<td>2.5</td>
<td>Conclusion</td>
<td>53</td>
</tr>
<tr>
<td>3</td>
<td>Economies of Scale and Scope</td>
<td>55</td>
</tr>
<tr>
<td>3.1</td>
<td>Introduction</td>
<td>55</td>
</tr>
<tr>
<td>3.2</td>
<td>Model Specification and Econometric Methods</td>
<td>57</td>
</tr>
<tr>
<td>3.3</td>
<td>Definition of Economies of Scale and Scope</td>
<td>61</td>
</tr>
<tr>
<td>3.4</td>
<td>Data</td>
<td>63</td>
</tr>
<tr>
<td>3.5</td>
<td>Results and Interpretation</td>
<td>64</td>
</tr>
<tr>
<td>3.5.1</td>
<td>Regression Results</td>
<td>64</td>
</tr>
<tr>
<td>3.5.2</td>
<td>Economies of Scale and Scope for Representative Output Levels</td>
<td>65</td>
</tr>
<tr>
<td>3.5.3</td>
<td>Economies of Scale and Scope for Real Firms</td>
<td>68</td>
</tr>
<tr>
<td>3.6</td>
<td>Conclusion</td>
<td>69</td>
</tr>
<tr>
<td>4</td>
<td>Potential Gains from Mergers</td>
<td>71</td>
</tr>
<tr>
<td>4.1</td>
<td>Introduction</td>
<td>71</td>
</tr>
<tr>
<td>4.2</td>
<td>Methodology</td>
<td>73</td>
</tr>
<tr>
<td>4.2.1</td>
<td>Data Envelopment Analysis</td>
<td>73</td>
</tr>
<tr>
<td>4.2.2</td>
<td>Decomposing Merger Gains</td>
<td>74</td>
</tr>
<tr>
<td>4.2.3</td>
<td>Bias Correction with Bootstrapping</td>
<td>77</td>
</tr>
<tr>
<td>4.3</td>
<td>Data and Model Specification</td>
<td>79</td>
</tr>
<tr>
<td>4.3.1</td>
<td>Data Set</td>
<td>79</td>
</tr>
<tr>
<td>4.3.2</td>
<td>Model</td>
<td>80</td>
</tr>
<tr>
<td>4.3.3</td>
<td>Mergers</td>
<td>81</td>
</tr>
<tr>
<td>4.4</td>
<td>Results and Interpretation</td>
<td>82</td>
</tr>
<tr>
<td>4.4.1</td>
<td>Average Efficiencies for the Unmerged Firms</td>
<td>82</td>
</tr>
<tr>
<td>4.4.2</td>
<td>Merger Gains under Variable and Constant Returns to Scale</td>
<td>84</td>
</tr>
<tr>
<td>4.4.3</td>
<td>Merger Gains with/without Incorporating Differences in the Production of Tram and Light Railway Services</td>
<td>85</td>
</tr>
<tr>
<td>4.4.4</td>
<td>Alternative Decompositions of Synergy and Size Gains</td>
<td>85</td>
</tr>
<tr>
<td>4.5</td>
<td>Conclusion</td>
<td>90</td>
</tr>
</tbody>
</table>
## III  Competition

### 5  Operator Changes through Competitive Tendering  93

5.1  Introduction  

5.2  Sector and Tenders  

5.2.1  Theoretical and Regulatory Framework  

5.2.2  Data  

5.3  Empirical Analysis  

5.3.1  Change in Concession Ownership  

5.3.2  Probit Estimation  

5.4  Conclusion  

### 6  Prospects of Express Coach Services  111

6.1  Introduction  

6.2  Selected International Express Coach Experience  

6.2.1  International Literature on Express Coach Services  

6.2.2  Market Shares, Turnover Figures, and Profitability  

6.3  German Situation  

6.3.1  Regulatory Barriers to Market Entry  

6.3.2  Diversification Opportunities for Public Transport Companies  

6.4  Analysis of External and Internal Costs  

6.5  Market Share Estimation  

6.5.1  Methodology: Conjoint Analysis  

6.5.2  Questionnaire and Sample  

6.5.3  Market Share Results  

6.6  Conclusion  

### Appendix  125

#### A  Program Code  127

A.1  LIMDEP Code for Chapter 2  

A.2  LIMDEP Code for Chapter 3  

A.3  R Code for Chapter 4  

A.4  STATA Code for Chapter 5  

### Bibliography  147
# List of Figures

1.1 Strategic player analysis of the German bus market .......................... 11
1.2 Returns to scale and orientation in DEA ................................. 17

2.1 Comparison of efficiency predictions ........................................ 52
2.2 Kernel density of efficiency predictions ...................................... 53

4.1 Geography of local public transport mergers in Nordrhein-Westfalen .......................................................... 83
4.2 Bias-corrected merger gains decomposition for variable returns to scale without structural variables (Model 1) ........................................ 87
4.3 Bias-corrected merger gains decomposition for variable returns to scale with tram index (Model 3) ........................................ 88

5.1 Structure of bus tenders .............................................................. 97
5.2 Competition intensity over time .................................................. 100

6.1 Operating profit margin of express coach market leaders in the UK, Sweden, and the US ......................................................... 115
6.2 External costs in long-distance passenger traffic under consideration of different operating grades .................................................. 119
6.3 Internal and external costs in long-distance passenger traffic considering different operating grades ............................................... 120
6.4 Market shares in long-distance passenger traffic for routes of 300 km length ............................................................... 123
6.5 Market shares for the scenario of lower network coverage differentiated by income and age ...................................................... 124
## List of Tables

1.1 DEA single-product local public transport study survey ........................................ 18
1.2 Econometric single-output local public transport studies ......................................... 21
1.3 SFA local public transport studies with focus on regulatory contracts ............................. 25
1.4 Empirical multi-output local public transport studies ............................................. 28

2.1 Descriptive statistics for multi-product companies ...................................................... 44
2.2 Data correlations .......................................................................................................... 46
2.3 Regression results for the translog cost function .......................................................... 48
2.4 Descriptive efficiencies ................................................................................................. 50
2.5 Efficiency correlations ................................................................................................. 51
2.6 Rank correlations .......................................................................................................... 52
2.7 Efficiency comparisons and Kruskal-Wallis tests .......................................................... 54

3.1 Data structure: observations .......................................................................................... 63
3.2 Descriptive statistics for bus and multi-product companies .......................................... 65
3.3 Regression results for the quadratic cost function ......................................................... 66
3.4 Economies of scale and scope for representative output levels ..................................... 67
3.5 Economies of scale and scope for real companies ......................................................... 69

4.1 Possible input-output specifications .............................................................................. 80
4.2 Average efficiency estimates with seat-kilometers as output ........................................ 84
4.3 Decomposition of bias-corrected potential merger effects for variable and constant returns to scale (Model 1) .......................................................... 86
4.4 Evaluation of bias-corrected synergy and size effects for variable returns to scale ................ 89

5.1 Descriptive statistics for 196 tendered batches .............................................................. 99
5.2 Batch migration matrix ................................................................................................. 101
5.3 Vehicle-km migration matrix ......................................................................................... 102
5.4 Probit regression results of structural variables on operator changes .......................... 103
5.5 Additional probit regression results with combined variables .......................... 106
# List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>AG</td>
<td>Aktiengesellschaft</td>
</tr>
<tr>
<td>BEA</td>
<td>Bureau of Economic Analysis (in the US)</td>
</tr>
<tr>
<td>bn</td>
<td>billion</td>
</tr>
<tr>
<td>BSAG</td>
<td>Bremer Straßenbahnen AG</td>
</tr>
<tr>
<td>BT</td>
<td>Berlin Transport</td>
</tr>
<tr>
<td>BVG</td>
<td>Berliner Verkehrsbetriebe</td>
</tr>
<tr>
<td>CATV</td>
<td>cable television</td>
</tr>
<tr>
<td>CBMS-NSF</td>
<td>Conference Board of the Mathematical Sciences-National Science Foundation</td>
</tr>
<tr>
<td>CE</td>
<td>cost efficiency</td>
</tr>
<tr>
<td>CORE</td>
<td>Center for Operations Research and Econometrics (Université catholique de Louvain)</td>
</tr>
<tr>
<td>CRS</td>
<td>constant returns to scale</td>
</tr>
<tr>
<td>DB</td>
<td>Deutsche Bahn</td>
</tr>
<tr>
<td>DEA</td>
<td>Data Envelopment Analysis</td>
</tr>
<tr>
<td>DGP</td>
<td>data generating process</td>
</tr>
<tr>
<td>DMU</td>
<td>decision making unit</td>
</tr>
<tr>
<td>DVB</td>
<td>Dresdner Verkehrsbetriebe</td>
</tr>
<tr>
<td>EC</td>
<td>European Community</td>
</tr>
<tr>
<td>Ed.</td>
<td>editor</td>
</tr>
<tr>
<td>edn.</td>
<td>edition</td>
</tr>
<tr>
<td>EEC</td>
<td>European Economic Community</td>
</tr>
<tr>
<td>ETH</td>
<td>Eidgenössische Technische Hochschule</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>EWEPA</td>
<td>European Workshop on Efficiency and Productivity Analysis</td>
</tr>
<tr>
<td>FDH</td>
<td>Free Disposal Hull</td>
</tr>
<tr>
<td>FE</td>
<td>Fixed Effects</td>
</tr>
<tr>
<td>FTE</td>
<td>full-time equivalent</td>
</tr>
<tr>
<td>GERNER</td>
<td>German network regulation</td>
</tr>
<tr>
<td>GWF</td>
<td>Gas- und Wasserfach</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Full Form</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------</td>
</tr>
<tr>
<td>HERMES</td>
<td>Higher Education and Research on Mobility Regulation and the Economics of Local Services</td>
</tr>
<tr>
<td>HHA</td>
<td>Hamburger Hochbahn AG</td>
</tr>
<tr>
<td>HVV</td>
<td>Hamburger Verkehrsverbund</td>
</tr>
<tr>
<td>ICB</td>
<td>In-der-City-Bus</td>
</tr>
<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers</td>
</tr>
<tr>
<td>INVERMO</td>
<td>Intermodale Vernetzung</td>
</tr>
<tr>
<td>LA</td>
<td>licensing authority</td>
</tr>
<tr>
<td>LSVB</td>
<td>Leipziger Stadtverkehrsvertriebe</td>
</tr>
<tr>
<td>LVB</td>
<td>Leipziger Verkehrsbetriebe</td>
</tr>
<tr>
<td>m</td>
<td>million</td>
</tr>
<tr>
<td>MA</td>
<td>Massachusetts</td>
</tr>
<tr>
<td>MIT</td>
<td>motorized individual transport</td>
</tr>
<tr>
<td>mm</td>
<td>millimeter</td>
</tr>
<tr>
<td>MVG</td>
<td>Münchner Verkehrsgesellschaft</td>
</tr>
<tr>
<td>MVV</td>
<td>Münchner Verkehrsverbund</td>
</tr>
<tr>
<td>NIRS</td>
<td>non-increasing returns to scale</td>
</tr>
<tr>
<td>NSB</td>
<td>Norges Statsbaner/Norwegian State Railways</td>
</tr>
<tr>
<td>NY</td>
<td>New York (state)</td>
</tr>
<tr>
<td>obs.</td>
<td>observations</td>
</tr>
<tr>
<td>OLS</td>
<td>ordinary least squares</td>
</tr>
<tr>
<td>ÖSPV</td>
<td>Öffentlicher Straßenpersonennahverkehr</td>
</tr>
<tr>
<td>PTA</td>
<td>passenger transport authority</td>
</tr>
<tr>
<td>RE</td>
<td>Random Effects</td>
</tr>
<tr>
<td>RegG</td>
<td>Regionalisierungsgesetz</td>
</tr>
<tr>
<td>RES</td>
<td>Resvaneundersökningen/Swedish travel survey</td>
</tr>
<tr>
<td>RMV</td>
<td>Rhein-Main Verkehrsverbund</td>
</tr>
<tr>
<td>RP</td>
<td>Random Parameter</td>
</tr>
<tr>
<td>rrp</td>
<td>rhein ruhr partner(-Verkehr)</td>
</tr>
<tr>
<td>SDEA</td>
<td>Stochastic Data Envelopment Analysis</td>
</tr>
<tr>
<td>SFA</td>
<td>Stochastic Frontier Analysis</td>
</tr>
<tr>
<td>SGB</td>
<td>Sozialgesetzbuch</td>
</tr>
<tr>
<td>SJ</td>
<td>Statens Järnvägar/Swedish Railways</td>
</tr>
<tr>
<td>SME</td>
<td>small- and medium-sized enterprises</td>
</tr>
<tr>
<td>STOAG</td>
<td>Stadtwerke Oberhausen AG</td>
</tr>
<tr>
<td>SUR</td>
<td>seemingly unrelated regression</td>
</tr>
<tr>
<td>TED</td>
<td>Tenders Electronic Daily</td>
</tr>
<tr>
<td>TEN-T</td>
<td>Trans-European Transport Network</td>
</tr>
<tr>
<td>TFP</td>
<td>total factor productivity</td>
</tr>
<tr>
<td>TRE</td>
<td>True Random Effects</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Full Form</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------</td>
</tr>
<tr>
<td>UIC</td>
<td>Union Internationale des Chemins de Fer/International Union of Railways</td>
</tr>
<tr>
<td>UK</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>US</td>
<td>United States</td>
</tr>
<tr>
<td>VDV</td>
<td>Verband Deutscher Verkehrsunternehmen</td>
</tr>
<tr>
<td>VGF</td>
<td>Verkehrsgesellschaft Frankfurt</td>
</tr>
<tr>
<td>vol.</td>
<td>volume</td>
</tr>
<tr>
<td>VRS</td>
<td>variable returns to scale</td>
</tr>
<tr>
<td>WLS</td>
<td>weighted least squares</td>
</tr>
</tbody>
</table>
Part I

Overview
Chapter 1

Overview

1.1 The Issue

As a student of Business Engineering at the University of Karlsruhe, I had to develop a sectoral focus by choosing an engineering minor. My choice was Transportation, offered by the Institute for Transportation of Prof. Zumkeller at the Department of Civil Engineering, Geo- and Environmental Sciences. Although I was not able to take the economic counterpart courses at the Institute for Economic Policy Research, Sector Transportation and Communication, Prof. Rothengatter accredited my environmental, public, and macroeconomic courses taken at Lund University, Sweden. After one more seminar about the Trans-European Transport Network (TEN-T), I wrote my diploma thesis at his institute about European railway reforms.

My engagement with the sector could have led directly to a career in transport. However, I wanted to gain experience in other sectors. The best possibility appeared to be strategy consulting, in my case at Booz Allen Hamilton. After two extensive projects in media (for an information service provider and publisher) and the public sector (for a pension insurance company), I was given the opportunity to work in the transportation sector again. Evaluating the strategic long-term options for railway reorganization in a European country was so appealing that I felt getting to know other sectors was no longer necessary. Hence, I took the initiative and tried to get engaged in a new transport project. The first was not carried out because the client, a provider of regional railway services, no longer wanted to work with us. The second, with an airline, was carried out, but without me, because my project manager left the company. The third, with a transportation systems manufacturer, was postponed. I became somewhat anxious, because I knew that they were intensively looking for consultants on a big project for a mobile phone service provider. So the last chance was a project
proposal which I co-presented in the *Federal Ministry of Transport, Building and Urban Affairs*. We lost and my way for the next few months led to the mobile phone service provider.

I decided to apply for a new job where I could focus and do fundamental and strategic research on transport. Hence I hesitated to apply for a research position at the Chair of *Energy Economics* and Public Sector Management at Dresden University of Technology. But I was told that I could solely focus on public transport research. How did it work out? I became the project manager for the Chair in the *GERNER IV* project (Agrell et al., 2008a,b,c). In this project, efficiency scores for the incentive regulation of gas transmission companies as well as gas and electricity distribution companies in Germany were calculated. My first paper published in a refereed journal was on benchmarking of water companies (Walter et al., 2009a).¹ At first glance, this may not look like a focus on transportation, and not at all like a *pure* focus on transportation.

But, most important, I have to confess that this is the introduction to my dissertation about efficiency and competition in public transport. To happily resolve this story: There must have been a focus on research in transportation economics in the past, and this focus is presented in the following thesis. Just like other sectors, public transport is affected by the financial crisis. Although there is uncertainty about the concrete effects, budgets will become far more restrictive for German urban public transport, as it is dominated by subsidized firms under municipal ownership. The major provider of regional bus services, DB Stadtverkehr, will be affected by the struggles its mother company faces in the sharp decline in freight transport. And all companies may have financing problems during the global credit crunch.

Summarizing the situation, the problems public transport faces will be intensified. Unfortunately the sector lacks an appropriate regulation which could give some guidelines for the strategic development of firms. A goal of this thesis is to analyze the sector’s characteristics, providing scientific and economic evidence that can support strategic decision-making and effective regulation. Based on empirical methods, the thesis finds one of its motivation points in the low level of cost coverage across nearly all companies with a mean level of 73.8% (Verband Deutscher Verkehrsunternehmen, 2008). This is still a very high estimate, since it includes all non-user related transfers to the companies. Efficiency analysis is used to calculate cost efficiency over a panel of several hundred public road transport companies from 1997 until 2006. To provide some evidence for the management of local public transport companies, attention is paid to the evaluation of two possible efficiency determinants: vehicle utilization rate and

¹Engagement with the water sector resulted in other publications; see Hirschhausen et al. (2009a,b).
outsourcing share. Another motivating factor is the high fragmentation: There are several hundred operators in the German market and nearly every city has its own provider. Hence it appears necessary to evaluate possible economies of scale and scope, and to propose and evaluate mergers. The European Union has already provided a renewed overall framework via regulation (EC) No 1370/2007. Competitive tendering for bus services is so far only used in Hessen (Hesse) and around Hamburg and München, but the question remains whether the design of these tenders is optimal. Other legislation such as the Passenger Transport Act (Personenbeförderungsgesetz – PBefG) contains some antiquated rules, e. g., the obstruction of regular express coach services. Therefore, a final motivating factor of this thesis is to evaluate the economics of current regulation and to show the necessity for change.

The thesis is organized as follows. Chapter 1 gives an overview. Section 1.2 is devoted to the local public transport sector, Section 1.3 introduces the main methodology, scientific efficiency analysis, with a comparative review of the literature. Section 1.4 is dedicated to the detailed structure and summary of the following chapters as well as the contribution of this dissertation. Chapters 2 and 3 (Part II – Efficiency) apply Stochastic Frontier Analysis (SFA) to the German local public transport sector, and Chapter 4 applies Data Envelopment Analysis (DEA). Part III (Competition) applies econometrics to competitive tendering in German local bus transport (Chapter 5) and to the prospects of express coach services in Germany (Chapter 6). Each chapter ends with concluding remarks.

1.2 Sector Consideration

1.2.1 Public Transport

Mobility is seen as one key element of the prosperity of our society. The demand for mobility is satisfied by both individual transport and public transport. Through technological progress and tariff enhancements, public transport has a unique role in increasing mobility. Public transport has even positive side-effects on individual transport through avoiding congestion on roads and parking lots (Parry and Small, 2009).

Public transport can be classified into long-distance passenger transport, served by aircrafts, buses, ferries, and railways, and local public transport (Öffentlicher Personennahverkehr – ÖPNV), served by buses, ferries, railways, taxis, and all types of aerial cableways, light railways, subway, and tramways. In Germany rail operations in local public transport are called regional rail services (Schienenpersonennahverkehr – SPNV). This includes suburban rail services (S-Bahn). Bus, aerial cableway, light railway, subway, and tram operations fall
under the category of road-bound local public transport, or public road transport (Öffentlicher Straßenpersonennahverkehr – ÖSPV).

Politics plays a major role in public transport. Public service obligations (Daseinsvorsorge), regulatory approval, and the peculiarities associated with certain types of infrastructure are all subject to public debate. Regarding the high public sector infrastructure investments, mobility is suspected to be subsidized by the society. Some members of society may also believe that public transport is, in fact, subsidized too much, forgetting that the provision of local transport services serves as a social right for the sector’s existence. It is true, however, that transport services are often not as cost-efficient as possible.

During the 20th century Western Europe developed unique, complex, and capacious local public transport systems, perhaps only mirrored by Japan. There are some characteristic differences among countries. These differences, for example, result from regulation, ownership, or market structure. The United Kingdom is a popular subject for liberalization and deregulation studies, whereupon experts often warn against immediate imitation. Sweden has long been at the forefront of competitive tendering. Italy faces financial pressure on losses occurring in local public transport, like so many countries. France is criticized for its foreclosure. Switzerland retains the federal thought, particularly for transport policy.

The European Union greatly influences change in this sector. Regulators hope that local public transport will help to mitigate climate change. However, Europe’s transport sector lags behind in reaching the targets set by the Kyoto protocol. The EU is also concerned about the impacts of demographic changes upon long-term transport planning. Competition concerns are raised through financing and awarding problems. The concerns, the framework, and the structure of public road transport in Germany are the subject to the next subsection.

1.2.2 Public Road Transport in Germany

The Regulatory Framework

Germany’s federal Passenger Transport Act provides the commercial principles for the provision of road-bound transport services that use trams, trolley-buses, and motor vehicles. Local public transport is defined as urban and regional transportations with a journey distance not exceeding 50 kilometer or a journey time not exceeding one hour in the majority of passenger transportations (§

\[\text{\footnotesize Additionaly, the German Ordinance on the Construction and Operation of Rail Systems for Light-Rail-Transit (Verordnung über den Bau und Betrieb der Straßenbahnen (Straßenbahn-Bau- und Betriebsordnung – BOStrab)) governs tram, light railway, and metro operations.}\]
Section 1 PBefG). From a legal view, the PBefG generally assumes that the provision of transport services occurs at a company’s own risk (§ 8 Section 4 PBefG and Verband Deutscher Verkehrsunternehmen, 2007a). This is why it is also called commercial transportation (Eigenwirtschaftlicher Verkehr), as distinguished from non-commercial transportation (Gemeinwirtschaftlicher Verkehr, § 13a PBefG).

Both types of transportation can require subsidies, but non-commercial transportation services receive direct subsidies which are not assessed as other operational revenues (Beck, 2009). According to the PBefG, the basic market access for commercial transportation occurs during the licensing application process. Should several companies apply for similar routes, this is called license competition (Genehmigungswettbewerb). To protect incumbents and the railways, the PBefG specifies some limitations. For example, a concession for a new passenger service will not be granted when an existing operator already serves actual demand. Even if the new service is of superior quality, the law states that the existing operator or operators must first be allowed to offer a comparable service (§ 13 Section 2 no. 2. b) and c) PBefG). This provision functions as the major legal barrier for express coach services, because Germany’s dense railway network makes it almost impossible to establish express coach routes formerly not served by railways.

In the legal exception of non-commercial transportation, the public transport authority (PTA – Aufgabenträger) procures the transportation service and the European Regulation in force applies. Until recently this has been regulation (EEC) No 1191/1969 and its amendment 1893/91, which require subsidized services to be tendered out.

In Germany, the Altmark Trans decision is a famous legal dispute concerning the legality of subsidies. The European Court of Justice 2003 issued a judgment that the following conditions must be satisfied for subsidies to comply with European law:

1. The recipient operator has a clearly defined public service obligation.
2. The compensation criteria and parameters have been clearly and objectively established.
3. The compensation just covers cost plus a reasonable profit margin.

\textsuperscript{3}Parts of this subsection draw on Augustin and Walter (2009) and Walter et al. (2009b).
\textsuperscript{4}The railway density in Germany reaches almost 100 kilometers per 1000 km\textsuperscript{2} area, but only half this value averaged for the entire European Union (calculation based on data from Eurostat and Railisa UIC Statistics Database).
\textsuperscript{5}A transportation company either applies for the right for a service at the licensing authority (LA – Genehmigungsbehörde) or participates in a tender process initiated by the PTA.
\textsuperscript{6}European Court of Justice, 24 July 2003, Case C-280/00.
4. If competitive tendering is not used, the compensation must be equivalent to a well run and adequately provided transportation company.

Direct awards, still representing the vast majority of service assignment in Germany, fall under commercial transportation, at least from a legal point of view. The latest regulation (EC) No 1370/2007 which took effect on 3 December 2009 provides detailed rules for transparent, fair competitive award procedures. It strives to stimulate competition in public passenger transport through compulsory competitive tendering, but it also allows for exceptions. It implies no obligation for competitive tendering:

- as long as the transportation company is under control of a transportation authority (Article 5 Section 2) and is not active outside the authority’s area of responsibility (principle of reciprocity; Article 5 Section 2 (b));

- or

- if the value of the service contract is less than one million EUR or the annual passenger kilometers are less than 300 000 (Article 5 Section 4).

Nevertheless, the duration of all contracts is limited to ten years (15 years in case of an extension) (Article 4 Section 6). In Germany there is a legal obligation to provide local public transport services. Therefore, the licensing authority must collaborate with the public transport authority and the public transport companies. Sufficient transport services under an economical regime must be achieved through cooperation, integration of fares, and timetable matching (§ 8 Section 3 PBefG). Enforcement is delegated to the federal states through the Law on the Regionalization of Public Transport (Regionalisierungsgesetz – RegG)\(^7\), which states that serving the population with local public transport services is a public service obligation (§ 1 RegG).

One consequence of regionalization is that several different policies now regulate local public transport. For regional rail services, competitive tendering is used throughout the country, although the incumbent, DB Regio, still holds a high market share. The use of competitive tendering in public road transport differs from state to state. The most common scenario is that competitive tendering goes unused; Hessen is the only federal state that has made competitive tendering (Ausschreibungswettbewerb) for non-commercial services compulsory, announced in 2002. First price auctions with bids in closed envelopes are usually used, where awards are articulated after one bid trial without negotiations (Beck, 2009). Normally gross-cost contracts are used. In this case, the provider

---

\(^7\)Gesetz zur Regionalisierung des öffentlichen Personennahverkehrs, notably a two-page law with only six articles.
bears the production risk and the authority bears the revenue risk. Net-cost contracts, under which both risks are borne by the provider, have rarely been used. Both gross-cost contracts and net-cost contracts are variants of fixed-price contracts (Roy and Yvrande-Billon, 2007). Management contracts, under which both risks are born by the authority, correspond to cost-plus contracts.

The gross-cost contracts used in Hessen include constructive and functional elements in the service specification (Achenbach, 2006). Constructive elements describe the service provision in detail. The provider has little freedom of action. Functional elements only define the targets, and the applicant must propose how it plans to achieve them. The contracts contain price escalation clauses that are attached to price indices (Rehn and Valussi, 2006).

In Bayern (Bavaria) and Schleswig-Holstein, competitive tendering is solely used as an instrument to award regional bus services around the urban agglomerations of München (Munich) and Hamburg, respectively. In the inner city of München, as elsewhere in Germany, the municipality represents the public transport authority and at the same time owns the public transport company (Schenck et al., 2003). Obviously, conflicts of interest can arise. Municipal ownership is seen as barrier to competition (Weiß, 2003), because then competitive tendering is only seldomly used for such services. Interestingly, in Sachsen-Anhalt (Saxony-Anhalt) the framework of commercial transportation is used to introduce competition for services with stronger subsidy requirements (Karnop, 2007). The authorities provide a lump sum and the public transport companies compete for the license through quality competition as opposed to price competition via competitive tendering. It is the opposite of the classical optimization strategy in local public transport. Price competition aims at input minimization whereas quality competition aims at output maximization. Named after a city in Sachsen-Anhalt, the novel approach is called Wittenberger Modell.

Market Structure

Figure 1.1 classifies Germany’s bus companies by type, major strategic activities, and any additional passenger transport business segments apart from bus operations. Urban public transport in Germany is dominated by domestic municipal companies. In nearly all of the larger cities, there is a municipally-owned company, leading to a high degree of fragmentation. Public ownership is further represented by DB Stadtverkehr GmbH, a subsidiary of Deutsche Bahn AG. It is the primary player in regional services, organized in 22 major subsidiaries (Deutsche Bahn AG, 2009a). Market concentration and the presence of multinational companies has not yet developed as in other countries, e.g., Great Britain, although some companies like Arriva and Veolia have entered the market through participation in competitive tenderings in regional rail transportation.
Usually, neither the larger domestic municipal companies nor international firms have enough bus service capacities for the network in which they operate. Therefore, sub-contracts are negotiated with small-scale private bus companies. These 4992 small- and medium-sized enterprises (SMEs) (Bundesverband Deutscher Omnibusunternehmer, 2009) represent the third pillar (besides local public and integrated international transport companies) of the local public transport market. They also operate independently and take part in competitive tenderings. Although the number of competitive tenderings is low compared to the overall market size, the pressure on subsidies requires changes. To avoid too strongly depending on their home markets, public transport companies are now looking for alternative fields of business or expanding into other regions to strengthen their market positions (Elste, 2007).

Municipal companies have reacted to the changing market structures with mergers of special functions or entire companies. Thus, Essener Verkehrs-AG founded a common subsidiary for transport operations with neighboring Mülheimer Verkehrsgesellschaft, called Meoline. Together with Duisburg, the three cities merged their transportation management functions into rhein ruhr partner (rrp). In the Hannover area, a proposed intermodal joint venture (intalliance) between the local urban operator, Üstra, and the regional subsidiary of Deutsche Bahn was halted by anti-trust legislation. Other companies, especially large and multimodal operators, have acquired smaller firms in neighboring areas: Hamburger Hochbahn (HHA) bought 49.9% of Stadtverkehr Lübeck (before building the expansion subsidiary Benex) and Dresdner Verkehrsbetriebe (DVB) acquired Verkehrsgesellschaft Meißen in Sachsen (Saxony).

To reduce the higher operating costs resulting from higher salaries in public enterprises, some urban transport companies have created sub-companies which then operate economically challenging services using lower-paid drivers. Examples are Leipziger Verkehrsbetriebe (LVB) and its subsidiary Leobus, Berliner Verkehrsbetriebe (BVG) and its subsidiary BT Berlin Transport, and Verkehrsgesellschaft Frankfurt (VGF) with In-der-City-Bus (ICB).

Furthermore, some public companies participate in competitive tendering beyond their home regions. Since the regulation (EC) No 1370/2007 only allows direct tendering to city-owned companies that are not active outside the respective area, some firms have restructured into independent enterprises, i.e., a local company allows the public owner to direct tenders to its own company, while a second company participates in competitive tendering elsewhere in Germany. A prominent example is Hamburger Hochbahn (HHA) which operates the local

---

8The joint venture was intended to efficiently encompass the whole of Hannover’s local and regional passenger transport by regional rail, tram, and bus.
**Figure 1.1:** Strategic player analysis of the German bus market (as of December 2008)

<table>
<thead>
<tr>
<th>Enterprise type</th>
<th>Main strategic activities</th>
<th>Other passenger transport business segments</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Municipal public transport company</td>
<td>Mergers</td>
<td>Tram, light railway, metro, regional rail (only HHA), hired coach (e.g. HHA, BVG)</td>
<td>Meoline, rrp, Intalliance (failed)</td>
</tr>
<tr>
<td></td>
<td>Acquisitions</td>
<td></td>
<td>DVB, HHA</td>
</tr>
<tr>
<td></td>
<td>Subcompanies</td>
<td></td>
<td>LVB with Leobus, BVG with BT, VGF with ICB</td>
</tr>
<tr>
<td></td>
<td>Direct tendering</td>
<td></td>
<td>Meoline, HHA, BVG, VGF, many others</td>
</tr>
<tr>
<td></td>
<td>Competitive tendering</td>
<td></td>
<td>HHA, VGF</td>
</tr>
<tr>
<td>Domestic state-run public transport company</td>
<td>Acquisitions, competitive and direct tendering</td>
<td>Regional rail, long-distance rail, domestic and international express coach, hired coach</td>
<td>DB Stadtverkehr</td>
</tr>
<tr>
<td>Foreign state-run public transport company</td>
<td></td>
<td></td>
<td>NedBahnen</td>
</tr>
<tr>
<td>International public transport company</td>
<td>Competitive and direct tendering</td>
<td>Hired coach, holiday travel</td>
<td>Veolia, Arriva, FirstGroup</td>
</tr>
<tr>
<td>Small and medium sized bus and coach enterprises</td>
<td></td>
<td></td>
<td>4992 enterprises (Bundesverband Deutscher Omnibusunternehmer, 2009)</td>
</tr>
</tbody>
</table>

Source: Own illustration
bus network in Fulda.\textsuperscript{9}

DB subsidiaries try to defend their incumbent position in rail and bus services. As mentioned above, a few foreign companies have entered the market in recent years. Most of them first acquired a local public or private transport company and then began to compete with German incumbents in competitive tenderings.\textsuperscript{10} A state-owned example is Dutch NedBahnen. SMEs are building more bidding associations to participate in competitive tenderings. In the past, they have also benefited from heavily subsidized student transportation.

In addition to the high market fragmentation, most public transport companies have joined one of the 60 so-called public transport associations. The associations are responsible for standardized ticketing, marketing, etc.

**Financing**

In 2006 VDV (Verband Deutscher Verkehrsunternehmen – Association of German Transport Companies) member companies earned 8.8 bn EUR (according to § 275 HGB\textsuperscript{11}). The figure includes sales revenues, inventory changes, capitalized services on own account, other operating revenues, earnings from investments, other financial earnings, interest, earnings from transfer of losses, and extraordinary income. 6.1 bn EUR were earned by companies active in public road transport with the remainder by regional rail operators, and 7.7 bn EUR originate from ticket sales of all local public transport companies (Verband Deutscher Verkehrsunternehmen, 2008, pp. 7, 66).

The revenues of public transport come from many sources. Local public transport companies receive compensation payments for student transportation (§ 45a PBeG) and for transportation of handicapped persons (Social Security Code, § 148 SGB IX).\textsuperscript{12} These compensation payments are part of securing the public service obligation. Compensation payments and investment subsidies originate from federal sources according to the RegG and the Local Authority Traffic Financing Act (GVFG).\textsuperscript{13} Many local public transport operations are further subsumed under holdings with electricity, gas, water, sewage and other activities. Such cross-subsidization (Querverbund) gives tax advantages.

\textsuperscript{9}With the commencement of regulation (EC) No 1370/2007 on 3 December 2009, it is doubtful whether this legal unbundling will remain an accepted solution. Interestingly, the constraint mentioned above only holds for line services and not, for example, maintenance activities.

\textsuperscript{10}A recent example is FirstGroup buying the private company Merl in Speyer near the French border.

\textsuperscript{11}German Commercial Code – Handelsgesetzbuch.

\textsuperscript{12}Sozialgesetzbuch Neuntes Buch (IX) – Rehabilitation und Teilhabe behinderter Menschen.

\textsuperscript{13}Gemeindeverkehrsfinanzierungsgesetz – Gesetz über Finanzhilfen des Bundes zur Verbesserung der Verkehrsverhältnisse der Gemeinden.
Since expenditures generally are much higher than earnings, the level of cost coverage reached only 73.8% in 2006. West German companies achieved a level of cost coverage of 74.6%, while East German companies reached 68.4% (Verband Deutscher Verkehrsunternehmen, 2008, p. 9). In 1997 (the first year covered in the data set applied for efficiency analysis), these numbers accounted for 68.1% and 58.1% respectively (Verband Deutscher Verkehrsunternehmen, 2002, p. 21). Some of the losses can be attributed to the fact that local public transport is considered as a public service obligation, and is subject to a high degree of political influence (Aberle, 2009, p. 316). However, as public budgets tighten, long-term losses will not be sustainable and subsidies are expected to decrease in the future (Lasch et al., 2005). After a linear extrapolation of the recent levels of cost coverage and with the assumption that these levels will increase in the future, West German local public transport could reach profitability in 2042 and East German local public transport at least in 2034.

I also note that it can be welfare enhancing to subsidize urban transit. This is most probably the case if fares are subsidized, whereas the services are provided in an economical and efficient way. Parry and Small (2009) find that subsidies of more than 50% of operating costs improve welfare. Their results are derived for three major metropolitan areas: Washington D.C., Los Angeles, and London.

1.3 Modern Efficiency Analysis Applied to Local Public Transport

1.3.1 Outline of Literature

This section describes the approach used in this dissertation. Economic research can concentrate on institutional and policy issues, without expectations that readers are equipped with deeper knowledge of mathematics and formal expressions. Economic research is often theoretical. Economic theory lays out the principles of economic behavior and it is the indispensable connector between all approaches of economic research. Economic research can also be quantitative. In its simplest form it is descriptive, without allowing for well-founded inference or predictions. Almost all qualitative research incorporates descriptive analysis. Quantitative research can be based on numeric modeling with an emphasis on the prognosis of future developments and scenarios. Quantitative research can

---

14There are different definitions of the level of cost coverage. The one cited here (Verband Deutscher Verkehrsunternehmen, 2008) surely results in percentages on the upper end.

15One may be tempted to classify such research as qualitative. However, qualitative data can itself be a major input to econometric research, in the absence of data, hypotheses can be qualitative, yet highly theoretical.
also be empirical, where the available data is the main input and focus of inter-
est. Backhaus et al. (2006, pp. 2 ff.) state that multivariate analysis is one of
the pillars of empirical research, and classify it by structure-verifying methods
and structure-detecting methods. In the former they include different types of
regression analyses; in the latter they include cluster analysis, factor analysis,
and so on.

This thesis is based on quantitative, more precise empirical, more precise
econometric methods. This may be more obvious in some chapters and less ob-
vious in others. Chapters 2 and 3 use Stochastic Frontier Analysis to evaluate
cost efficiency and some of its determinants and to evaluate economies of scale
and scope in Germany’s public road transport. SFA is known as the econometric
approach to efficiency analysis (Greene, 2008). Chapter 4 uses Data Envelopment
Analysis to calculate the potential gains from mergers. DEA is non-parametric,
meaning that no coefficients are estimated. Clearly, it is not a type of regres-
sion analysis. However, by incorporating noise, the availability of inference, the
extension to semi-parametric approaches, etc., the historical drawbacks of DEA
and the differences between it and SFA tend to blur. DEA no longer has to be
deterministic, since the stochastic DEA (SDEA – order-m) approach allows for
noise. This development has gone so far that in the XI European Workshop on
Efficiency and Productivity Analysis (EWEPA) in Pisa in 2009, non-parametric
models were classified as econometric models (Simar, 2009) without opposition.
Chapter 5 uses an econometric probit estimation to examine the structural con-
ditions and the probability of operator changes in local bus transport tenders.
Chapter 6, which evaluates the future prospects of express coach services,
includes a conjoint analysis to estimate market share. Backhaus et al. (2006,
pp. 7 ff.) classify conjoint measurement as a structure-verifying method. Thus,
my basic scientific approach is econometrics. And it is microeconometrics be-
cause I always look at an individual level, i.e., firms in Chapters 2, 3, and 4,
tenders in Chapter 5, and people in Chapter 6.

The purpose of this section is to recall the basics of the methods of Chapters 2–
4, scientific efficiency analysis, and to give a comprehensive and comparative
review of the literature on efficiency analysis used in the public road transport
sector. The remainder of this section does not go deeper into the models and
literature used in Chapters 5 and 6. The reasons are twofold. First, the focus
of Chapters 2–4 is more methodological, and second, more specific literature is
available on the efficiency analysis of public road transport than, for example,
on structural conditions in competitive tendering in local bus transport.

Scientific efficiency analysis has been broadly applied to sectors such as agri-
culture (e.g., Lansink et al., 2002) to detect productivity differences, and to
electricity distribution (e.g., Cullmann and Hirschhausen, 2008) for the purpose
of regulation. Recently, interest has revived about applying it to local public transport. I am interested in the advancements in efficiency analysis applied to local public transport since a review of the literature by De Borger et al. (2002), i.e., bootstrapping and inference in non-parametric DEA and unobserved heterogeneity and panel data applications in parametric SFA, in the evaluation of regulatory contracts, and in multi-output studies.

The advantages of efficiency analysis, or scientific benchmarking, over the widely-used tool in business, managerial benchmarking, are many. It results in only one indicator measuring the overall performance of a company, and it can account for heterogeneity, stochasticity, and multi-dimensionality. Accounting for heterogeneity means that the environmental characteristics not under managerial control will be automatically considered when calculating efficiencies. Stochasticity refers to the possibility of measurement errors in the data set and exogenous shocks. Multi-dimensionality refers to multiple outputs that cannot be aggregated in one measure of output.

The review of the literature consists of the following four subsections. Subsection 1.3.2 evaluates DEA applications of single-product bus companies and the influence of structural variables. Subsection 1.3.3 looks at different kinds of econometric studies on single-output companies. It is not based purely on SFA studies, because there are cost-function estimations with average econometric functions instead of frontier functions that address similar research questions such as economies of scale. Subsection 1.3.4 looks at an increasingly large cluster of SFA studies that analyze performance under different regulatory contracts. Subsection 1.3.5 looks at empirical multi-output studies in which not all companies necessarily produce all of the considered outputs, hence zero outputs occur. Some of these companies supply standard bus services as well as tram services, trolley-buses and similar services. In this thesis, the word “output” means the technical output variables in the model specification and the word “product” means the services supplied. For example, an urban and intercity bus company can be modeled through one summarized output, but provide two products.

1.3.2 DEA Single-Product Applications

DEA is a performance measurement tool that uses linear programming to find the relative efficiency estimates of decision-making units (DMUs). Figure 1.2

\footnote{Under local public transport, the authors understand transport services to consist chiefly of buses, but also other road-bound transport services such as tram or light railways. In the following I use “local public transport” as a synonym for “public road transport” for convenience.}

\footnote{In contrast to the application order in Chapters 2–4 (I apply SFA twice, then DEA once), the following review begins with DEA, because some of the basic concepts of efficiency analysis are more intuitive in the context of DEA.}
OVERVIEW

illustrates the basic assumptions in DEA for a one input-one output case. Using physical inputs and outputs, technical efficiency scores are assessed. Efficiency scores can be calculated under constant returns to scale (CRS), variable returns to scale (VRS), and non-increasing returns to scale (NIRS) (see Cooper et al., 2007, pp. 131 ff., for other possible scale assumptions). Under CRS, all DMUs are benchmarked against the one efficient DMU. Under VRS, DMUs are only benchmarked against DMUs with similar size. NIRS evaluate all DMUs smaller than the efficient DMU against the efficient DMU(s), whereas larger DMUs are benchmarked against peers of the same size. DEA programs can be executed under input or output orientation. Under input orientation, outputs are assumed to be fixed and the efficiency score reflects the proportion of inputs that can be saved. Under output orientation, inputs are assumed to be fixed and the efficiency score reflects the extent to which outputs can be increased.

As applied to local public transport, consider firm F in Figure 1.2 under input orientation. Under VRS, F is fully technically efficient, because it lies on the frontier. Under CRS however, its technical efficiency score is determined by the proportion of inputs that could be saved. This proportion is calculated as the minimum input usage (a) divided by the actual input usage (b). Under input orientation, the firms situated above firm E (including F) exhibit decreasing returns to scale, indicating that they are too large. Firms situated below firm E exhibit increasing returns to scale, i.e., they are too small.

Table 1.1 lists the recent DEA studies of single-product local public transport companies ordered by year of publication. The first column gives the author(s) and the year of appearance. The second column characterizes the data set with the number of observations, number of firms, country, type of operator, and period. The third column gives information about the type of orientation, scale assumption(s), and further methodological information. The fourth and fifth columns give the inputs and outputs, and the sixth column summarizes the studies’ significant results for comparison.

Three of the studies in the table are restricted to observations taken in a single year, reflecting the appropriateness of DEA to cross-sectional data sets. Applications for panel data sets like Window Analysis (Cooper et al., 2004, pp. 42 ff.) exist but the development of panel data models for DEA is not as advanced as for SFA. The predominant orientation in DEA studies of local public transport is input orientation because of predetermined route frequency (Odeck and Alkadi, 2001). Input orientation is also examined when looking at cost minimization. The corresponding calculation of cost efficiency (CE) evaluates how much can be saved while maintaining current output levels. For the calculation of cost efficiency, information about input quantities and prices is needed, which

\(^{18}\)Several in the usual case of more than one input and output.
Figure 1.2: Returns to scale and orientation in DEA

is frequently absent in previous studies. From the studies in Table 1.1, only De Borger et al. (2008) are able to use such information. As can be seen from Figure 1.2, technical efficiency scores are defined as between larger than 0 and 1, with 1 indicating an efficient DMU. The same applies for CE. Whereas broad consensus exists about the optimum input variables, there is constant discussion about output variables. One group favors pure supply-oriented measures, vehicle-kilometer or seat-kilometer, while another group favors demand-oriented measures, i.e., passengers and passenger-kilometer. The supply-oriented supporters argue that demand is not under the control of management; the demand-oriented supporters argue that it is actual carriage that counts; otherwise the firm running its buses empty through less-congested areas would be the most efficient.

Four studies rely on supply-oriented measures, with Odeck and Alkadi (2001) taking passenger-kilometer into account in a second model. Only Boame (2004) relies on a demand-oriented measure. All five studies are in fact semi-parametric analyses because they carry out second stage regressions, mostly to determine exogenous influences on the efficiencies.

The most recent study of De Borger et al. (2008) is at the methodological forefront. The authors make use of the developments of DEA driven by the
### Table 1.1: DEA Single-Product Local Public Transport Study Survey

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Data sample</th>
<th>DEA specification</th>
<th>Inputs</th>
<th>Output(s)</th>
<th>Main results</th>
</tr>
</thead>
<tbody>
<tr>
<td>De Borger et al. (2008)</td>
<td>154 Norwegian local and 55 French bus operators</td>
<td>1991</td>
<td>Input orientation</td>
<td>Fuel costs, driver costs, other costs</td>
<td>25% bias by uncorrected CE, CRS assumption rejected, operating in coastal area with positive, population density, sea transport, and type of contract without impact on efficiency</td>
</tr>
<tr>
<td>Boame (2004)</td>
<td>30 Canadian bus operators</td>
<td>1990-1998</td>
<td>Input orientation</td>
<td>Buses, fuel, paid employee hours</td>
<td>Bias is significant, speed and year with positive, peak/base ratio with negative, and bus age without significant impact on efficiency</td>
</tr>
<tr>
<td>Cowie (2002)</td>
<td>282 observations of 58 British bus operators</td>
<td>1992-1996</td>
<td>Input orientation</td>
<td>Staff, vehicles</td>
<td>Significant rise in technical (TE CRS) and managerial (TE VRS) efficiency, no significant increase in SE for acquired and group firms</td>
</tr>
<tr>
<td>Odeck and Alkadi (2001)</td>
<td>47 of the larger Norwegian bus operators</td>
<td>1994</td>
<td>Input and output orientation</td>
<td>Seats, fuel, equipment costs, driving hours, other staff</td>
<td>No scope effects with auto-repair and welding services, public versus private ownership and urban vs. regional operations without significant impact</td>
</tr>
<tr>
<td>Pina and Torres (2001)</td>
<td>15 Catalan (Spanish) bus operators (no year given)</td>
<td></td>
<td>Input orientation</td>
<td>Fuel/100 km, subsidy/cost/km, cost/traveler</td>
<td>Public companies more efficient, but not significantly, economical sector focus, geographical extension, population density, no. of cars, income per capita, and population age without significant influence</td>
</tr>
</tbody>
</table>
publications of Simar and Wilson (1998, 2000, 2002, 2007) which suggest procedures for bias correction and inference via bootstrapping methods\textsuperscript{19} in DEA. Simar and Wilson (2008) show that DEA estimators are biased by construction, stating that the true efficiency frontier is unknown. They propose to construct a bias-corrected estimator with the help of pseudo data samples. De Borger et al. find an average bias of 25% with the standard DEA CE measure often not lying in the 95% confidence interval of corrected estimates. This finding points to the importance of bootstrapping usage. Additionally, no average efficiency differences can be observed between Norwegian and French operators by De Borger et al. when the sample size is taken into account.

Boame (2004) agrees with De Borger et al. (2008) that the standard DEA measures are so much higher than the bootstrap estimates that they most often do not lie in the bootstrapped 95% confidence interval. Boame (2004) finds that 56% of the firms operate under increasing returns to scale with an average output level of 5.8 m revenue vehicle-kilometer. Additionally, average speed and a time trend exhibit a positive impact on efficiency, according to the results of Boame’s second stage tobit regression. However, a peak/base ratio has a negative impact and bus age is found to be insignificant for efficiency.

In Great Britain a consolidation process emerged in response to competition and liberalization (Cowie, 2002). Cowie finds that during 1992 and 1996, technical and managerial efficiency levels improved, but not scale efficiency. Odeck and Alkadi (2001) find that the average bus company (161 m seat-kilometer) in their sample of Norwegian bus companies is smaller than optimal, and the average input savings potential is 28%.\textsuperscript{20}

The influence of other variables on efficiency is also tested by Odeck and Alkadi (2001). Type of ownership in particular is insignificant, a result confirmed by Pina and Torres (2001) for Catalonia. This reinforces the finding of a recent survey of studies on the performance of bus-transit operators (De Borger and Kerstens, 2008). They conclude that the degree of competition and regulatory issues are more relevant. Such a conclusion has also been drawn for other sectors like water distribution. Thus, Walter et al. (2009a) find that institutional setting, not ownership, is significant. Pina and Torres (2001), however, appear at odds with the literature. First, partial productivity measures instead of pure inputs and outputs enter their DEA model. Second, after a standard DEA procedure, they regress efficiency scores on inputs to verify their explanatory power.

Summarizing the results of these semi-parametric DEA studies, structural variables can play an important role in efficiency measurement, although no

\textsuperscript{19}See Efron and Tibshirani (1993) for an introduction to bootstrapping.

\textsuperscript{20}See Odeck (2003) and Odeck and Alkadi (2004) for further DEA studies on Norwegian bus services.
overall conclusion can be drawn on single variables, partly because of the different environments in which the firms operate.

1.3.3 Econometric Single-Output Applications

SFA is a performance measurement tool that uses econometrics to establish relative efficiency estimates of decision-making units. It is closely related to standard econometric estimations of average production and cost functions. Therefore it is not unusual that one of the most popular application, the estimation of economies of scale and density, is conducted with both average and frontier functions. Practically speaking, average functions represent scale and density economics for the current industry structure, and frontier functions represent scale and density economics for the optimal industry structure. However, the differences between the two approaches have hardly been pursued in the literature. Table 1.2 illustrates four standard econometric and SFA studies in chronological order that use data sets from the 1990s and employ translog cost functions, the most popular functional form in cost-function estimation. In contrast to the Cobb-Douglas functional form, which is at best suitable for first-order approximations, the translog functional form is a second-order approximation (Chambers, 1988, pp. 158 ff.). The translog functional form does not result in the same economies of scale for all observations as does Cobb-Douglas. Cambini et al. (2007) and Filippini and Prioni (2003) rely on seemingly unrelated regressions (SUR). Farsi et al. (2006) and Bhattacharyya et al. (1995) use sophisticated methods of SFA. The choice of outputs is again reflected by the supply- vs. demand-oriented debate, with a tendency to use seat-kilometer as the dominant output variable. To differentiate between economies of scale and density, the single-output studies by Cambini et al. (2007), Farsi et al. (2006), and Filippini and Prioni (2003) use the network length as additional output variable.

There is more consensus about factor prices. A factor price for labor is sometimes broken out by drivers and by administrative personnel. The energy or fuel price is separated if data is available and significance during estimations is given. Residual costs divided by some quantity measure form a material price in the case of a variable cost function and a capital price in the case of a total cost function. Cambini et al. (2007) pursue a more unique approach. First, the input price for materials and services is calculated as the corresponding costs divided by seat-kilometer. Hence, seat-kilometer represents output and at the same time one of the inputs. Second, the capital price is calculated with the help of an estimated cost of capital. This estimation is based on information provided by companies about the purchase cost for new vehicles.

Modeling heterogeneity is important in modern efficiency analysis. The studies in Table 1.2 include additional structural variables in the cost functions, i.e.,
<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Data sample</th>
<th>Methodology</th>
<th>Variables</th>
<th>Main results</th>
</tr>
</thead>
</table>
| Cambini et al.  | 231 observations of 33 Italian urban, intercity, and mixed bus operators 1993-1999 | Translog TC and VC functions and cost share equations estimated by iterated SUR with Fixed Effects | Output: seat-km | Speed decreasing in costs EoS: 1.14/1.30 (LR/SR) for intercity [1242 m seat-km] & 1.59/1.79 for urban companies [2885]
| Farsi et al.    | 985 observations of 94 Swiss regional bus operators 1986-1997 | Translog TC frontier estimated with pooled, RE (ML), Fixed Effects, True RE models | Outputs: seat-km | Increasing costs over time EoS: from 1.49-1.91a [5.72 m seat-km] to 1.01-2.25a [53.13]
| Filippini and Prioni (2003) | 170 observations of 34 Swiss regional bus operators 1991-1995 | Translog TC function with factor share equations (SUR) estimated by ML | Outputs: seat-km | Private firms tend to lower costs Decreasing costs over time High elasticities of substitution between capital & labor EoS: 1.17 [29 m seat-km] EoD: 1.97
| Bhat-tacharyya et al. (1995) | Unbalanced panel of 32 Indian bus operators 1983-1987 (no. of observations unknown) | Translog VC frontier with factor share equations, time-specific effects & heteroscedastic inefficiency estimated by iterated SUR in 1st step & ML in 2nd step | Output: passenger-km | Units managed by government transportation departments most efficient, followed by large transport corporations and nationalized companies Efficiency increasing in vehicle utilization & decreasing in the breakdown rate

TC = total cost, VC = variable cost, SUR = seemingly unrelated regression, EoS = economies of scale, EoD = economies of density, LR = long-run, SR = short-run, Corresponding mean output levels in squared brackets (median for Filippini and Prioni, 2003), RE = Random Effects, ML = maximum likelihood, a Depending on the model Source: Own illustration.
average speed, load factor, etc., to account for observed heterogeneity in the production model. Although I should add a critical note on the assumed exogeneity of some environmental variables that appear not only in local public transport studies (why do airlines employ sophisticated yield management systems if the load factor is exogenous?), there is a nice intuition of their application in SFA: Coefficients and standard errors of structural variables provide information about the direction and the impact of influence, in contrast to traditional one-stage DEA models, where the beneficial or harmful role of these variables must be known a priori (Daraio and Simar, 2007, p. 98). The same intuition applies for time trends which are included to account for technical change. A new enhancement is given by Farsi et al. (2006) who account for unobserved heterogeneity in the sense that no data is available for this kind of heterogeneity. Based on Greene (2004, 2005b) the so-called “true” models add an individual time-invariant random or fixed term to the prevailing inefficiency and white noise terms. This allows better differentiation between inefficiency and other unexplained factors. Farsi et al. (2006) conclude that the True Random Effects model shows improved estimations of inefficiency and slopes. Pooled models fed with panel data, Fixed (Schmidt and Sickles, 1984) and Random Effects models (Pitt and Lee, 1981) may give imprecise results. The True Random Effects model may also be used as a benchmark for the regulation of network industries. A mechanical transfer of efficiency levels into individual X-factors must, however, be avoided.

The Italian and Swiss bus industry evaluated by Cambini et al. (2007) and Farsi et al. (2006) and Filippini and Prioni (2003) respectively appear to exhibit increasing returns to density, and though to a lower extent, increasing returns to scale. Increasing returns to scale and density are prevalent when the indicators shown in Table 1.2 are greater than 1. The indicator for economies of scale measures the proportion of output increase to cost increase while extending output and network. The indicator for economies of density measure the proportion of output increase to cost increase while extending only the output with the network held fixed. Filippini and Prioni (2003) also employ bus-kilometer and the network length as alternative outputs. Interestingly, the measures for economies of scale and density at the time were slightly higher in comparison to the original output specification with seat-kilometer and the number of stops.

The results from Italy and Switzerland are confirmed by De Borger and Kerstens (2008) who find in an international survey that more intensive use of an existing network reduces the per kilometer costs. For economies of scale, they

---

21Kumbhakar (1991) proposed a similar model.

22In Table 1.2, the network length is classified as an additional variable, but in the functional specification it shows output characteristics because of the cross and squared terms.
argue in favor of a U-shaped average cost curve with increasing returns to scale for small companies followed by constant returns to scale and decreasing returns to scale. The exact form of this curve again may depend on country and environmental characteristics. In an earlier version of their 2003 paper, Filippini et al. (2001) additionally evaluate the influence of stop density and mountainous regions on costs. Based on the same data set used in their later 2003 paper, they find that higher stop densities and mountainous regions increase costs. Bhatcharyya et al. (1995) taking a unique approach that allows for both heterogeneity and heteroscedasticity, are able to closely focus on a rather unattended aspect of efficiency measurement: the internal sources of inefficiency. These determinants are modeled as heteroscedastic variables of the inefficiency function. The authors conclude that efficiency increases in the vehicle utilization rate and decreases in the breakdown rate.

1.3.4 SFA Applications with Focus on Regulatory Contracts

Interest has arisen concerning SFA studies that compare the performance of different regulatory contracts. In particular there is a debate about low-powered cost-plus schemes vs. high-powered fixed-price contracts. Low-powered schemes are expected to leave no additional rents to the regulated firms as excess profits, because firms receive a predetermined return on their costs independent of how high the real costs are. The major disadvantage is the low incentives given to management to actually decrease costs. The underlying hypothesis of the papers I review in this subsection is that firms with high-powered contracts have more incentives to decrease costs and hence become more efficient. Under high-powered contracts, firms are allowed to retain all achieved cost savings. However, when costs are above the fixed price, no profits will be left to the firm (Joskow, 2007, pp. 1301 ff.).

Table 1.3 lists the most recent studies ordered by year of data availability, with the exception of Gagnepain and Ivaldi (2002b) inserted after Roy and Yvrande-Billon (2007), for easier comparison of the French experience. Table 1.3 only contains studies from Europe. Local public transport as a public service obligation plays a comparatively higher role in Europe than elsewhere. Further, the research intensity appears to be higher, although there are differences among the European countries. The main model used in this subsection is Battese and Coelli (1995) which allows the parametrization of the mean of the inefficiency function. Exogenous variables are included as inefficiency determinants. In contrast to the inclusion of structural variables directly in the functional form like outputs, the Battese and Coelli (1995) approach assumes that only the inefficiency is affected and not the entire production process. Hence, heterogeneity is modeled in the inefficiency, not in the production. This appears to be a suitable
approach for the variables characterizing the regulatory scheme, because there is no obvious reason why firms under different regulatory contracts should operate with different production technologies.

Roy and Yvrande-Billon (2007) estimate a production function to determine the influence of regulation and ownership. As output they use bus-kilometer, and as inputs, proxies for capital, labor, and energy. Two additional control variables are included: network length and population. Both have positive impacts on production choice. Returns to scale are found to lie around 0.92 which indicates slightly decreasing scale economies for a mean output level of 2.462 m bus-kilometer. This contrasts with the Italian case evaluated by Cambini et al. (2007) who find increasing returns to scale for a much higher production level. Turning to the core of Roy and Yvrande-Billon (2007) private companies appear to be most efficient followed by public companies and semi-public companies. Since competitive tendering is used in France only for private operations, this result is not surprising. For semi-public companies, the higher inefficiency is explained by the difficulties in responsibility attribution. Noteworthy, although significant, The inefficiency differences between the mean-efficient semi-public and the mean-efficient private company are in fact significant, but only 2%. The superior efficiency of private operators can also be attributed to the type of regulatory contract. Roy and Yvrande-Billon (2007) differentiate net-cost contracts, gross-cost contracts, and management contracts. The first two are fixed-price contracts, the third is a cost-plus contract. A useful differentiation can be made via the risk exposure of the franchisee. Under a net-cost contract, the operator faces production risk associated with the cost of providing an amount of transport, and revenue risk associated with the sale of the transport services. Under a gross-cost contract, revenue risk is assumed by the transportation authority. Under a management contract, both risks are assumed by the transportation authority. Roy and Yvrande-Billon (2007) find that firms operating under fixed-price contracts are more technically efficient than those operating under cost-plus contracts. Within fixed-price contracts, gross-cost contracted firms are more efficient than net-cost contracted firms. The authors explain this by the possible focus of net-cost contracted firms on revenue increase rather than on cost-minimization and technical efficiency.

The superiority of fixed-price contracts in comparison to cost-plus contracts in France is also determined in a study by Gagnepain and Ivaldi (2002b). They evaluate short-run cost efficiency with seat-kilometer as output, taking the size of vehicles into account.\textsuperscript{23}

\textsuperscript{23}See also Gagnepain and Ivaldi (2002a) for more information on their approach. It should be noted that short-run cost functions must not be confused with variable cost functions. Short-run cost functions can include both variable and fixed costs (Coelli et al., 2005, p. 27); it is merely that some inputs are held fixed for the short run.
Table 1.3: SFA local public transport studies with focus on regulatory contracts

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Data sample</th>
<th>Methodology</th>
<th>Variables</th>
<th>Main results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gagnepain and Ivaldi</td>
<td>531 obs. of 59 French bus operators 1985-1993</td>
<td>Cobb-Douglas SR cost frontier estimated with FE &amp; pooled asymmetric information model</td>
<td>Output: seat-km&lt;br&gt;Input prices: labor, material, soft capital (commercial vehicles, computer service &amp; office supplies)&lt;br&gt;Quasi-fixed input: vehicles</td>
<td>Test on non-nested models favors structural approach against FE&lt;br&gt;Fixed-price contracts related to lower costs</td>
</tr>
<tr>
<td>Piacenza</td>
<td>308 obs. of 44 Italian urban, intercity &amp; mixed operators 1993-1999</td>
<td>Translog VC frontier estimated with Battese and Coelli (1995)</td>
<td>Output: seat-km&lt;br&gt;Input prices: labor, fuel, materials &amp; services&lt;br&gt;Structural variables: vehicles (quasi-fixed input), speed, intercity &amp; mixed operation dummies, time trend&lt;br&gt;Efficiency determinants: regulation dummy, speed, time, interaction regulation-speed</td>
<td>Fixed-price contracts related to lower costs, in particular as more years elapsed under this type&lt;br&gt;Decreasing efficiency over time</td>
</tr>
<tr>
<td>Dalen and Gómez-Lobo</td>
<td>1136 obs. of 142 Norwegian bus operators 1987-1997</td>
<td>Log-linear VC frontier with output cross term estimated with Battese and Coelli (1995)</td>
<td>Outputs: urban and intercity vehicle-km&lt;br&gt;Input prices: driver labor, administrative labor, fuel&lt;br&gt;Structural variables: time dummies, seats (capital), population density, centrality index, industry type, NSB ownership&lt;br&gt;Efficiency determinants: dummies for yardstick &amp; subsidy cap contract, time</td>
<td>Yardstick contracts (costs linked to output) support efficiency catch up with time dynamics&lt;br&gt;No clear conclusion for subsidy caps with decreasing subsidies, just recently introduced</td>
</tr>
</tbody>
</table>

Obs. = observations, FTE = full-time equivalent, PPP = public-private partnership, SR = short-run, FE = Fixed Effects, VC = variable cost

Source: Own illustration
Piacenza (2006) evaluates cost efficiency under fixed-price and cost-plus contracts using a sample of 44 urban, intercity, and mixed operators in Italy; six also provide tram and railway services. Simplifying the supply structure, the rail-bound services are included in the common bus output seat-kilometer. The authors find increasing returns to scale (1.93 in the short-run, 1.83 in the long-run) for a mean output level of 997 m seat-kilometer.

Concerning structural variables, mixed operators tend to have lower costs than pure intercity operators, and pure intercity operators have lower costs than pure urban operators. Increasing speed also brings cost reductions and costs are decreasing over time. Piacenza (2006) and Roy and Yvrande-Billon (2007) also find lower cost distortions for operators that are subject to fixed-price mechanisms. This effect becomes stronger the more that time has elapsed since the introduction of the contractual scheme. However, inefficiency in general increases over time. The authors argue that some laxity of government accompanied by extraordinary funds to cover old deficits support this regress.

Whereas Piacenza (2006) include dummies for urban and intercity operators, Dalen and Gómez-Lobo (2003) use two output variables for Norway to differentiate between these two types of services. This differentiation is already justified by the finding of stronger economies of scale in intercity services compared to urban services. The results indicate diseconomies of scope and that overall returns to scale are 1.038. By contrast, Di Giacomo and Ottoz (2007) find economies of scope and hence fixed cost savings for urban and intercity bus operators in Italy.

Dalen and Gómez-Lobo (2003) state that higher population densities and industrialized areas exhibit higher costs whereas costs decrease in a centrality index and for NSB ownership. They conclude that the introduction of high-powered contracts based on yardstick regulation reduces operating costs. The yardstick character is emphasized by the fact that the standard cost model is then applied to all firms within a county. No clear conclusion can be drawn about whether subsidy caps with decreasing subsidies are more efficient than the original individual-bargaining scheme, due to the scheme’s recent introduction.

Summarizing the results of this review of SFA studies of regulatory contracts, high-powered fixed-price schemes clearly have a significant positive impact on costs. This is affirmed by a mixed DEA-SFA study by Margari et al. (2007) using a panel of Italian companies. The authors separate inefficiency caused by exogenous factors like regulation and network from management skills, and conclude that pure managerial skills play a minor role.

Further research is necessary to analyze the different forms of high-powered

---

Footnote: The exact average output level for which the scale economies are calculated is not given in the paper.
schemes, e.g., gross-cost vs. net-cost contracts. As revenues play an important role in net-cost contracts, it is important to rethink the traditional way of calculating cost efficiency based on supply-oriented output measures.

### 1.3.5 Empirical Multi-Output Applications

Until now, I have reviewed only one study with multiple outputs: Dalen and Gómez-Lobo (2003). Each company in their sample produced both kinds of urban and intercity bus services. In many cases, the local public transport sector is far more complex. Rail-bound services play a major role, and not all companies supply all kinds of output. The approach of Cambini et al. (2007) to sum the output of bus and tram services in one variable is only possible when the share of tram output is very low. The technology of rail-bound systems is unique to each European city, e.g., London’s Underground and Paris’s Métro. German cities are generally served by multi-product companies with tram systems as the major transportation mean. In comparison to the role of rail-bound services, the multi-product companies have not been mirrored in efficiency analysis. Table 1.4 lists some of the few existing multi-output studies sorted by date of publication. In all studies, the data set contains some zero outputs. This implies that the popular translog functional form is not suitable.

Evangelinos and Matthes (2009) describe the results of two separate analyses for pure bus companies and bus and tram companies in Germany. The ease of this approach is accompanied by the missing possibility of evaluating synergy effects. The calculation of total factor productivity (TFP) shows a superior productivity growth for multi-output companies. The authors find minor efficiency differences between East and West German pure bus companies, but stronger differences for multi-output companies, with the Western companies performing better.

Farsi et al. (2007) estimate a quadratic cost function for 16 Swiss urban multi-output operators. The use of a quadratic function allows the consideration of zero outputs without Box-Cox transformation. The authors’ cross-sectional heteroscedastic regression model with autoregressive errors estimates an average function, not an SFA frontier function. The results indicate decreasing costs over time and the number of stops contributes to cost increases. Focusing on the estimation of economies of scale and scope, the authors find product-specific and global economies of scale and economies of scope.

Pioneering studies of multi-product local public transport providers have been carried out by Viton (1992, 1993, 1997). Viton (1997) uses DEA to evaluate the efficiency of US motor-bus and demand-responsive output providers. First, he states that public and private systems share the same distribution of technical efficiency, but considering the high efficiency levels (80% of firms are fully efficient), a critical note should be assigned to the high number of inputs and
### Table 1.4: Empirical multi-output local public transport studies

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Data sample</th>
<th>Methodology</th>
<th>Variables</th>
<th>Main results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evangelinos and Matthes (2009)</td>
<td>1080 obs. of 108 German bus and tram operators 1995-2004</td>
<td>Bus operators: CRS</td>
<td>Vehicle-km</td>
<td>0% TFP growth for bus only, 3% for bus and tram companies. East German bus and tram companies less efficient, smaller differences for bus companies.</td>
</tr>
<tr>
<td>Farsi et al. (2007)</td>
<td>300 obs. of 16 Swiss urban multi-output operators 1985-2003</td>
<td>Quadratic total cost function estimated with cross-sectionally heteroscedastic and time-wise autoregressive model</td>
<td>Outputs: seat-km trolley-bus [mean: 249 m], motor-bus [334 m], and tramways [365 m]</td>
<td>Increasing global returns to scale: 1.16 for mean output. Global economies of scope: 0.19 for mean output.</td>
</tr>
<tr>
<td>Viton (1997)</td>
<td>217 US motor-bus and/or demand-responsive service operators 1990</td>
<td>DEA input and output orientation</td>
<td>Inputs: speed, fleet, fuel, labor hours split into transportation, maintenance, and administrative, capital, tires and materials cost (these inputs separated for both modes), fleet age, motor-bus directional miles, service costs, utilities cost, insurance cost</td>
<td>80% of firms fully efficient.</td>
</tr>
<tr>
<td>Viton (1992, 1993)</td>
<td>289 obs. of US urban mass transit operators 1984-1986</td>
<td>Quadratic long-run operating cost function estimated with Aigner et al. (1977)</td>
<td>Outputs: vehicle-km motor-bus [mean: 14 m], rapid rail [16 m], streetcar [3 m], trolley-bus [2 m], demand-responsive [1 m], and other [1 m]</td>
<td>Product-specific economies of scale except for motor-bus. Effect of consolidation depends on the resulting systemic wage and the output level.</td>
</tr>
</tbody>
</table>

**Source:** Own illustration

- **Note:** CRS = constant returns to scale, VRS = variable returns to scale, NIRS = non-increasing returns to scale, TFP = total factor productivity.
outputs used in his study. Since it is sufficient in DEA to outperform other firms in one input-output ratio to reach an efficiency score of one, more inputs and outputs used increase the mean efficiency.

Viton (1992, 1993) evaluates economies of scale and scope and gains from organizational restructuring in San Francisco’s Bay Area. Viton applies a quadratic cost function to enable the inclusion of companies with zero outputs for some of the outputs for motor-bus, rapid and commuter rail, streetcar, trolley-bus, demand-responsive, and other means of public transport. The cost frontier is estimated based on a pooled data set with observations from 1984 until 1986 following the cross-sectional model by Aigner et al. (1977), who first introduced SFA. Viton finds that product-specific economies of scale with the exception of motor-bus support the formation of larger entities. However, the exact effects of consolidation depend on the resulting systemic wage, the output mix, and the firm size. Whereas no potential merger would yield more than 8% savings, a complete consolidation of all the San Francisco Bay Area’s seven operators would increase costs.

1.3.6 Recommendations

The preceding subsections provide a descriptive overview of modern efficiency analysis and its applications to local public transport. Brons et al. (2005) have conducted a meta-regression analysis to identify determinants of efficiency of local public transport operators. Using ordinary least squares (OLS), they conclude that efficiency values in time series and panel data applications are significantly higher than in cross-section studies. US studies report higher efficiency predictions than European studies. DEA studies on the contrary report lower efficiency predictions. The use of the outputs, passengers, vehicles, and seats leads to lower efficiency predictions than the use of revenues. The number of inputs appears as a positive determinant of efficiency. Using weighted least squares (WLS) with weighting for sample size as an alternative, US studies and the output seats lose significance. In contrast the estimation of cost frontiers and the sample size appear to be negative determinants of efficiency.

The results of this meta regression also appear valid for the more recent studies, e.g., the high efficiency values of Roy and Yvrande-Billon (2007) can be attributed to the fact that the authors estimate a production function. While production functions can be a useful alternative in cross-border benchmarking, to avoid problems with different accounting rules, depreciations, exchange rates, price deflators, and the like, it appears preferable to use monetary data in single-country studies. Consistent efficiency analysis actually demands the use of price deflators that correspond to the nature of the data, for example, using producer price indices when cost efficiency is measured and, if available, price de-
flators that correspond directly to the local public transport sector. There is a general need for superior data quality and availability. Information about the number of seats can take into account vehicle size. Lack of data may partially explain the many blank spots on the map of efficiency analyses in local public transport. Some Western European countries (Italy, Switzerland, and possibly France and Norway) can be regarded as recent benchmarks for study availability and methodological progress. For all intended studies, a careful collection of variables, especially structural and environmental variables, is necessary to take different production environments into account. Careful interpretation is important, e.g., average speed has (justifiably) often been a network characteristic. The vehicle utilization rate, closely related to average speed, can be seen as a variable in the influence of management, because it considers vehicle deployment times, repair times, scheduling, etc.

Methodological enhancements are also needed. Referring to environmental variables, the use of conditional measures of efficiency in non-parametric studies may be useful even compared to sophisticated two-, three-, or four-stage bootstrapping approaches, because it does not assume separability between the input and output space and the space of environmental variables (Daraio and Simar, 2007, pp. 95 ff.). According to the significant influence of panel data and non-parametric methods on efficiency scores (Brons et al., 2005), the use of panel data and the comparison of SFA and DEA studies must also be encouraged.

Additionally, the lack of multi-output studies is troublesome. Much research is necessary to evaluate product-specific economies of scale and the different kinds of economies of scope. The literature on cost savings from the combined operation of bus and tram services is scant, and it is difficult to find evidence on cost savings from the combined infrastructure and transport provision of tram services in one company. Although economies of scale have been a natural point of interest for researchers, as of yet no final conclusion has been reached on this issue. I reiterate that much additional analysis is required to evaluate product-specific economies of scale and identify all possible cost savings.

1.4 Structure of the Thesis

1.4.1 Contribution Part II: Efficiency

The efficiency analysis is the first scientific study in Germany that addresses the market structure problem of inefficiency, particularly through small-scale operations and the opportunities through mergers. I create a unique panel cost data set with several hundred observations which was culled from firms’ financial reports and statements.
Cost Efficiency and Some of its Determinants

In Chapter 2, I use Stochastic Frontier Analysis to evaluate cost efficiency and some of its determinants. A translog functional form, combined with different econometric models, is applied on a reduced data set. A Random Effects model pays tribute to the panel aspect of my data. A True Random Effects model allows for the consideration of unobserved heterogeneity, likely to exist through unobserved network characteristics. A Random Parameter model acknowledges differences in products, in particular for tram and light railway services.

Mean efficiencies lie between 0.849 and 0.952, depending on the applied panel data model. The inefficiency levels correspond to a savings potential between 1.40 and 4.43 bn EUR based on the 28.23 bn EUR total costs (in 2006 prices) for 254 observations of 39 companies 1997–2006. I find a high degree of tramcar utilization and a high outsourcing degree to be positive managerial determinants of influence.

The result points to a successful outsourcing strategy of many companies which have set up subsidiaries to benefit from lower wages. The significance of the vehicle utilization rate points to network congestions that many firms face. On tracks without separate railroad embankments motorized individual traffic blocks trams. Main stops in the inner cities are overloaded. Political support for measures against congestions is missing. The improvement potential in management lies in the introduction of express lines, better scheduling and maintenance, and so on.

Economies of Scale and Scope

The inefficiency levels found in the analysis of cost efficiency cannot fully explain the low level of cost coverage in German local public transport. The obligation to provide certain services in sparsely populated areas may play a role. I also suspect the small-scaled market structure as another cause.

In Chapter 3, I use Stochastic Frontier Analysis to estimate economies of scale and scope in German local public transport. The estimations are hence aligned at optimal cost curves rather than econometric average curves. The analysis is based on 573 observations of 82 single-product bus companies and multi-product bus, tram, and light railway companies in 1997–2006. The results derived from the quadratic function are consistent for both a Random and a True Random Effects model: I find both bus-specific and rail-bound-specific increasing returns to scale along with slight diseconomies of scope between the provision of bus and tram and light railway services. Overall, there are substantial global economies of scale, the main decision factor when mergers are considered.

Although the finding of slight diseconomies of scope supports that bus and
rail-bound services should not be integrated on the cost side, there may be political opposition to the cost of separation of services. The presence of rail-bound increasing returns to scale and diseconomies of scope points to a structural problem for small tram and light railway systems in Germany, with the “Karlsruher Modell” as solution.\textsuperscript{25} Two more conclusions can be drawn, directly relating to two other chapters of the thesis. First, the presence of economies of scale has to be kept in mind when competitive tendering is used (Chapter 5). Second, mergers and acquisitions should be politically supported, particularly for companies in geographical proximity. This proposal is pursued in Chapter 4.

**Potential Gains from Mergers**

In 2005, Bogetoft and Wang proposed a calculation scheme to analyze potential gains from hypothetical mergers using Data Envelopment Analysis. The approach specifically addresses different firm characteristics and the fact that mergers must be evaluated on a case-by-case basis.

Merger gains following Bogetoft and Wang (2005) are decomposed into individual technical efficiency, synergy, and size effects. All three are summed into overall merger gains, the latter two into real merger gains. From a methodological point of view, I extend the framework to the use of bias correction by means of bootstrapping when calculating merger gains and to alternative decompositions of real merger gains.

I choose Nordrhein-Westfalen (North Rhine-Westphalia) as Germany’s most densely populated region to represent the area where mergers could be most promising. Forty-one companies are evaluated in 80 geographically meaningful mergers. As the data set also contains small companies, the analysis is based on physical data (in contrast to cost data such as in Chapters 2 and 3). I form larger units by merging companies that operate partially on a joint tram network, and select 14 as the ones with the highest real merger gains. The empirical findings suggest that substantial gains up to 16% of factor inputs are present, mainly resulting from synergy effects.\textsuperscript{26} Prominent examples for mergers are the consolidation of municipal companies from Köln, Bonn, and Siegen, from Düsseldorf, Krefeld, and Neuss, or from Duisburg, Mülheim, Essen, Oberhausen, and Moers.

\textsuperscript{25}Karlsruhe, a city with 290 000 inhabitants in South-West Germany, was the first city that connected its inner-city tram system with the regional rail network to provide direct connections between rural locales and the city center.

\textsuperscript{26}The definition of size and synergy gains is different from economies of scale and scope.


1.4.2 Contribution Part III: Competition

Whereas efficiency analysis proves to be useful to analyze the problems of local public transport in Germany and to suggest solutions, its application in practice lags, in contrast to the energy and water distribution sectors. The regulation discussion is driven by the state, federal, and European legislation. In Part III of this thesis, I select two competition issues for further evaluation.

Operator Changes in Competitive Tendering

Absent the implementation of a yardstick regulation based on scientific efficiency analysis, competitive tendering is another instrument to increase efficiency in a sector. Competitive tendering of bus services in Germany is limited to Hessen and other areas such as the public transport associations around München (Münchner Verkehrsverbund – MVV) and around Hamburg (Hamburger Verkehrsverbund – HVV). The first results of competitive tendering in bus service provision suggest decreasing subsidy requests, with the quality remaining stable or even increasing (Beck and Wanner, 2007, 2008; Wanner and Zietz, 2008). However, typically for network industries in Germany, I diagnose a lack of transparency. I access a 196 observations-data set with incumbent operator, winner, the number of bidders, and several structural variables such as the volume in terms of vehicles and the operation period. The data set makes it possible to analyze the market structure and to identify structural conditions that have a significant influence on the number of bidders and on an operator change.

I show that the focus has been on regional services, which led to a loss in market share for DB Stadtverkehr companies and gains for private companies, whereas municipal companies have been spared. The high average number of bidders (5.1) and the high probability of an operator change (58.2%) is positively influenced by tendering in bigger volumes. With a mean of 11.4 and a maximum of 58 vehicles, the tenders are rather small-scale compared to a mean fleet size of 184 buses in Chapter 3. Longer operation periods and tender in early years have also been positively influencing an operator change. By contrast, complexity, such as the number of lines and mixed urban and regional transports negatively influence competition.

Prospects of Express Coach Services

Concerning the low level of cost coverage in German local public transport, the problem is likely to be not only on the cost side but also on the revenue side. This could entail higher fares and/or the development of new business segments, such as express coach services. In Germany, these services historically have been
heavily restricted by regulation to protect the national railway from competition. The facilities and skills for the service provision are existent in local public and integrated transport companies. In other countries, such as Great Britain or Sweden, express coach services have shown higher profitability rates than other transport services.

My analysis of external and internal costs shows that express coaches have significant cost advantages that are intensified by the possible internalization of external costs. To determine the possible demand, a survey of customers is evaluated with a conjoint analysis. The results suggest a market share for express coach services in Germany of at least 5.3%.

1.4.3 Concluding Remarks

The main contributions of this thesis are the application of state-of-the-art scientific benchmarking methods to Germany’s local public transport and the enrichment of the international discussion on efficiency in this important economic sector. I apply Stochastic Frontier models which can account for unobserved heterogeneity. The analysis is based on a unique cost data set with 573 observations specifically collected for this dissertation. I also combine a merger gain decomposition based on Data Envelopment Analysis with bias correction. To my knowledge, the econometric analysis of competitive tendering of bus services is the first of its kind for Germany. The supply and demand analysis for express coach services contributes real data to a policy debate that to a large degree has been based upon anecdotal evidence. The dissertation supports five main hypotheses:

1. Stochastic Frontier Analysis can serve as a useful tool to evaluate the efficiency and its determinants of Germany’s local public transport.

2. Substantial economies of scale favor the formation of larger companies.

3. Nordrhein-Westfalen is one of the most appealing region for mergers and substantial size and synergy gains can be expected.

4. Significant structural conditions in competitive tendering of bus services favor operator changes, i.e., a long operation period and tendering in larger volumes.

5. Express coach services have substantial external and internal cost advantages compared to other means of transport, paired with a demand potential that is sufficient for the introduction of regular line services.
Part II

Efficiency
Chapter 2

Cost Efficiency and Some of its Determinants

2.1 Introduction

As local monopolies public transport networks are a natural point of interest for researchers conducting efficiency analysis. The results of such analyses can be very useful for yardstick competition among the transportation companies. However scientific benchmarking has not yet found its way into practical regulation in Germany. Instead, competitive tendering, which is encouraged via regulation (EC) No 1370/2007, is used to provide incentives for efficient transport services, but only in some regions. Hence the question is what conclusions can be drawn from applying efficiency analysis to local public transport. Two possibilities emerge: evaluation of market structure and supporting strategic firm decisions. This chapter focuses on the second point and evaluates cost efficiency and some of its determinants for multi-output companies. Multi-output companies are those which provide bus services and tram, light railway, and metro (in the sense of underground) services – aggregated as rail-bound services.¹

The method used in this chapter is Stochastic Frontier Analysis. SFA is a parametric benchmarking method which compares decision-making units relative to the best-practice peer. It does not assume, as does neoclassical theory (Samuelson, 1983), that all players act optimally. I prefer SFA instead of Data Envelopment Analysis mainly because of the applicability of panel data models with SFA that incorporates the time horizon into the analysis. Furthermore, SFA is very useful because of the possible derivations from the deployment of a functional form, for example, significance levels, and because it can handle data

¹The subsequent chapter is based on Walter (2009b).
errors. Three SFA models are used in the following analysis because there is substantial difference in how they allow for unobserved heterogeneity and observed heterogeneous output characteristics. Additionally, the vehicle utilization rate and the outsourcing share are suspected to be determinants of efficiency which are under the control of management. For these reasons the usual assumption of independent and identically distributed inefficiencies may not be justifiable.

Since these managerial determinants are endogenous it may not be appropriate to allow them to directly affect the mean of the inefficiency function, unlike the treatment of exogenous variables in Battese and Coelli (1995). I therefore follow the approach of Bhattacharyya et al. (1995) and Hadri et al. (2003b) who include these managerial determinants as heteroscedastic variables in the inefficiency function, and then compare efficiency levels. The analysis is conducted on a unique panel data set which has been collected for this research project and represents the first of its kind for local public transport in Germany. For this chapter, it consists of 254 observations for 39 multi-output companies from 1997 until 2006.

The importance of unobserved heterogeneity is emphasized by Cullmann et al. (2009). They conduct international benchmarking on a Swiss-German data set. Whereas I allow for heterogeneous output characteristics, they allow for heterogeneity in each variable of the distance function.

The remainder of this chapter is structured as follows: Section 2.2 provides the functional form with its specification as well as the econometric models. Section 2.3 describes the data in combination with the activity in the German local public transport sector. Section 2.4 gives the results as well as their interpretation and Section 2.5 concludes.

2.2 Methodology

2.2.1 Cost Function

The application of a cost function requires the assumption of cost-minimizing behavior with given input prices and output quantities (Coelli et al., 2005, p. 21). Transport economists have typically applied a cost function instead of a profit function, probably also due to data constraints. Nowadays, it is more difficult to determine whether local public transport companies in Germany minimize costs or maximize profits because of the increasing policy demands for fewer subsidies. The exogeneity of output quantities can be justified with the definiteness of

---

2I am aware that the a priori assumption of a special functional form imposes some restrictions on the analysis. See Greene (2008) for an in-depth introduction of the econometric approach to efficiency analysis.

3See Berechman (1993, pp. 111 ff.) for an introduction.
the supplied area, typical for a local monopoly, and the requirement to supply, because local transport is a public service obligation. In this case, a total cost \( C \) function can be written as

$$ C = f(Y, Q, w_L, w_K, ID, D_t) $$

(2.1)

dependent on two outputs, the number of seat-kilometers for buses \( Y \) and the number of seat-kilometers in trams, light railways, and metros \( Q \),\(^4\) on two input prices, for labor \( w_L \) and capital \( w_K \), on an inverse density index \( ID \) which is beyond the firm’s control and on the time, represented by year dummies \( D_t \)\(^5\). Seat-kilometers is preferred as output over vehicle-kilometers, because the size of vehicles, a substantial cost driver, is then included. Both measures however represent a pure supply side consideration of output. In contrast, passenger-kilometers, passengers, or revenues also take demand into account. In the literature there is an intensive debate on the appropriate output specification (see e.g., De Borger et al., 2002, or De Borger et al., 2008, in recent years). Management’s limited control over network and frequency planning, and political considerations predominate today. The first competitive tenderings carried out in the last decade have also mostly relied on gross contracts, leaving the revenue risk to the public transport authority. Since this chapter evaluates management performance, the use of demand-oriented output measures would punish management for requirements imposed by authorities. Hence, I follow Farsi et al. (2006), Farsi et al. (2007), Margari et al. (2007), Piacenza (2006), and Roy and Yvrande-Billon (2007) and use the supply-oriented measure, seat-kilometers. I note that demand-oriented measures are only available as aggregates in the data set and the cost of applying an aggregate for losing one output is too high and would inadequately reflect the production technology of local public transport.

The year dummies capture technical progress and other unobserved year-specific factors like changes in collective labor contracts. In contrast to a linear time trend, year dummies assume that technical progress does not follow a linear trend, which is an unrealistic assumption in many cases. The effects of technical progress are assumed to be neutral, thus affecting all firms equally. The most commonly applied flexible functional forms are the first-order flexible Cobb-Douglas and the second-order flexible translog functions. Both allow the variables to enter the estimation in logs in contrast to the quadratic function, which makes them linear in parameters and less fragile to extreme data points. Increased flexibility is usually preferred if the function remains estimable. Additionally, the Cobb-Douglas function follows the same returns to scale for all

\(^4\)Including both sitting and standing room.

\(^5\)Following Farsi et al. (2005a) and Farsi and Filippini (2009).

company sizes. As economies of scale have proven to vary across output levels in central European local public transport studies (see for example Farsi et al., 2007), this restriction should be avoided if possible. The translog function applied here requires the approximation at a local point which is chosen to be the mean following Farsi et al. (2008). The median is less influenced by extreme outliers, whereas the mean reflects better the actual position of all data points in the sample. Hence, all variables have been corrected at the point of approximation (Farsi et al., 2005b). After imposing the linear homogeneity in input prices of degree one by dividing costs and the capital price by the factor price for labor, the function can be written as

\[
\ln C_{it}^* = \ln \frac{C_{it}}{w_{L_{it}}} = \alpha + \beta_Y \ln Y_{it} + \beta_Q \ln Q_{it} + \beta_K \ln \frac{w_{K_{it}}}{w_{L_{it}}}
+ \frac{1}{2} \left( \beta_{YY} (\ln Y_{it})^2 + \beta_{QQ} (\ln Q_{it})^2 + \beta_{KK} \left( \ln \frac{w_{K_{it}}}{w_{L_{it}}} \right)^2 \right) \\
+ \beta_{YQ} \ln Y_{it} \ln Q_{it} + \beta_{YK} \ln Y_{it} \frac{w_{K_{it}}}{w_{L_{it}}} \\
+ \beta_{QK} \ln Q_{it} \frac{w_{K_{it}}}{w_{L_{it}}} + \beta_{ID} ID_{it} + \sum_{t=2}^{10} \beta_t D_t
\] (2.2)

with \( \alpha \) representing an intercept term, \( i = 1, 2, ..., 39 \) denoting the company and \( t = 1, 2, ..., 10 \) denoting the year (for the year dummies, \( t = 1 \) (1997) is the omitted year to avoid collinearity).

### 2.2.2 Econometric Models

The focus here is on Stochastic Frontier models exploiting the panel structure of the data. The first proposed models were the Random Effects (RE) model (Pitt and Lee, 1981) and the Fixed Effects (FE) model (Schmidt and Sickles, 1984). Since the amount of within variation in the data is considerably low (at most 6% within variation based on overall variation for costs, outputs, and the remaining factor price)\(^7\) and the Fixed Effects model does not allow the incorporation of efficiency determinants as heteroscedastic factors in the inefficiency function (Kumbhakar and Lovell, 2000, p. 123), I do not consider the Fixed Effects model.

\(^6\)The other properties of the cost function, e.g., that all costs have to be strictly positive, are verified in Sections 2.3 and 2.4.

\(^7\)I calculated the within variation following Farsi et al. (2005a). For further discussion see also Farsi et al. (2005b).
This chapter uses the RE model and its advancements. The Stochastic Frontier RE model as suggested by Pitt and Lee (1981) interprets the panel data random effects as inefficiency. Thus it does not account for firm heterogeneity and the inefficiency measure is time-invariant. Moreover it assumes the explanatory variables to be uncorrelated with the firm-specific effects. The details of the RE model estimated in this chapter are as follows:

\[ \ln C_{it}^* = \alpha + x_{it}'\beta + v_{it} + u_i \]  

with \( x_{it}'\beta \) representing the parameters and the coefficients to be estimated from Equation 2.2 and a normal-half-normal distribution of the stochastic term. The time-variant, firm-specific error part \( v_{it} \sim iid \mathcal{N}(0, \sigma_v^2) \) is independently and identically distributed. \( u_i \) represents the non-negative, time-invariant, firm-specific inefficiency component. The usual assumption is that \( u_i \) is also independently and identically distributed, particularly when there is no evidence about internal firm determinants. In this case, the outsourcing share and the vehicle utilization rate are suspected to be such factors. Including these factors directly in the mean of the inefficiency function as Battese and Coelli (1995) for environmental factors would raise the endogeneity discussion in applied econometrics, although endogeneity does not appear to have the same effect in SFA compared to the econometric estimation of average functions (Coelli, 2000). The approach followed here is to include the managerial determinants \( z_i \) as heteroscedastic variables in the inefficiency function, directly parameterizing the variance of the inefficiency. Formally, \( \sigma_{u_i}^2 = \exp(\gamma'z_i) \) with \( \gamma' \) including an estimated coefficient for an intercept.\(^9\) Such an approach is used by Bhattacharyya et al. (1995).\(^10\) \( z_i \) are the degree of tramcar utilization and the outsourcing grade and should be “... variables related to characteristics of firm management ...” according to Hadri et al. (2003b, p. 206). These authors combine the approach with the Battese and Coelli (1995) model, not followed here.

Introducing heteroscedasticity, the mean of \( u_i \) then becomes to \( E(u_i) = \sigma_{u_i} \varphi(0) = 0.798 \cdot \sigma_{u_i} \) (where \( \varphi \) is the probability density function of the nor-
COST EFFICIENCY AND SOME OF ITS DETERMINANTS

ormal distribution and $\phi$ is the cumulative distribution function of the normal distribution) (Greene, 2007a, pp. E33-38 ff.).

This approach is especially useful when the instrumental variable approach is not suitable, for example due to data constraints. Two-stage estimations also have not proven to be a generally accepted solution in such cases.

This RE model is estimated using the maximum likelihood method. From the composed error term, the inefficiencies are attained through the Jondrow et al. (1982) estimator which uses the conditional mean of the inefficiency term $E[u_i|u_i+v_{it}]$. Disadvantageous to the RE model, the inefficiency is time-invariant and unobserved heterogeneity (likely to exist through the omission of structural variables for network shapes, altitude differences, environmental conditions, etc.) is not accounted for.

The limitations of the RE model can be overcome with the True Random Effects (TRE) model proposed by Greene (2004, 2005b). The details of the TRE model (also known as Random Constant model) estimated in this chapter are as followed:

$$\ln C_{it}^* = \alpha_0 + \alpha_i + x_{it}'\beta + v_{it} + u_{it} \quad (2.4)$$

with $\alpha = \alpha_0 + \alpha_i$, $\alpha_0$ representing the firm-invariant intercept, $\alpha_i \sim iid \mathcal{N}(0, \sigma_\alpha^2)$ and representing a firm-specific random intercept term to capture unobserved heterogeneity, $v_{it} \sim iid \mathcal{N}(0, \sigma_v^2)$ and $u_{it}$ representing the non-negative, time-variant, firm-specific inefficiency component. There are major differences to the RE model. First, the TRE model has a random intercept being normally distributed and capturing unobserved time-invariant heterogeneity. Second, the inefficiency term is time-variant, allowing a much more realistic image of reality. Third, it also assumes the explanatory variables to be uncorrelated with the firm-specific effects, which may be an unrealistic assumption. However, as Farsi et al. (2005b) point out, at least time-variant efficiency measures are not very sensitive to such a correlation because such correlations may be captured by the coefficients of the cost function and do not affect residuals.

The conditional expectation of the inefficiency term $E[u_{it}|r_{it}]$ with $r_{it} = \alpha_i + u_{it} + v_{it}$ is calculated by Monte Carlo simulations (Greene, 2005a) in order to be able to approximate the maximization of the log-likelihood (Greene, 2005b). All estimations for this model are done in one step. Apart from this, the model is very similar to that proposed by Kumbhakar (1991), also applied by Kumbhakar and Hjalmarsson (1995), who use a two-step estimation. The estimations presented in the following again allow for heteroscedasticity in the inefficiency component, so that $\sigma_{u_{it}}^2 = exp(\gamma'z_{it})$. The model is a special case of the Random Parameter (RP) model. An RP model with not only random intercept, but also
random output parameter is the third model estimated in this chapter. The randomness of output parameters is justified by the different technological systems summarized in the rail-bound output category. A relatively slow overground tram in Dresden definitely uses a different technology than a metro-similar light railway system in Stuttgart, with lots of tunnels and a railroad embankment separated from motorized individual transport (MIT). Furthermore, the track gauge of tram systems differs from 1000 mm (Meterspur) to 1435 mm standard railway gauge in Germany. A gauge of only 1000 mm leads to a constant disadvantage in service provision as vehicles have to be smaller with smaller gauges. The heteroscedastic specification is the same as for the TRE model. All the models estimated here assume that the regressors are uncorrelated with the explanatory variables.\footnote{For a more detailed and structured overview of panel data models see the publications by Farsi et al., for example 2006.}

\section{Data}

The data set consists of an unbalanced panel of 254 observations of German multi-output local public transport operators from 1997 until 2006. In total, 39 companies are included with a mean of 6.5 observations per company.\footnote{The exact data structure is as follows: 1997: 22 obs. (observations), 1998 and 1999: 23 obs., 2003: 24 obs., 2004 and 2006: 25 obs., 2000 and 2005: 26 obs., 2002: 29 obs., and 2001: 31 obs.} The physical data (output quantities, input quantities, etc.) was taken from the annual VDV statistics (Verband Deutscher Verkehrsunternehmen, 2007b, and preceding years). All monetary data was extracted separately from annual reports. Table 2.1 shows the descriptive statistics for the data set. The monetary values are given in 2006 prices and inflated by the German producer price index (Statistisches Bundesamt, 2008). Total expenditures include: labor, materials, other operating expenses, depreciation, interest on borrowed capital, and opportunity costs of capital. Cost of equity was not directly available from the data set, and was calculated by taking the equity base for each company and year and multiplying by the interest rates for corporate bonds at that time plus 2% risk premium (source for interest rates: Deutsche Bundesbank, 2007). Notably this approach treats all companies equally. This may be justified by the public ownership of the vast majority of Germany’s local public transport companies.

For the purpose of calculating factor prices, all cost items except labor costs are included into capital and operating expenses. The shares for personnel costs as well as capital and operating expenses show a relatively wide range from 0.19 to 0.62 and 0.38 to 0.81, respectively. The reason for this is outsourcing of services to private partners and particularly to privately organized subsidiaries,
COST EFFICIENCY AND SOME OF ITS DETERMINANTS

Table 2.1: Descriptive statistics for multi-product companies

<table>
<thead>
<tr>
<th>Measure</th>
<th>Sum(^a)</th>
<th>Min.</th>
<th>Mean</th>
<th>Median</th>
<th>Max.</th>
<th>Std. dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total cost ((C)) ([\text{m EUR}])</td>
<td>2823</td>
<td>12</td>
<td>111</td>
<td>70</td>
<td>363</td>
<td>87</td>
</tr>
<tr>
<td>Share personnel costs ([\text{EUR/FTE}])</td>
<td>0.19</td>
<td>0.46</td>
<td>0.46</td>
<td>0.62</td>
<td>0.08</td>
<td></td>
</tr>
<tr>
<td>Share capital costs ([\text{EUR/seat}])</td>
<td>0.38</td>
<td>0.54</td>
<td>0.54</td>
<td>0.81</td>
<td>0.08</td>
<td></td>
</tr>
<tr>
<td>Labor price ((w_L)) ([\text{EUR/FTE}])</td>
<td>30 639</td>
<td>49 636</td>
<td>50 409</td>
<td>82 610</td>
<td>8714</td>
<td></td>
</tr>
<tr>
<td>Capital price ((w_K)) ([\text{EUR/seat}])</td>
<td></td>
<td>934</td>
<td>1917</td>
<td>1679</td>
<td>5064</td>
<td>766</td>
</tr>
<tr>
<td>Output ([\text{m seat-km}])</td>
<td></td>
<td>17 122</td>
<td>4 656</td>
<td>459 2303</td>
<td>503</td>
<td></td>
</tr>
<tr>
<td>Bus ((Y))</td>
<td></td>
<td>27 482</td>
<td>50 1018</td>
<td>644 4800</td>
<td>974</td>
<td></td>
</tr>
<tr>
<td>Rail-bound ((Q))</td>
<td></td>
<td>50 1018</td>
<td>644 4800</td>
<td>974</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inverse density index ((ID)^b)</td>
<td></td>
<td>138 862</td>
<td>787 2958</td>
<td>458</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outsourcing share ((OUT)^c,d)</td>
<td></td>
<td>0.00 0.16</td>
<td>0.12 0.59</td>
<td>0.19</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Railcar utilization rate ((UR)^b,e)</td>
<td></td>
<td>47.33 135.66</td>
<td>128.11 250.23</td>
<td>39.27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vehicles</td>
<td></td>
<td>3650 2 146 103 470</td>
<td>106</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bus</td>
<td></td>
<td>2855 6 124 85 513</td>
<td>106</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) Sum values for 2006, \(^b\) Inhabitants per km network length, \(^c\) Based on total costs, \(^d\) Calculated over 254 observations (note that the Random Effects model uses group means as z-variables), \(^e\) Vehicle-km per day and vehicle.

Source: Own calculation

which often employ significant amounts of transport labor. In the profit and loss accounts, expenses for such employment are classified as expenses for purchased services.

The labor price is calculated as personnel costs divided by the number of full-time-equivalents (FTEs). The high range from 30 639 to 82 610 EUR is related to regional wage differences, different age structures, outsourcing of low-paid functions, and different handling of pension accruals. The capital price is calculated as residual costs (total costs minus personnel costs) divided by a measure of capital quantity, the number of seats in buses and rail-bound cars (both standing and sitting), following Farsi et al. (2007). The number of seats was not directly available from the VDV statistics, but approximated by the number of seat-kilometers multiplied by the number of buses and cars divided by the number of vehicle-kilometers. The underlying assumption is that the deployment of each bus and railcar is uniformly distributed.

Assuming a common factor price for capital and operations for both kinds of outputs has two shortcomings. First, buses and rail-bound cars are treated
equally which may diverge from actual fixed and variable costs proportions. Second, dividing by the number of seats is a pure capital measure neglecting operational costs like energy costs. However, absent more detailed information about the structure of non-personnel costs, this is the best approach available.

The two outputs are seat-kilometers in buses and seat-kilometers in rail-bound cars. Tram, light railway, and metro services are not split into different outputs because there is no clear definitional separation between these services and transitions are smooth. The inverse density index is defined as population in the supplied area divided by the sum of bus line length and rail-bound track length.

Turning to the heteroscedastic variables, the outsourcing share is defined as purchased services (part of material costs) divided by total costs. According to the German Commercial Code, purchases, e.g., for energy or line services, are always considered material costs. The outsourcing share has steadily increased from 0.09 in 1997 to 0.24 in 2006. Some companies like Leipziger Verkehrs-betriebe and Verkehrsgesellschaft Frankfurt have founded subsidiaries for bus and tram operations. The subsidiaries Leobus and Leipziger Stadtverkehrvertriebe (LSVB) and In-der-City-Bus pay lower wages that are not bound to civil service tariffs. These subsidiary operations have been classified as purchased services. This can also be seen in the correlation matrix in Table 2.2. The capital price and the outsourcing share show a relatively high correlation (0.663) because outsourcing shifts personnel costs into the capital block. With the capital quantity remaining unchanged, a higher capital price without any real price increases results. This favors companies with higher outsourcing shares almost automatically because the capital price is assumed to be exogenous in the cost-function specification. Hence, a higher capital price explains the variation of the dependent variable and firms become more efficient.

This potential bias could be overcome with the introduction of a third factor price for purchased services. Unfortunately no information is available for the quantity of purchased services and the only price index would be a country-wide

\footnote{Tram services are usually characterized as pure overground services often with no separate railroad embankment (from MIT). Examples include the major East German cities like Dresden and Leipzig and the smaller West German cities. Light railway services are typically characterized by higher average speeds and inner-city tunnels, although their overall operations are similar to suburban tramways. In the 1970s, many bigger West German cities invested in new infrastructure for light railways to transform their existing tram services.}

\footnote{In a preliminary estimation I introduced the network length as alternative network variable. This resulted in significance problems.}

\footnote{I am aware that, in an unbalanced panel, this increase can also be due to the data structure, e.g., firms in early years with low outsourcing share and firms in late years with high outsourcing share. However, a closer look on the data provides no evidence to defend this hypothesis.}

\footnote{LVB achieved an outsourcing share of approximately 59% in 2006 with 133 m EUR of purchased services.}
one assigning a common factor price to all companies. Therefore, the results must be interpreted with care. On the other hand, some concurrent tendencies in the covered period may partially explain the high correlation, e.g., the capital price includes purchased energy which showed a steady price increase in past years, corresponding to an increasing outsourcing share. Furthermore this is a luxury problem in comparison to the evaluation of technical efficiencies with production or distance functions which very often neglect the presence of outsourcing.

The second heteroscedastic component is the vehicle utilization rate of railcars per day defined as vehicle-kilometers divided by the number of railcars and 365 days. The broad range from 47.33 for Jena in 1997\(^{17}\) to 250.23 for Oberhausen (STOAG – Stadtwerke Oberhausen) in 2005 indicates an improvement potential. The indicator is a measure for the actual deployment time and for the average speed of these transport systems.\(^{18}\) The low correlation coefficient between the utilization rate and the inverse density index (0.082) shows that a low utilization rate is mostly unrelated to congestion costs, and may be related instead to technological constraints and network characteristics which are supposed to be manageable, at least in the long-term, especially for the municipal owners of local public transport firms. The utilization rate is furthermore also related to pure managerial factors like maintenance time planning, vehicle scheduling, and to a certain degree peak demand levels, which are outside the influence of the management. For these reasons I use the utilization rate as in-

\(^{17}\)47.33 relies on construction activities in Jena’s inner city in 1997, though many tram services were replaced by bus services in that year. The second-lowest value is 72.98 with similar other values in the near range.

\(^{18}\)A similar vehicle utilization rate could be calculated for bus operations. However, I was not able to estimate a model in which all managerial variables, outsourcing share, utilization rate for railcars and vehicle utilization rate for buses, were significant. This may be due to the high dependency between outsourcing and bus utilization. Many firms employ small- and medium-sized bus companies from the surrounding areas that can be called up on short notice as subcontractors.
fluenceable by management, acknowledging that it could also be interpreted as exogenous (e.g., Piacenza, 2006).

It would be nice to have data on the quality of services. Nowadays, many buses are low-floor buses for ease of entry and exit. No consistent data basis for amenities such as the availability of air conditioning exists. I can deduce from the data that speed matters, causing many potential customers to choose private auto over local transport.

Although the data offers rich interpretation possibilities, there are some aspects to consider. First, the asset valuation excludes subsidies from the public sector (and hence distorts the opportunity cost of capital) and second, the land for stops and the road bed is very often public property. Still, it is valuable to examine total costs instead of variable costs, because the measure of efficiency can be biased when looking only at parts of the total costs.

2.4 Results and Interpretation

2.4.1 Regression Results

Table 2.3 shows the regression results for the Random Effects (RE), for the True Random Effects (TRE) and for the Random Parameter (RP) models. All first-order coefficients show the expected signs and are significant at the 1% level. The positive coefficients of output quantities and input prices verify the non-decreasing-conditions of the cost function. All model parameters are in logs, so the output coefficients can be interpreted as cost elasticities at the local point of approximation, which is represented here by the mean. Across all models, the cost elasticities for rail-bound services are substantially higher (between 0.493 and 0.500) than for bus services (between 0.387 and 0.430). An additional seat-kilometer in a bus is hence approximately 25% cheaper than in a tram, light railway, or metro. This may be reflected by the high fixed-cost proportion in rail-bound services for the network and the cars which are mostly custom-made for each single operator. These higher cost elasticities accompany the greater comfort of rail-bound cars which are wider and quieter.

The capital price coefficient varies slightly around 0.47, closely representing

---

19I have conducted the estimations with Limdep 9.0, using 1000 Halton draws for the RP models after initial estimations using 50 Halton draws. Accuracy, as Train (2003) points out, improves with an increasing number of Halton draws.

20The random output coefficients of the RP model hereby should be interpreted with care, because, through the randomization, there is no unique parameter to assess, only a mean coefficient given.
Table 2.3: Regression results for the translog cost function

<table>
<thead>
<tr>
<th>Model</th>
<th>RE</th>
<th>TRE</th>
<th>RP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
<td>Estimate</td>
<td>Estimate</td>
<td>Estimate</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>-0.105**</td>
<td>0.036</td>
<td>0.013</td>
</tr>
<tr>
<td>$\sigma_K$</td>
<td>0.095***</td>
<td>0.096***</td>
<td>(0.044)</td>
</tr>
<tr>
<td>$\beta_Y$</td>
<td>0.430***</td>
<td>0.406***</td>
<td>0.387***</td>
</tr>
<tr>
<td>$\sigma_{\beta_Y}$</td>
<td>.</td>
<td>.</td>
<td>0.103***</td>
</tr>
<tr>
<td>$\beta_Q$</td>
<td>0.494***</td>
<td>0.500***</td>
<td>0.493***</td>
</tr>
<tr>
<td>$\sigma_{\beta_Q}$</td>
<td>.</td>
<td>.</td>
<td>0.030***</td>
</tr>
<tr>
<td>$\beta_K$</td>
<td>0.464***</td>
<td>0.467***</td>
<td>0.473***</td>
</tr>
<tr>
<td>$\beta_{YY}$</td>
<td>0.145**</td>
<td>0.165***</td>
<td>0.159***</td>
</tr>
<tr>
<td>$\beta_{QQ}$</td>
<td>0.151***</td>
<td>0.150***</td>
<td>0.162***</td>
</tr>
<tr>
<td>$\beta_{KK}$</td>
<td>0.381</td>
<td>0.276***</td>
<td>0.252***</td>
</tr>
<tr>
<td>$\beta_{YQ}$</td>
<td>-0.098**</td>
<td>-0.149***</td>
<td>-0.152***</td>
</tr>
<tr>
<td>$\beta_{YK}$</td>
<td>0.061</td>
<td>0.019</td>
<td>0.024</td>
</tr>
<tr>
<td>$\beta_{QQ}$</td>
<td>-0.058</td>
<td>-0.058***</td>
<td>-0.059***</td>
</tr>
<tr>
<td>$\beta_{1998}$</td>
<td>-0.058</td>
<td>-0.033</td>
<td>-0.032</td>
</tr>
<tr>
<td>$\beta_{1999}$</td>
<td>-0.057</td>
<td>-0.041</td>
<td>-0.041</td>
</tr>
<tr>
<td>$\beta_{2000}$</td>
<td>-0.098**</td>
<td>-0.074**</td>
<td>-0.073***</td>
</tr>
<tr>
<td>$\beta_{2001}$</td>
<td>-0.126***</td>
<td>-0.091***</td>
<td>-0.091***</td>
</tr>
<tr>
<td>$\beta_{2002}$</td>
<td>-0.160***</td>
<td>-0.121***</td>
<td>-0.122***</td>
</tr>
<tr>
<td>$\beta_{2003}$</td>
<td>-0.212***</td>
<td>-0.162***</td>
<td>-0.161***</td>
</tr>
<tr>
<td>$\beta_{2004}$</td>
<td>-0.235***</td>
<td>-0.186***</td>
<td>-0.186***</td>
</tr>
<tr>
<td>$\beta_{2005}$</td>
<td>-0.236***</td>
<td>-0.182***</td>
<td>-0.183***</td>
</tr>
<tr>
<td>$\beta_{2006}$</td>
<td>-0.237***</td>
<td>-0.184***</td>
<td>-0.185***</td>
</tr>
<tr>
<td>$\beta_{1D}$</td>
<td>0.064**</td>
<td>0.047***</td>
<td>0.050***</td>
</tr>
<tr>
<td>$\gamma_0$</td>
<td>.</td>
<td>6.072***</td>
<td>6.134***</td>
</tr>
<tr>
<td>$\gamma_{OUT}$</td>
<td>.</td>
<td>-0.260*</td>
<td>-0.252*</td>
</tr>
<tr>
<td>$\gamma_{UR}$</td>
<td>-2.744</td>
<td>-6.749***</td>
<td>-6.722***</td>
</tr>
<tr>
<td>$\sigma_u$</td>
<td>0.714</td>
<td>0.035</td>
<td>0.036</td>
</tr>
<tr>
<td>$\lambda = \sigma_u / \sigma_v$</td>
<td>12.948</td>
<td>0.799</td>
<td>0.888</td>
</tr>
</tbody>
</table>

* ** Significant at 1%, ** significant at 5%, * significant at 10%, Standard errors in parentheses, omitted for year dummies for reasons of space.

Source: Own calculation
COST EFFICIENCY AND SOME OF ITS DETERMINANTS

the 54% share of capital and operational costs. The year dummies are significantly negative from 2000 on, suggesting cost decreases because of technological progress between 7 and 10% in comparison to 1997. Further cost decreases are observable until 2004 when cost savings between 18 and 23% are established. Afterwards the level remains stable. This trend is obviously not linear, leading my preliminary estimations with a linear time trend to implausible results. Applying the approach by Saal et al. (2007) and allowing for technical change to vary with input and output levels did not produce significant interaction terms between independent variables and time. The technological progress may be represented by new buses and tramcars, e.g., East Germany’s old Tatra tramcars have been replaced. The use of innovative information technology may also play a role. The coefficient of the inverse density index is significantly positive indicating that higher population per network length leads to higher costs, for example through reduced speed in urban areas, wait times at traffic lights, higher wages, and so on. The inverse density index can be seen as an efficiency determinant outside the influence of management.

The coefficient of the second derivative of the cost function with respect to the capital price is positive across all models, violating the concavity property of the cost function (Cornes, 1992, p. 106). According to Farsi et al. (2005b) and Farsi and Filippini (2009), this may originate from some constraints in the cost-minimizing strategy. For instance, competitive pressure may not be too strong and responses to input prices are quite small. The reasons are that publicly owned local transport firms are vulnerable to political concerns and the transfer of losses from municipalities and affiliated energy companies.

I will next consider the model-specific heteroscedastic (\(z\)) variables and the random parameter. There are two heteroscedastic variables: outsourcing rate and tramcar utilization. These variables are not significant for the RE model. I conducted likelihood-ratio tests in order to check the explanatory power of the heteroscedastic variables. A model with tramcar utilization rate (UR) as only heteroscedastic variable is preferred to a basic model without heteroscedasticity at a p-value of 1.4%. Adding the outsourcing share does not lead to any improvement and is rejected at a p-value of 99.1%. The coefficient for UR is negative suggesting that firms with high utilization rates tend to have less variability in efficiency; hence it appears to introduce planning reliability (see Hadri et al., 2003a, on how to interpret heteroscedastic variables). For the TRE and RP models, Wald tests have been used to check for the explanatory power of the heteroscedastic components. The hypothesis that the coefficient of the tramcar utilization rate is equal to zero is rejected at a p-value of 0% for both models.

\[ \text{Through imposing the linear homogeneity in input prices, a labor price coefficient of 0.53 follows.} \]
The hypothesis that the coefficient of the outsourcing share is zero is rejected at p-values of 7.3 and 6.7% respectively. The coefficient for both models is also significantly negative, meaning that a higher outsourcing share leads to less variability in efficiency. The delegation of services to third parties on short notice appears to reduce risks and introduces stability in economic efficiency.

The random output parameters for the RP model are both significant, supporting the use of this model. The variation for bus services appears to be even higher than for tram, light railway, and metro services. This can be related inter alia to the deployment of standard and articulated buses.

### 2.4.2 Efficiencies

Table 2.4 shows statistics for the efficiency predictions. Efficiency predictions are given as levels in a range between greater than 0 and 1. The cost savings potential is given by the difference from 1, that is, a global minimum efficiency level of 0.650 means 35% excess costs.

As expected, the mean for the RE model is much lower than for the TRE model, because the latter treats all persistent inefficiency (as Kumbhakar, 1991, calls it) as unobserved heterogeneity. From the descriptive statistics, the TRE model and the RP model appear quite similar with a slightly higher standard deviation of efficiency predictions for the RP model which allows more diversity. As Farsi and Filippini (2009) point out, the true efficiencies should lie somewhere between the RE model, which is supposed to underestimate efficiency, and the TRE model, which is supposed to overestimate efficiency. The happy medium is around 0.9, which is in a realistic albeit relatively high range. Restructuring and increased cost efficiencies throughout Germany appear to be somehow successful. An example for substantial efficiency differences between the two models is Bremer Straßenbahnen AG (BSAG) with an efficiency prediction of 0.768 in the RE model and up to 0.957 for 2005 in the TRE model. The question remains whether this is related to unobserved heterogeneity (Bremen’s tram system does

<table>
<thead>
<tr>
<th>Model</th>
<th>RE</th>
<th>TRE</th>
<th>RP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>0.650</td>
<td>0.855</td>
<td>0.844</td>
</tr>
<tr>
<td>Mean</td>
<td>0.862</td>
<td>0.952</td>
<td>0.949</td>
</tr>
<tr>
<td>Median</td>
<td>0.866</td>
<td>0.960</td>
<td>0.954</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.990</td>
<td>0.993</td>
<td>0.993</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>0.090</td>
<td>0.031</td>
<td>0.032</td>
</tr>
<tr>
<td>No. of efficiencies</td>
<td>39</td>
<td>254</td>
<td>254</td>
</tr>
</tbody>
</table>

Source: Own calculation

The hypothesis that the coefficient of the outsourcing share is zero is rejected at p-values of 7.3 and 6.7% respectively. The coefficient for both models is also significantly negative, meaning that a higher outsourcing share leads to less variability in efficiency. The delegation of services to third parties on short notice appears to reduce risks and introduces stability in economic efficiency.

The random output parameters for the RP model are both significant, supporting the use of this model. The variation for bus services appears to be even higher than for tram, light railway, and metro services. This can be related inter alia to the deployment of standard and articulated buses.

### 2.4.2 Efficiencies

Table 2.4 shows statistics for the efficiency predictions. Efficiency predictions are given as levels in a range between greater than 0 and 1. The cost savings potential is given by the difference from 1, that is, a global minimum efficiency level of 0.650 means 35% excess costs.

As expected, the mean for the RE model is much lower than for the TRE model, because the latter treats all persistent inefficiency (as Kumbhakar, 1991, calls it) as unobserved heterogeneity. From the descriptive statistics, the TRE model and the RP model appear quite similar with a slightly higher standard deviation of efficiency predictions for the RP model which allows more diversity. As Farsi and Filippini (2009) point out, the true efficiencies should lie somewhere between the RE model, which is supposed to underestimate efficiency, and the TRE model, which is supposed to overestimate efficiency. The happy medium is around 0.9, which is in a realistic albeit relatively high range. Restructuring and increased cost efficiencies throughout Germany appear to be somehow successful. An example for substantial efficiency differences between the two models is Bremer Straßenbahnen AG (BSAG) with an efficiency prediction of 0.768 in the RE model and up to 0.957 for 2005 in the TRE model. The question remains whether this is related to unobserved heterogeneity (Bremen’s tram system does
COST EFFICIENCY AND SOME OF ITS DETERMINANTS

Table 2.5: Efficiency correlations

<table>
<thead>
<tr>
<th>Model</th>
<th>RE</th>
<th>TRE</th>
<th>RP</th>
</tr>
</thead>
<tbody>
<tr>
<td>RE</td>
<td>100.00%</td>
<td>95.58%</td>
<td>96.11%</td>
</tr>
<tr>
<td>TRE</td>
<td>100.00%</td>
<td>98.52%</td>
<td>98.75%</td>
</tr>
<tr>
<td>RP</td>
<td></td>
<td>100.00%</td>
<td></td>
</tr>
</tbody>
</table>

Based on average firm values (39 obs.), in brackets based on all observations

Source: Own calculation

not rely on a sophisticated infrastructure with tunnels, etc.) or if it is persistent inefficiency. Interestingly, in 2005 BSAG achieved a very low level of cost coverage of only 50.95%.²²

The value of 0.9 also corresponds to the mean efficiency at the outset of incentive regulation for German electricity and gas distribution companies (Agrell et al., 2008a,b, taking a best-of value of SFA and DEA values), which makes this number a reasonable value for local network monopolies. The inefficiencies refer to a savings potential of 1.40 to 4.43 bn EUR in 2006 prices, depending on the applied panel data model, for all 254 observations from 1997 until 2006. I note that for the TRE model at least 117 m EUR could have been saved by the 25 firms considered in 2006.²³

Table 2.5 shows the efficiency correlations with high consistencies. The rank correlations shown in Table 2.6 show similar results. However, a comparison of individual efficiency levels (mean over years) in Figure 2.1 shows that unobserved heterogeneity plays an important role for some specific firms with differences up to 20% between the RE and TRE models.

A detailed look at the Kernel Density Estimate in Figure 2.2 also shows that the distribution of efficiency predictions differs most between the RE and the other two models. All curves suggest the efficiency to be negatively skewed which is the usual assumption in Stochastic Cost Frontier models. The bimodal distribution in the RE model however goes against the assumption of a half-normally distributed inefficiency. As Farsi and Filippini (2009, p. 313) point out, this may be explained by “... cost differences that are not due to inefficiencies but to other external factors.” In such a case, a RE model would not be appropriate for the given data.

I now look at the efficiency determinants under managerial control, the outsourcing share and the vehicle utilization rate. To check whether observations

²² Calculated as revenues (corrected from subsidies) divided by the total cost definition applied here.
²³ Savings potential is calculated as the sum of individual inefficiency scores multiplied by individual total costs.
COST EFFICIENCY AND SOME OF ITS DETERMINANTS

Table 2.6: Rank correlations

<table>
<thead>
<tr>
<th>Model</th>
<th>RE</th>
<th>TRE</th>
<th>RP</th>
</tr>
</thead>
<tbody>
<tr>
<td>RE</td>
<td>100.00%</td>
<td>94.99%</td>
<td>95.50%</td>
</tr>
<tr>
<td>TRE</td>
<td>100.00%</td>
<td>97.70% [98.77%]</td>
<td></td>
</tr>
<tr>
<td>RP</td>
<td>100.00%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Based on average firm values (39 obs.), in brackets based on all observations.

Source: Own calculation

Figure 2.1: Comparison of efficiency predictions

Source: Own calculation

with low values of these indicators really are less efficient, I split the sample into values below and values equal or above the median (for both indicators). Mean efficiencies for these sub samples are given in Table 2.7. In all three models, mean efficiencies for low outsourcing shares and low vehicle utilization rates are significantly lower. For the outsourcing share the differences in mean efficiencies are somehow lower (between 0.007 and 0.019) resulting in p-values between 0.0002 and 0.0198. These p-values are still low enough to reject the hypothesis of equal distribution of efficiency values in the groups with low respectively high outsourcing share. Outsourcing therefore appears to increase efficiency. Still, this variable has to be interpreted carefully. Compared with the vehicle utilization rate, higher values do not necessarily mean better values, for there could be an optimal outsourcing grade.

The results are even clearer for the vehicle utilization rate. Differences in mean efficiencies of the group with a low vehicle utilization rate compared to the group with a high vehicle utilization rate account for approximately 0.03-0.07, depending on the applied panel data model. These distribution differences are all significant with very low p-values. Higher values of the railcar utilization rate
have a positive influence on efficiency, as expected. This is related to higher average speeds, better deployment times, and lower maintenance and stop times and costs. The effect on efficiency also appears to be stronger than for the outsourcing share.

2.5 Conclusion

In this chapter, I estimated state-of-the-art models of Stochastic Frontier Analysis incorporating unobserved heterogeneity and allowing for heteroscedasticity in the inefficiency function. Incorporating unobserved heterogeneity is important when the data set omits environmental/structural variables which are likely to influence the production process. This is an important application, although I also showed that observed heterogeneity plays a significant role as well. The inverse density index defined as population living in the network area has a cost-increasing influence.

Two efficiency determinants under managerial control were included as heteroscedastic variables in the inefficiency function. I conducted tests on the influence of these managerial determinants on mean efficiencies of groups with
Table 2.7: Efficiency comparisons and Kruskal-Wallis tests

<table>
<thead>
<tr>
<th>Model</th>
<th>RE</th>
<th>TRE</th>
<th>RP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outsourcing (OUT)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean efficiency for low OUT</td>
<td>0.837</td>
<td>0.948</td>
<td>0.944</td>
</tr>
<tr>
<td>Mean efficiency for high OUT</td>
<td>0.855</td>
<td>0.955</td>
<td>0.953</td>
</tr>
<tr>
<td>$\chi^2$-value</td>
<td>5.432</td>
<td>9.712</td>
<td>14.353</td>
</tr>
<tr>
<td>Probability</td>
<td>1.98%</td>
<td>0.18%</td>
<td>0.02%</td>
</tr>
<tr>
<td>Vehicle utilization (UR)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean efficiency for low UR</td>
<td>0.811</td>
<td>0.936</td>
<td>0.934</td>
</tr>
<tr>
<td>Mean efficiency for high UR</td>
<td>0.881</td>
<td>0.967</td>
<td>0.963</td>
</tr>
<tr>
<td>$\chi^2$-value</td>
<td>34.979</td>
<td>63.114</td>
<td>52.008</td>
</tr>
<tr>
<td>Probability</td>
<td>0.01%</td>
<td>0.01%</td>
<td>0.01%</td>
</tr>
</tbody>
</table>

Source: Own calculation

high vs. low outsourcing and high vs. low vehicle utilization. All Kruskal-Wallis tests indicated that the high values show a higher efficiency distribution. This implies great potential for improvements. Optimization of outsourcing should be in focus for businessmen emphasized for firms that have neglected it in the past. The options include establishing subsidiaries or cooperating with small- and medium-sized firms. The vast differences in the vehicle utilization rate for railcars (shown in the descriptive data statistics) are somewhat surprising. Improvement options can be related to enhancing speed through infrastructure measures (separate rail embankments, prioritization at traffic lights, tunnels in inner-city areas, new tracks, express trains similar to those in Karlsruhe, etc.). Furthermore maintenance times could be reduced and procurement optimized.

In an international context, the analysis shows how cost efficiency and hence economic success of local public transport relates to the utilization degree of vehicles. For example, local public transport must achieve intermodally competitive average speeds, supported by adequate transport planning and policy measures.

Considering Germany’s low mean level of cost coverage with 73.8% (Verband Deutscher Verkehrsunternehmen, 2008), the problem is likely to extend beyond the cost side. I found mean efficiencies roughly about 0.9, meaning that full efficiency would also imply a negative level of cost coverage. Some past improvements have often been attributed to wage reductions. The revenue side should bear further optimization potential and should be analyzed in the future. These results impact corporate strategies and point to the need for a comprehensive, national regulation.
Chapter 3

Economies of Scale and Scope

3.1 Introduction

Germany’s urban public transport is undergoing industry consolidation at the same time that changes in structure and market rules are occurring. A fragmented market comprising several 1000 companies has begun to alter due to the mergers and acquisitions of neighboring companies and efforts by firms with strong capital bases seeking opportunities for growth. Moreover, tenders have become an instrument for introducing market competition. In the past, large shares of local public transport services have been financed by subsidies from public authorities. However, in the present budgetary crisis, public transport is under pressure to operate as efficiently as possible.¹

The purpose of this chapter is to determine these efficient structures from two angles: First, to evaluate scale economies, i.e., if existing services in larger entities could be produced at less cost; second, to determine the appropriate economies of scope, i.e., the cost savings from the combined services or products. There are various types of economies of scope in transport. Here I refer to economies of scope from producing bus services on the one hand and tram and light railway services on the other hand together.² The approach to the estimation of economies of scale and scope applied in this chapter follows three guidelines:

1. Econometric cost functions are applied. The major requirement for such an analysis is the availability of a consistent and sufficiently large enough panel data set containing information about cost items and production

¹The subsequent chapter is based on Walter (2009a).
²This chapter does not address economies of scope in the sense of potential savings between the tram network and the actual service provision, as is often performed for railways. This chapter assumes integration (status quo in Germany).
quantities of urban public transport operators. Such a data set has not been available in the past. This thesis is the first empirical application of this kind for Germany.

2. Historically, analysis relied on the estimation of average functions with ordinary least squares or panel data models (see Berechman, 1993, pp. 111 ff., for an introduction). Employing Stochastic Frontier Analysis allows researchers to estimate for the optimal (frontier) cost levels and acknowledge the presence of firms’ inefficiency. Since economies of scale and scope are used to determine the optimal market structure, it appears natural to do this with optimal cost curves.

3. SFA also allows the use of panel data models. These models should be preferred to a pooled model (Aigner et al., 1977) because a pooled model treats each observation independently from other observations which is obviously not satisfied in a panel data set. In such a case, panel data models exhibit estimation advantages over techniques for cross-sectional data (Kumbhakar and Lovell, 2000, p. 255). A basic SFA panel data model is the Random Effects model by Pitt and Lee (1981) which treats all heterogeneity as inefficiency. The results can then be compared to a True Random Effects model by Greene (2004, 2005a) which is able to account for unobserved heterogeneity and separates this effect from inefficiency. Unobserved heterogeneity is not recorded through structural variables in the data set but is likely to be present in local public transport through network complexities, i.e., differences in network configurations, stop densities, altitudes, etc.

An econometric study relying on an average cost function on economies of scale and scope in Switzerland’s local public transport was carried out by Farsi et al. (2007). Their results for the provision of trolley-bus, motor-bus, and tramway systems indicate such significant increasing returns to scale and economies of scope that the authors favor integrated operations over unbundling. Viton (1992, 1993) evaluated economies of scale and scope for different means of transport in the San Francisco Bay Area with a cross-sectional SFA, and determine that the extent of the savings potential depends on firm size, type of transport modes, and level of wages.

The investigation of scale economies and cost efficiency of single-mode transport systems appears more frequently in the literature because of the ease of modeling and data availability. Farsi et al. (2006) emphasize the need to distinguish between inefficiency and heterogeneity and therefore also apply Greene’s TRE model (2004, 2005a).
This chapter is structured in the following way: Section 3.2 provides the model specification and the econometric methods and Section 3.3 presents the calculation scheme for economies of scale and scope. Section 3.4 describes the data, Section 3.5 discusses the results and interpretations, and Section 3.6 concludes.

### 3.2 Model Specification and Econometric Methods

The total cost \( C \) frontier

\[
C = f(Y, Q, w_L, w_K, N, t)
\]  

(3.1)

applied in this chapter is dependent on the two outputs \( (Y) \) and \( (Q) \), on two factor prices for labor \( (w_L) \) and capital \( (w_K) \), on the network length for rail-bound services \( (N) \), and on a time trend \( (t) \). To evaluate the economies of scope the output is split into output of bus services \( (Y) \) and output of rail-bound services \( (Q) \), i.e., tram and light railway services. I do not differentiate among the different rail-bound services since there are no distinctive criteria available for separation; e.g., one could use average speed as well as the existence of tunnels. The outputs are represented by the number of seat-kilometers (including both sitting and standing room). Using seat-kilometers is preferable to using vehicle kilometers because the latter does not account for size of vehicles. Both measures represent a pure supply side consideration. Other applicable output variables are passenger-kilometers, the number of passengers, or even revenues. In order to estimate economies of scope between different types of services, the outputs have to be available separately for each transport mode. In the data set at hand, passenger-kilometers and revenues are only available as aggregates, the number of passengers is not at all reported.\(^3\) If output-oriented measures were available, a comparison to supply-oriented output measures would be interesting. This chapter gives full intervention possibilities by management only for the input side; thus, the estimation of a cost function with assumed cost minimizing behavior\(^4\) and supply-oriented output measures appears reasonable (Gagnepain and Ivaldi, 2002b; Farsi et al., 2007). Nevertheless, passenger-kilometers and the

---

\(^3\) Whereas local public transport companies know the number of vehicle- and seat-kilometers from their operation schedules, there is limited knowledge about the other measures. Customers who buy single tickets do not reveal their destinations because the tariff system is organized in zones with fixed payment tariffs. Moreover, buying a bus ticket can involve transfers. Monthly and seasonal passes do not report the actual trips taken. This distinguishes local public transport from airlines and to a lesser extent, from railways. Additionally, buses do not distinguish between classes of service, unlike rail and air.

\(^4\) This implies input orientation. Outputs and input prices are assumed to be exogenously given.
number of passengers are further important indicators, and the same number of seat-kilometer can generate different amount of revenues, depending on the tariff system, the percentage of monthly tickets, the subsidies for transporting pupils and disabled people, the amount of paid advertising on vehicles, etc. However, demand would take me far from measures of cost efficiency and productivity, to measures of effectiveness (De Borger et al., 2002), and further to the question whether the companies actually achieve to maximize their revenues. Though, the purpose of this chapter is to evaluate the adequate supply structures for local public transport. Demand and revenues are beyond the scope of this chapter.

Generally, transport studies identify one input as personnel expenditures. Farsi et al. (2005a) suggest two additional inputs: energy expenditures and capital expenditures, with the latter calculated as residual costs after subtracting personnel costs and energy costs from total costs. When the share of energy costs is low, and thus coefficients of parameters could be insignificant, the literature suppresses the energy input and summarizes capital costs and energy costs as a common second input (e.g., Farsi et al., 2007). Since this chapter’s data set lacks information about energy consumption, I use two factor prices: one for labor \( (w_L) \) and one for capital \( (w_K) \).

From an economic point of view, other factor price specifications may be useful, e.g., the substantial difference in capital costs for bus services and rail-bound services could be modeled. Usually, the provision of rail-bound services is preferred to the provision of bus services, because of increased customer attractiveness and increased capacity. On the other hand rail-bound services clearly have higher infrastructure costs. However, in the absence of detailed information about the companies’ cost structure concerning bus and rail-bound capital costs, it is difficult to implement such a differentiation. A common allocation with the same split for all companies can lead to collinearity problems in the estimation procedure. This chapter omits this possibility.

In addition, I am confident that reliable results are produced by the accepted approach that introduces two factor prices for labor and capital, the assumed exogeneity of factor prices, and the rich data set.

However, I do include track length of the tram and light rail network \( (N) \) as an additional network characteristic and control variable because it heavily influences a company’s cost. This variable can also serve as a quality proxy because users often prefer trams because of their superior comfort. I also tested the influence of two other possible structural variables: network length including line length of bus services and track length of rail-bound services and a density index calculated by the number of inhabitants in the influence area divided by the network length. Neither showed significant coefficients in the estimation procedure. However, it is probable that more network heterogeneity (different shapes, num-
ber of stops, etc.) is of substantial influence. This makes it important to model this unobserved heterogeneity with the TRE model explained below. A linear time trend \((t)\) captures the shift in technology representing technical change.

To evaluate economies of scope in a multi-output context, it is crucial to use a quadratic cost function because it allows the incorporation of zero outputs.\(^5\) This is not possible with a logarithmized Cobb-Douglas nor translog functional forms where all outputs are given in logs.\(^6\) The quadratic cost function can be written as:

\[
C_{it} = \alpha + \beta_Y Y_{it} + \beta_Q Q_{it} + \beta_K w_{K_{it}} + \beta_L w_{L_{it}} \\
+ \frac{1}{2} \left( \beta_{YY} (Y_{it})^2 + \beta_{QQ} (Q_{it})^2 + \beta_{KK} (w_{K_{it}})^2 + \beta_{LL} (w_{L_{it}})^2 \right) \\
+ \beta_Y Q_{it} Q_{it} + \beta_{YK} Y_{it} w_{K_{it}} + \beta_{YL} Y_{it} w_{L_{it}} \\
+ \beta_{QK} Q_{it} w_{K_{it}} + \beta_{QL} Q_{it} w_{L_{it}} + \beta_{KL} \ln w_{K_{it}} w_{L_{it}} \\
+ \beta_N N_{it} + \beta_t t + \epsilon_{it} \tag{3.2}
\]

with subscript \(i\) denoting the company and subscript \(t\) denoting the year. The \(\beta\)s are the coefficients to be estimated. The specification of \(\alpha\) and \(\epsilon_{it}\) are dependent on the applied econometric model, explained below. Linear homogeneity in input prices is an important property of cost functions. For the actual estimation, the linear homogeneity can be imposed by dividing all cost measures (i.e., the dependent variable total costs and the factor prices) by an arbitrarily chosen factor price, here the price for labor (Featherstone and Moss, 1994; Martínez-Budría et al., 2003; Farsi et al., 2007):

\[
C^*_{it} = \frac{C_{it}}{w_{L_{it}}} = \alpha + \beta_Y Y_{it} + \beta_Q Q_{it} + \beta_K \frac{w_{K_{it}}}{w_{L_{it}}} \\
+ \frac{1}{2} \left( \beta_{YY} (Y_{it})^2 + \beta_{QQ} (Q_{it})^2 + \beta_{KK} \left( \frac{w_{K_{it}}}{w_{L_{it}}} \right)^2 \right) \\
+ \beta_Y Q_{it} Q_{it} + \beta_{YK} Y_{it} \frac{w_{K_{it}}}{w_{L_{it}}} + \beta_{QK} Q_{it} \frac{w_{K_{it}}}{w_{L_{it}}} \\
+ \beta_N N_{it} + \beta_t t + \epsilon_{it} \tag{3.3}
\]

\(^5\) The name “quadratic” refers to the presence of quadratic terms of outputs and factor prices; it does not impose any a priori assumption of the trend of the cost curves. As Equation 3.11 shows, the estimation of economies of scope demands cost predictions where specific outputs are set to zero.

\(^6\) I follow Baumol et al. (1988, p. 453) and Mayo (1984). See Pulley and Humphrey (1993) for an explanation of why a quadratic specification should be preferred to a translog specification when some outputs can be zero. See Farsi et al. (2007, 2008) for a technical discussion on the choice of the functional form.
Additionally, flexible cost functions like the quadratic or the translog require the approximation at a local point, here chosen by the mean. Consequently, all explanatory variables except the time variable are divided by their means before the estimation.

The evolution of SFA can be summarized in the following steps (see also Coelli et al., 2005, Greene, 2008, and Kumbhakar and Lovell, 2000). Aigner et al. (1977) propose a pooled model ignoring the possible panel characteristic of data. Its composed error term ($\epsilon$) includes noise ($v$) and inefficiency ($u$). Disregarding firm-specific unobserved factors can lead to inaccurate results (Farsi et al., 2006). Treating each observation independently is eliminated by using the Random Effects model developed by Pitt and Lee (1981) and with the Fixed Effects model developed by Schmidt and Sickles (1984). In contrast to the RE model, the FE model allows correlation of firm-specific effects with the explanatory variables. I perform a Hausman test that confirms the non-correlation in favor of the RE model at a significance level of 1%. Hence the cost function’s coefficients (my major determinant for estimating economies of scale and scope) of the RE model can serve as an unbiased benchmark. The FE model is therefore not used in the following. The RE model parallels the random effects panel data model, which estimates average functions, and can be specified as:

$$C_{it}^* = \alpha_0 + x_{it}' \beta + v_{it} + u_i$$  \hspace{1cm} (3.4)$$

with $x_{it}' \beta$ standing for the parameter vector and the coefficients to be estimated (cp. Equation 3.3). Together with $\alpha = \alpha_0$ it represents the deterministic part of the cost function. In this model, the composed error term is defined so that $\epsilon_{it} = v_{it} + u_i$. $v_{it} \sim iid N(0, \sigma_v^2)$ is normal distributed and represents a time-variant, firm-specific stochastic error term (also called noise, e.g., data measurement errors). $u_i \sim iid N^+(0, \sigma_u^2)$ represents the time-invariant, firm-specific inefficiency and is truncated normal distributed. Because of this, the model is estimated using maximum likelihood. The inefficiency is estimated calculating the conditional mean of the inefficiency ($u_i$) as proposed by Jondrow et al. (1982), i.e., $E[u_i|\tilde{\epsilon}_i T] = E[u_i|\bar{\epsilon}_i]$, with $\bar{\epsilon}_i = (1/T_\tilde{i}) \sum_{t=1}^{T_\tilde{i}} \tilde{\epsilon}_{it}$.

The TRE model avoids at least two shortcomings of the RE model. As Greene (2005a) noted, the assumption of time-invariant inefficiency might be questionable in long panels, and the RE estimator forces any time-invariant heterogeneity in the inefficiency term which is likely to result in an overestimation of inefficiency. The TRE model can be specified as:

$$C_{it}^* = \alpha_0 + \alpha_i + x_{it}' \beta + v_{it} + u_{it}$$  \hspace{1cm} (3.5)$$
with $\alpha = \alpha_0 + \alpha_i$ and $\alpha_i \sim iid \mathcal{N}(0, \sigma^2_{\alpha})$ being independent and identically normal distributed and representing a time-invariant, firm-specific random intercept term introduced to capture unobserved heterogeneity separate from the actual production technology (e.g., firms situated in geographically unfavorable regions, network complexities, etc., for which data is not available). The composed error term is again made up with noise and inefficiency $\epsilon_{it} = v_{it} + u_{it}$. Precisely, $v_{it} \sim iid \mathcal{N}(0, \sigma^2_v)$ is independent and identically normal distributed and represents the time-variant, firm-specific stochastic error term and $u_{it} \sim iid \mathcal{N}^+(0, \sigma^2_u)$ is independent and identically truncated normal distributed representing the time-variant, firm-specific inefficiency. The cost of having a third stochastic term for unobserved heterogeneity is that the inefficiency is underestimated. The “true” inefficiency might hence lie somewhere between the prediction of the RE model and the TRE model. The TRE model is estimated using Simulated Maximum Likelihood. The conditional expectation of the inefficiency term $E[u_{it}|r_{it}]$ with $r_{it} = \alpha_i + u_{it} + v_{it}$ is calculated by Monte Carlo simulations (Greene, 2004, 2005a) to be able to approximate the maximization of the log-likelihood (Greene, 2005b). The differences of the RE and the TRE model in treating heterogeneity and inefficiency make it necessary to estimate both models to get a consistency check.

### 3.3 Definition of Economies of Scale and Scope

This chapter follows Baumol et al. (1988, pp. 50, 68, 73). Global economies of scale in the two outputs case are defined as:

$$SL_{Global} = \frac{C^*(Y, Q)}{Y \left( \frac{\partial C^*}{\partial Y} \right) + Q \left( \frac{\partial C^*}{\partial Q} \right)}$$  \hspace{1cm} (3.6)$$

with $Y$ representing the amount of seat-kilometers provided in buses and $Q$ representing the accumulated amount of seat-kilometers provided in trams and light railways.\(^7\) The derivatives used are deduced from Equation 3.3 as:

$$\frac{\partial C^*}{\partial Y} = \beta_Y + \beta_{YY} Y + \beta_{YQ} Q + \beta_{YK} \frac{w_{Ku}}{w_{L_{it}}}$$  \hspace{1cm} (3.7)$$

\(^7\)I do not differentiate between economies of scale and density. This would require network variables to be included with cross and squared terms in the cost function which, for a quadratic function, heavily affects the estimatability of the model.
The production technology implies increasing global returns to scale if Expression 3.6 is greater than one and decreasing global returns to scale if the expression is smaller than one. When global returns to scale are equal to one, the technology exhibits constant returns to scale. Increasing returns to scale imply decreasing average costs when increasing outputs whereas decreasing returns to scale imply increasing average costs with increasing outputs. Global economies of scale indicate the ratio of a proportional increase in all outputs to the increase in costs.

Bus-specific economies of scale are defined as:

\[
SL_Y = \frac{C^*\left(Y, Q\right) - C^*\left(0, Q\right)}{Y \left(\partial C^*/\partial Y\right)}
\] (3.9)

They indicate the ratio of an increase in bus output (with rail-bound output fixed) to the increase in costs. The numerator hereby represents the incremental costs of producing bus services. The interpretation of results proceeds equally to global returns to scale. Rail-bound-specific economies of scale are defined and interpreted similarly:

\[
SL_Q = \frac{C^*\left(Y, Q\right) - C^*\left(Y, 0\right)}{Q \left(\partial C^*/\partial Q\right)}
\] (3.10)

Economies of scope in the two-output case are defined as:

\[
SC = \frac{C^*\left(Y, 0\right) + C^*\left(0, Q\right) - C^*\left(Y, Q\right)}{C^*\left(Y, Q\right)}
\] (3.11)

Economies of scope display savings from the joint production of several outputs. Economies of scope exist if the expression above is greater than zero. \(SC\) then report the relative increase in cost from a separate production. For values smaller than zero there are diseconomies of scope.

Obviously there is interaction between global economies of scale, product-specific economies of scale, and economies of scope. The extent of global economies of scale depends on the specific measures of economies of scale as well as on economies of scope. A consideration of a simultaneous increase in both outputs implies that some of the scope effect is picked up. Whereas product-specific economies of scale can be used to evaluate whether a firm is a natural candidate for mergers in the single-product case, global economies of scale is a measure in the multi-product case.
Table 3.1: Data structure: observations

<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
<th>Multi-output</th>
<th>Single-output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>46</td>
<td>26</td>
<td>20</td>
</tr>
<tr>
<td>1998</td>
<td>51</td>
<td>27</td>
<td>24</td>
</tr>
<tr>
<td>1999</td>
<td>50</td>
<td>27</td>
<td>23</td>
</tr>
<tr>
<td>2000</td>
<td>63</td>
<td>32</td>
<td>31</td>
</tr>
<tr>
<td>2001</td>
<td>71</td>
<td>37</td>
<td>34</td>
</tr>
<tr>
<td>2002</td>
<td>68</td>
<td>38</td>
<td>30</td>
</tr>
<tr>
<td>2003</td>
<td>58</td>
<td>35</td>
<td>23</td>
</tr>
<tr>
<td>2004</td>
<td>53</td>
<td>31</td>
<td>22</td>
</tr>
<tr>
<td>2005</td>
<td>59</td>
<td>34</td>
<td>25</td>
</tr>
<tr>
<td>2006</td>
<td>54</td>
<td>29</td>
<td>25</td>
</tr>
<tr>
<td>Total</td>
<td>573</td>
<td>316</td>
<td>257</td>
</tr>
</tbody>
</table>

Source: Own calculation

3.4 Data

The unbalanced panel data set consists of 573 observations for the years 1997 to 2006. The majority of observations (316) are from multi-output companies. The exact data structure is given in Table 3.1. In total the data set includes information on 82 companies from all federal states in Germany except Berlin, resulting in approximately seven observations per company on average. All except five of the smaller companies are organized in regular public transport associations with zone tariffs. Although these public transport associations usually share marketing and ticketing, the exact assignment of tasks differs among the federal states.

All cost data is collected separately for each observation from annual reports and from balance sheets published in the Federal Bulletin (Bundesanzeiger). All physical data is obtained by extracting the yearly published VDV statistics (Verband Deutscher Verkehrsunternehmen, 1998, also for the following years).

Total costs comprise material costs (also called purchases, consisting of expenditures for raw materials and supplies, purchased goods, inter alia energy, and purchased services), personnel costs, depreciations, other operating expenses, and interests on borrowed capital as well as hypothetical interests on equity. These interests on equity are estimated as interest on corporate bonds.

---

8These companies are situated in Arnstadt, Eisenach, Gera, Mühlhausen, and Magdeburg in the federal states of Thüringen and Sachsen-Anhalt. They are organized in less-sophisticated tariff associations that mainly charge for kilometers traveled.

9For recent years there is an online version: https://www.ebundesanzeiger.de.

10Including salaries and wages as well as social insurance contributions and expenditures for pensions.
plus two percentage points of risk premium (source for interest rates: Deutsche Bundesbank, 2007). All companies considered in 2006 exhibit costs of over four billion EUR (see Table 3.2). Cost and price information are given in 2006 prices and are deflated with the German producer price index (Statistisches Bundesamt, 2008). The factor price for labor is calculated as personnel costs divided by the number of FTEs. As capital prices are not directly observable, capital costs have to be divided through some measure of capital quantity, i.e., assets or capital stock (Coelli et al., 2003, p. 85). The majority of capital costs paid by local public transport firms relate to rolling stock, i.e., buses and railcars. An even more accurate measure is the number of seats in buses and railcars. Again, this includes the size of vehicles in the analysis. Hence, capital costs are calculated as residual costs (total costs subtracted by personnel costs) divided by the number of seats. This implies that material costs and other operating expenses are assumed to represent payments for capital services (Friedlaender and Chiang, 1983). Establishing one more factor price for operations would be another option. This factor price could be calculated as material costs and other operating expenses divided by some measure of operations which is obviously output. But output in turn is already included in the cost function and, in the presence of cross terms with factor prices, this will lead to multicollinearity problems if additionally employed for calculating factor prices.

3.5 Results and Interpretation

3.5.1 Regression Results

Table 3.3 shows the regression results for the RE model and the TRE model. The coefficient estimates across the two models are quite similar. This similarity confirms observations by Farsi et al. (2005a,b). All coefficients, in particular for outputs and the capital price, show the expected signs and are significant. The results for the TRE incorporate an additional estimate $\sigma_\alpha$ characterizing the random intercept term. The output coefficients for bus services are much higher than for rail-bound services which is explained by the positive and significant coefficient of the rail-bound network in both models, and shows that the network is a substantial cost factor and that network extensions produce higher total costs. This variable picks up some of the costs related to tram and light railway services. The time trends show negative significant signs, suggesting that the

\footnote{For rail-bound services, the network is a further source of capital commitment. Costs however could be misleadingly reported because the land for stops and the road bed is very often on public property. Furthermore in the companies’ profit and loss accounts, costs are not broken down into expenses for railing stock and network expenses. Hence, the network is included as a structural variable assumed to be fixed at least in the short run.}
Table 3.2: Descriptive statistics for bus and multi-product companies

<table>
<thead>
<tr>
<th></th>
<th>Sum</th>
<th>Min.</th>
<th>Mean</th>
<th>Median</th>
<th>Max.</th>
<th>Std. dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total cost (C) [in EUR]</td>
<td>4313</td>
<td>1</td>
<td>85</td>
<td>60</td>
<td>391</td>
<td>86</td>
</tr>
<tr>
<td>Share personnel costs</td>
<td>.</td>
<td>0.05</td>
<td>0.46</td>
<td>0.46</td>
<td>0.69</td>
<td>0.11</td>
</tr>
<tr>
<td>Share capital costs</td>
<td>.</td>
<td>0.31</td>
<td>0.54</td>
<td>0.54</td>
<td>0.95</td>
<td>0.11</td>
</tr>
<tr>
<td>Labor price (w_L) [EUR/FTE]</td>
<td>17135</td>
<td>48388</td>
<td>49298</td>
<td>164079</td>
<td>11689</td>
<td></td>
</tr>
<tr>
<td>Capital price (w_K) [EUR/seat]</td>
<td>.</td>
<td>544</td>
<td>1704</td>
<td>1514</td>
<td>5078</td>
<td>784</td>
</tr>
<tr>
<td>Network length (N) [m seat-km]</td>
<td>1656</td>
<td>0</td>
<td>58</td>
<td>39</td>
<td>155</td>
<td>43</td>
</tr>
<tr>
<td>Vehicles</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bus</td>
<td>8745</td>
<td>0</td>
<td>184</td>
<td>148</td>
<td>1003</td>
<td>148</td>
</tr>
<tr>
<td>Rail-bound</td>
<td>3525</td>
<td>0</td>
<td>137</td>
<td>85</td>
<td>605</td>
<td>125</td>
</tr>
</tbody>
</table>

*Sum values for 2006, b For tram and light railway services, c Calculated for all non-zero observations

Source: Own calculation

Restructuring that has already occurred is successful and that total costs tend to be lower in recent years. Furthermore, \( \sigma_u \) relates to the standard deviation of the inefficiency and \( \sigma_v \) to the standard deviation of the noise. For both models, \( \sigma_u \) is reasonably higher, as indicated by \( \lambda \) in Table 3.3.

### 3.5.2 Economies of Scale and Scope for Representative Output Levels

Table 3.4 shows all defined measures of economies for the RE model and the TRE model. The results are given for four hypothetical firms: a firm producing outputs at the 25%-quartile of all sample firms, a firm producing at the median of all sample firms, a firm producing at the mean output, and a firm producing at the 75%-quartile. The network variable is also set at the corresponding quartile and mean levels. The firms in the sample with no rail-bound services are excluded from the quartile calculation of rail-bound output and network. According to Farsi et al. (2007) the capital price and the time trend are kept at

---

12 Particularly in some of the larger companies like Rheinbahn (Düsseldorf).
13 A detailed strategic efficiency analysis of individual firm scores could further evaluate these trends.
14 The determination of an output at the 25% quartile means that 25% of all firms in the sample produce less output.
Table 3.3: Regression results for the quadratic cost function

<table>
<thead>
<tr>
<th>Parameter</th>
<th>RE Estimate</th>
<th>TRE Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>$-29.89***(6.32)$</td>
<td>$-27.61***(2.29)$</td>
</tr>
<tr>
<td>$\sigma_\alpha$</td>
<td>.</td>
<td>$10.51***(0.36)$</td>
</tr>
<tr>
<td>$\beta_Y$</td>
<td>$45.75***(5.60)$</td>
<td>$51.58***(1.97)$</td>
</tr>
<tr>
<td>$\beta_Q$</td>
<td>$23.74***(4.73)$</td>
<td>$31.66***(1.37)$</td>
</tr>
<tr>
<td>$\beta_K$</td>
<td>$27.87***(4.96)$</td>
<td>$27.21***(2.52)$</td>
</tr>
<tr>
<td>$\beta_{YY}$</td>
<td>$-12.60***(3.24)$</td>
<td>$-14.22***(1.23)$</td>
</tr>
<tr>
<td>$\beta_{QQ}$</td>
<td>$-1.57*(0.89)$</td>
<td>$-4.23****(0.27)$</td>
</tr>
<tr>
<td>$\beta_{KK}$</td>
<td>$-8.13****(1.79)$</td>
<td>$-7.89****(1.25)$</td>
</tr>
<tr>
<td>$\beta_{YY}$</td>
<td>$-4.08****(1.40)$</td>
<td>$-0.06(0.38)$</td>
</tr>
<tr>
<td>$\beta_{QQ}$</td>
<td>$3.71*(2.14)$</td>
<td>$2.13*(0.99)$</td>
</tr>
<tr>
<td>$\beta_{KK}$</td>
<td>$8.05****(0.60)$</td>
<td>$8.25****(0.38)$</td>
</tr>
<tr>
<td>$\beta_t$</td>
<td>$-1.40****(0.11)$</td>
<td>$-1.15****(0.07)$</td>
</tr>
<tr>
<td>$\beta_N$</td>
<td>$15.28****(3.08)$</td>
<td>$7.20****(0.98)$</td>
</tr>
<tr>
<td>$\sigma_v$</td>
<td>$22.35***$</td>
<td>$15.33***$</td>
</tr>
<tr>
<td>$\lambda = \sigma_u/\sigma_v$</td>
<td>$2.34***$</td>
<td>$4.72***$</td>
</tr>
</tbody>
</table>

*Significant at 1%, ** significant at 5%, * significant at 10%; Standard errors in parentheses

Source: Own calculation

their mean values. The intercept term for the TRE model is not varied and kept constant at $\alpha$.\(^{15}\)

Looking at the specific scale economies one can observe increasing returns to scale for bus and for tram and light railway services (see Table 3.4). These results are in line with Farsi et al. (2006, 2007). While the bus-specific economies of scale are increasing from low to high output levels, the rail-specific economies of scale are decreasing. Further calculations for output levels beyond the 75%-quartile (not shown in Table 3.4) suggest a threshold around the 85%-percentile of output where rail-bound-specific economies of scale turn into diseconomies of scale. For bus-specific economies of scale this is not the case. However, as an econometric estimation always attempts to reflect the data as accurately as possible, the boundaries should be interpreted with care. The increasing returns to scale indicate the savings potential resulting from an increase in output levels or by a merger of adjacent single-output companies. The savings potential can be increased by sharing maintenance facilities or by a joint procurement that extends the existing cooperation among operators. An exact identification of the sources for these economies of scale is beyond this chapter.

\(^{15}\)Since the constant appears to exhibit a huge influence on the calculation of economies of scale and scope, I also experimented with an additional dummy variable for pure bus operators. The results did not change in any substantial way.
Table 3.4: Economies of scale and scope for representative output levels

<table>
<thead>
<tr>
<th>Output level</th>
<th>Fleet size</th>
<th>Bus-specific SL</th>
<th>Rail-bound-specific SL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>RE</td>
<td>TRE</td>
</tr>
<tr>
<td>25% quartile</td>
<td>83</td>
<td>46</td>
<td>1.21</td>
</tr>
<tr>
<td>Median</td>
<td>148</td>
<td>85</td>
<td>1.35</td>
</tr>
<tr>
<td>Mean</td>
<td>184</td>
<td>137</td>
<td>1.48</td>
</tr>
<tr>
<td>75% quartile</td>
<td>237</td>
<td>189</td>
<td>1.62</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Output level</th>
<th>Fleet size</th>
<th>Economies of scope</th>
<th>Global economies of scale</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>RE</td>
<td>TRE</td>
</tr>
<tr>
<td>25% quartile</td>
<td>83</td>
<td>-0.35</td>
<td>-0.26</td>
</tr>
<tr>
<td>Median</td>
<td>148</td>
<td>-0.15</td>
<td>-0.14</td>
</tr>
<tr>
<td>Mean</td>
<td>184</td>
<td>-0.06</td>
<td>-0.09</td>
</tr>
<tr>
<td>75% quartile</td>
<td>237</td>
<td>-0.02</td>
<td>-0.07</td>
</tr>
</tbody>
</table>

Source: Own calculation

The estimates for economies of scope are negative for both models at all output levels, i.e., it is more costly to operate bus and rail-bound services as one company than as separate entities. This, in connection with lower rail-bound economies of scale for higher output levels, would also encourage competitive bidding for tram and light railway services. Diseconomies of scope are present to a greater extent for low output values. Thus, it appears more complex for smaller firms to operate bus and rail-bound services as one company, especially when ticketing and marketing are already centralized in the local public transport associations. Another possible explanation is the lack of specialization in firms where employees are unable to focus on one mode of transport. Farsi et al. (2007) on the other hand find positive economies of scope for urban public transport in Switzerland. The observational difference can partially be explained by the authors’ data set that includes only one single-output company. A considerable part of the German observations consists of single-output bus companies, giving a realistic image of their cost structure. The Swiss data set differentiates between motor- and trolley-bus services. While determining costs of single-output tram companies Farsi et al. (2007) as well as this chapter’s application must rely on the econometric predictions.

Global economies of scale are present for both model specifications. Since they depend on both product-specific economies of scale and economies of scope, it is obvious that larger companies with zero economies of scope will exhibit greater global economies of scale. Two implications follow: First mergers of multi-output companies should be enhanced. Second, in the short term, assuming
the existing industry structure as fixed, large multi-output companies can still realize savings potential by increasing their output. Developing new customer segments, for example, will increase demand.

3.5.3 Economies of Scale and Scope for Real Firms

Comparing the results for the RE model and the TRE model for representative output levels reveals no substantial differences. One reason may be that the firm-specific random intercepts \( \alpha_i \), one characteristic for the TRE model, did not enter the calculations, because the only meaningful estimate for representative output levels is the constant \( \alpha \) for all firms. It is however meaningful to use the firm-specific random intercepts when looking at real companies. Table 3.5 shows quartile and mean levels of economies of scale and scope of the real multi-output companies included in the data set. Hence, for each single observation with different output levels, factor prices, network lengths, points in time and random intercepts, economies of scale and scope have been calculated. This calculation is only performed for multi-output companies because the defined measures for economies of scale and scope apply only to them and adding hypothetical tram outputs to pure bus companies would not give a true picture. The comparison between the estimates of economies of scale and scope for representative output levels on the one hand and real companies on the other hand is somewhat difficult because the order structure is dissimilar. For representative companies, it is output levels, for real companies, it is scale and scope levels. However, some tendencies are comparable. The general implication holds also for real companies: Global economies of scale are driven by substantial product-specific economies of scale and slight diseconomies of scope. The product-specific economies of scale appear to be present in lower amplitudes compared to the representative companies (e.g., an interquartile range of 0.21 for bus-specific economies of scale of real companies in the RE model compared to 0.41 for representative companies). For economies of scope and global economies of scale it is the reverse: Higher amplitudes for real companies compared to representative companies. Comparing the results for the RE and the TRE model, one can observe that the quartile range is always greater, except for bus-specific economies of scale for representative companies, for the RE model. Following this, unobserved heterogeneity appears to remove a prediction bias in differentiating the companies.

Interestingly, a detailed look at the individual estimates for real companies (not shown here) reveals some patterns: Strong diseconomies of scope in particular can be observed for smaller East German companies like Gera, Jena, Plauen, or Schwerin. Strong global economies of scale driven by economies of scope are present for larger municipal companies in the Ruhr area like Düsseldorf, Essen, or Köln. But other large companies like those in Stuttgart in the West or Dres-
Table 3.5: Economies of scale and scope for real companies

<table>
<thead>
<tr>
<th>Scale and scope level</th>
<th>Bus-specific SL</th>
<th>Rail-bound-specific SL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RE</td>
<td>TRE</td>
</tr>
<tr>
<td>25% quartile</td>
<td>1.05</td>
<td>1.06</td>
</tr>
<tr>
<td>Median</td>
<td>1.10</td>
<td>1.11</td>
</tr>
<tr>
<td>Mean</td>
<td>1.19</td>
<td>1.26</td>
</tr>
<tr>
<td>75% quartile</td>
<td>1.26</td>
<td>1.25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scale and scope level</th>
<th>Economies of scope</th>
<th>Global economies of scale</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RE</td>
<td>TRE</td>
</tr>
<tr>
<td>25% quartile</td>
<td>-0.33</td>
<td>-0.39</td>
</tr>
<tr>
<td>Median</td>
<td>-0.15</td>
<td>-0.16</td>
</tr>
<tr>
<td>Mean</td>
<td>-0.25</td>
<td>-0.30</td>
</tr>
<tr>
<td>75% quartile</td>
<td>0.03</td>
<td>-0.04</td>
</tr>
</tbody>
</table>

Source: Own calculation

den in the East also exhibit substantial global economies of scale. One more observation is of interest: Some mean values above the upper quartile levels (e.g., global economies of scale of 2.27 for the RE model compared to 1.81 for the upper quartile level) are driven by some very strong values above the upper quartile level.

Based on the results given, companies can manage their mergers and acquisitions (M&A). For single-output companies, a value of economies of scale above one indicates that the business should be expanded by either M&A or generic growth. For multi-output companies a corresponding negative value for economies of scope at the new output level should not prevent such mergers but is an indication that separation of divisions would be useful even if this is politically unenforceable. The savings potential should always be compared with the cost of merging, i.e., economies of scale should substantially exceed one for mergers to be pursued.

### 3.6 Conclusion

In this chapter, I estimated both Random Effects and True Random Effects Stochastic Cost Frontier models for urban public transport in Germany, to evaluate the extent of economies of scope and global and product-specific economies of scale. The RE model can serve as a benchmark for unbiased coefficients while the TRE model supplies unobserved firm heterogeneity. Rich data sets with a time frame of at least five to six years, and including as many firms as possible, are a prerequisite for useful estimations to represent the dynamic nature of
the economies of scale and scope. The models applied in this chapter evaluate
general industry trends. The product-specific estimates for economies of scale
and, even more important, the global economies of scale, are positive, suggesting
that the high fragmentation in the German market is not economically justified
and that mergers and acquisitions should be politically supported, particularly
for companies in geographical proximity. In an international context, the results
can enrich the discussion about the optimal firm size in local public transport,
e.g., there are no bus-specific diseconomies of scale observable in this chapter,
favoring large companies. From the finding of slight diseconomies of scope I
conclude that bus and rail-bound services should not be integrated on the cost
side. This encourages the use of a competitive bidding process for tram and light
railway services. An oligopoly structure appears preferable since high fragmenta-
tion will again lead to the unexploited economies of scale problem. The presence
of rail-bound increasing returns to scale and diseconomies of scope points to a
structural problem for small tram and light railway systems in Germany. Small
tram networks with few lines are expensive to operate; any expansion can prove
too costly when demand fluctuates. Small networks can be replaced by bus ser-
dvices (as has happened often in the past) or can be connected with the regional
rail network according to the “Karlsruher Modell”, where the traction units are
equipped with two power systems, one for inner-city operations and the other for
interurban operations. Few crossovers between the rail and the tram network,
e.g., near the main stations, enable direct connections from the rural areas to
the inner cities. Such systems can resolve the unexploited economies of scale
problem of small tram networks where rail and tram gauge is consistent.
Chapter 4

Potential Gains from Mergers

4.1 Introduction

For regional bus companies in Germany, there is evidence for increasing returns to scale. Two studies explicitly deal with this aspect: Based on a data set of 179 bus companies with physical inputs and outputs, Hirschhausen and Cullmann (2008) use DEA extended to bias correction and inference. A test on the returns to scale technology rejects the hypotheses of constant and non-increasing returns to scale. The authors conclude that smaller companies are characterized by increasing returns to scale.¹ Nieswand et al. (2008) use SFA to study cost efficiency and economies of scale and density in German bus transport. The cost data is estimated using a bottom-up approach. They find increasing returns to scale and density, independent from supply- and demand-oriented output specifications and the level of heterogeneity comprehension.

Also for multi-product companies in German local public transport, the preceding chapter has shown the presence of global economies of scale. Hence, the fragmentation in Germany appears to be inefficient and more cooperation, if not outright mergers, is likely to lead to significant cost reductions. This underlines the importance of a deeper analysis of merger gains, the approach pursued in this chapter.

The management of public transport provision in Germany at the local level has been justified on the grounds that strong cooperation with local authorities is necessary and that local circumstances must be considered. Therefore it is doubtful whether a “random” acquisition strategy with acquisitions in geograph-

¹The subsequent chapter is based on Walter and Cullmann (2008).
I model the potential gains from mergers in public transport in Germany’s most densely settled region, Nordrhein-Westfalen, whose attributes make the realization of merger gains feasible:

- Cities are close to each other so that combined operation is possible.

- Light railway and tram networks with connecting lines exist, e.g., in Köln and Bonn or in Düsseldorf and Krefeld; until now there have already been two or more public transport companies operating on a common network.

Some companies in Nordrhein-Westfalen have either launched mergers (Duisburg, Essen, and Mülheim) or at least proposed them (Köln and Bonn in 2003 and 2007). My empirical analysis is based on non-parametric Data Envelopment Analysis with bias corrections through bootstrapping. To model the potential gains, I apply a methodology proposed by Bogetoft and Wang (2005). Within this framework, a decomposition of the overall potential gains into three different effects is possible: a technical efficiency effect, a synergy effect and a size effect. Therefore, the results allow the quantification of overall potential gains from mergers for German public transport companies as well as the separate role and magnitude of each of the three components. The framework also allows identifying the most promising merger combinations and their respective characteristics. Possible merger cases that I analyze include cooperative efforts among up to five neighboring public transport companies. I also test the robustness of my calculations by applying different scale properties and introducing structural variables.

The remainder of this chapter is structured as follows: The next section gives an overview of the methodology. Section 4.3 introduces the data and model specification and introduces the proposed mergers. Section 4.4 presents average efficiencies for the unmerged firms, compares merger gains under variable and constant returns to scale, with and without incorporating differences in the production of tram and light railway services, and calculates alternative decompositions of synergy and size gains. In Section 4.5, I present conclusions and policy recommendations.

---

2Failures of such “random” acquisitions include the example of Hamburger Hochbahn withdrawing from their shareholding in WiBus in Wiesbaden, almost 500 kilometers distant from Hamburg, in 2007.
4.2 Methodology

4.2.1 Data Envelopment Analysis

My focus in this chapter is on non-parametric linear optimization using DEA. It relies on a production frontier where the individual efficiencies of the firms relative to the frontier are calculated by distance functions.\(^3\) DEA involves the use of linear programming methods to construct a piecewise linear surface or frontier over the data and measures the efficiency for a given unit relative to the boundary of the convex hull of the input output vectors (see Simar and Wilson, 2008).\(^4\) The determination of the efficiency score of the \(i\)-th firm in a sample of \(N\) firms in the constant returns to scale model under input orientation is equivalent to the following optimization (see Coelli et al., 2005, p. 163):

\[
\begin{align*}
\min_{\theta, \lambda} & \theta \\
\text{s.t.} & \quad -y_i + Y \lambda \geq 0 \\
& \quad \theta x_i - X \lambda \geq 0 \\
& \quad \lambda \geq 0 \\
\end{align*}
\]

with \(\lambda\) being an \(N \times 1\) vector of constants, \(X\) representing an input matrix and \(Y\) an output matrix. \(\theta\) measures the radial distance between the observation \((x, y)\) and a linear combination of efficient points, representing the efficiency target for this observation. \(\lambda\) determines the weights of these peers for the evaluated firm’s inputs and outputs. A value of \(\theta = 1\) indicates that a firm is fully efficient and thus is located on the efficiency frontier. To determine efficiency measures under the assumption of variable returns to scale a further convexity constraint \(\sum \lambda = 1\) must be added.

DEA can be carried out with either input or output orientation. Under input orientation, outputs are held fixed when contradicting inputs. Under output orientation, inputs are held fixed when increasing output. Here input orientation is applied, a realistic assumption for Germany’s local public transport when considering the supply obligation of the public transport sector (the output volume is

\(^{3}\)The concept of distance functions used to measure efficiency and productivity is closely related to the concept of production frontiers. The framework was independently proposed by Malmquist (1953) and Shepard (1953). By defining these functions the concept of radial contradictions and expansions is used, thus an input distance function considers by how much the input vector may be proportionally contracted with the output vector held fixed. See Färe and Primont (1995) for mathematical derivation of distance functions.

\(^{4}\)Another technique is the free disposal hull (FDH) estimator, which only assumes free disposability and no convexity constraint. I limit myself in this chapter to DEA.
mostly predetermined by contracts between local authorities and the companies). Thus the companies’ intention is to use the fewest possible resources.

4.2.2 Decomposing Merger Gains

Following a framework proposed by Bogetoft and Wang (2005) for agricultural offices and applied by Bagdadioglu et al. (2007) to the energy sector I decompose efficiency gains from mergers\(^5\) into technical efficiency gains, synergies from joint operation, and size gains. The results allow me to quantify both the overall potential gains from mergers and the separate role of the three effects.

Assume that utilities that are geographically close merge into larger units. The merged unit is denoted \(DMU^J\) where \(J\) determines the number of merged units. By summing inputs and outputs I obtain a unit that has used \(\sum_{j \in J} x_j\) to produce \(\sum_{j \in J} y_j\). Based on Bogetoft and Wang (2005), a radial input-based measure of the potential overall gains from merging the \(J\) DMUs under an input orientation is:

\[
\begin{align*}
\min_{\theta^J, \lambda} & \quad \theta^J \\
\text{s.t.} & \quad - \sum_{j \in J} y_j + Y \lambda \geq 0 \\
& \quad \theta^J \sum_{j \in J} x_j - X \lambda \geq 0 \\
& \quad \lambda \geq 0
\end{align*}
\]

\(\theta^J\) is the maximal proportional reduction in the aggregated inputs \(\sum_{j \in J} x_j\) that allows the production of the aggregated output \(\sum_{j \in J} y_j\). A value below one indicates that merging can reduce costs or input requirements.\(^6\) Since I consider a radial measure of input contradiction, each input is reduced in the same proportion. As shown by Bogetoft and Wang (2005) the measure \(\theta^J\) of the potential overall merger gains can be decomposed into the following three effects.

**Technical Efficiency Effect (T)**

The technical inefficiency of the individual utilities in \(J\) may be captured in \(\theta^J\). These inefficiencies could be eliminated by the new management processes, e.g.,

\(^5\)It should be noted that merger gains are only feasible for a perfect technology, e.g., that bus services are transferable and scalable.

\(^6\)See Bogetoft and Wang (2005) for sufficient conditions about feasible solutions and the requirement of weak gains for arbitrary mergers.
by imitating the better performers of the same size without any utilization of scale or synergy effects. This effect is defined as the technical efficiency effect and it is useful to adjust the overall gains caused by mergers to identify the pure merger effects. Note that a merger is not ultimately necessary to realize these effects.

Bogetoft and Wang (2005) propose to project the original units to the production possibility frontier and use the projected units as the basis for evaluating the remaining gains from the merger. Thus, for example, I may project \((x^i, y^i)\) into \((\theta^i x^j, y^j)\), where \(\theta^i\) is the standard technical efficiency score under an input orientation for a single decision-making unit. In a second step the projected units \((\theta^ix^j, y^j)\) are used as the basis for calculating the adjusted overall or real merger gains:

\[
\begin{align*}
\min_{\theta^*, \lambda} & \quad \theta^* \in J \\
\text{s.t.} \quad & -\sum_{j \in J} y^j_i + Y \lambda \geq 0 \\
& \theta^* \sum_{j \in J} \theta^j x^j_i - X \lambda \geq 0 \\
& \lambda \geq 0
\end{align*}
\]

Letting \(T^J = \theta^J / \theta^*\) I obtain \(\theta^J = T^J \cdot \theta^*\). \(T^J\) indicates what can be saved by individual adjustments in the different units in \(J\). I now describe the two most interesting “production” effects of a merger: the synergy effect \((H)\) and the size effect \((S)\).

**Synergy Effect (H)**

As a merger typically involves different input and output combinations, it may prove advantageous when the result is a more productive use of the product space and hence savings can be increased by a more efficient joint production of several outputs. This is termed the synergy effect \((H)\). Bogetoft and Wang (2005) propose to capture the synergy gains by examining how much of the average input can be saved in the production of the average output, i.e., by the measure \((H)\), which can be expressed in the DEA optimization by:

\footnote{Bogetoft and Wang (2005) refer to the synergy effect as harmony, scope, or input mixture effects.}
\[ \begin{align*}
\min_{H^J, \lambda} & \quad H^J \\
\text{s.t.} & \quad -\alpha \sum_{j \in J} y^j_i + Y \lambda \geq 0 \\
& \quad H^J \alpha \sum_{j \in J} \theta^j x^j_i - X \lambda \geq 0 \\
& \quad \lambda \geq 0
\end{align*} \]

where \( \alpha \in [0, 1] \) is a scalar determining the size of the firm evaluated with the synergy measure. To eliminate the size effect, \( \alpha \) is typically chosen to be equal to \( |J|^{-1} \). As shown by Bogetoft and Wang (2005), the mean input and the average output reveal what can be saved at most by a pure reallocation of inputs and outputs. Other values for \( \alpha \) can be used for sensitivity testing. \( H^J < 1 \) indicates a savings potential due to improved harmony, while \( H^J > 1 \) indicates a cost of harmonizing the inputs and outputs. This cost of harmonizing can only occur when not looking at the mean input and average output because of the assumed convexity.\(^8\)

**Size Effect (S)**

To analyze the scale effects I must consider the properties of the underlying production technology. A merger results in a unit that operates at a larger scale. The outcome depends on the scale properties of the underlying technology. A positive size effect is characterized as follows: Assuming that the original input-output combinations of firm \( A = (x_1, y_1) \) and firm \( B = (x_2, y_2) \) are efficient and improvement potentials are present in the merged unit \( A + B \) using \( x_1 + x_2 \) to produce \( y_1 + y_2 \), it is sufficient for unit \( A + B \) to use \( \theta(x_1 + x_2) \) in the production process to produce \( y_1 + y_2 \), cleaned from any synergy effects.

In the next linear optimization program I can capture the size gains by asking how much is saved by operating at full scale rather than at \( \alpha \)-scale. This can be reflected by the measure \( S^J \):

\(^8\)However, there is one merger shown in the following with a synergy effect for average inputs and outputs slightly higher than one. This results from the bias correction obtained through the use of bootstrapping in the merger gains decomposition because this value is below one when applying standard DEA.
\[
\begin{align*}
\min_{S^J, \lambda} & \quad S^J \\
\text{s.t.} & \quad - \sum_{j \in J} y_i^j + Y \lambda \geq 0 \\
& \quad S^J \left[ H^J \sum_{j \in J} \theta^j x_i^j \right] - X \lambda \geq 0 \\
& \quad \lambda \geq 0
\end{align*}
\]

(4.5)

\(S^J < 1\) indicates that rescaling is advantageous given the synergy improvements, whereas \(S^J > 1\) shows that the returns to scale property does not favor larger units and thus the merger is costly.

Summarizing the effects using the definition from the linear optimization leads to \(\theta^{* J} = H^J \cdot S^J\) and by means of \(\theta^J = T^J \cdot \theta^{* J}\) I obtain the basic decomposition \(\theta^J = T^J \cdot H^J \cdot S^J\). In turn it corresponds to a decomposition of the overall potential gains into a technical efficiency index \(T^J\), a synergy index \(H^J\), and a size index \(S^J\).\(^9\)

\[4.2.3\] Bias Correction with Bootstrapping

The deterministic non-parametric frontier models offer the great advantage of flexibility. Some of the drawbacks are the sensitivity to outliers and extreme values, and the disallowance of noise in the data (see Simar and Wilson, 2000, 2008). Related to this is the conduction of statistical inference using bootstrapping to correct for the bias in my empirical deterministic efficiency estimates. I begin by briefly summarizing the statistical properties of the non-parametric DEA estimators.\(^10\)

With respect to consistency it is sometimes difficult to prove convergence of an estimator in non-parametric statistics and to obtain its rate of convergence (Simar and Wilson, 2008).\(^11\) The rates of convergence depend on the dimensionality of the problem. When there are large numbers of inputs and outputs, the imprecision of the results will be reflected in large biases, large variances, and wide confidence intervals (Simar and Wilson, 2008). As I dispose of a relatively small number of observations it becomes important within my framework to conduct bias correction.

\(^9\)For alternative decomposition concepts see Bogetoft and Wang (2005).
\(^11\)The convergence properties for the DEA estimators for the univariate input and multivariate output case have been shown by Korostelev et al. (1995); the convergence rates for the multivariate input and multivariate output case have been established by Kneip et al. (1998).
To make inferences about empirical applications, the asymptotic sample distributions of the envelopment estimators are required (Simar and Wilson, 2000, 2008). The bootstrap algorithm remains the only practical way of making inferences when using the multivariate DEA approach (Simar and Wilson, 1998, 2000, 2008, provide an extensive discussion). This chapter applies the bootstrap algorithm established in Simar and Wilson (1998) that is based on the bootstrap idea by Efron (1979, 1987) and Efron and Tibshirani (1993) who approximated the sampling distributions of interest by simulating, or mimicking, the data generating process (DGP). Its use for non-parametric envelopment estimators was developed by Simar and Wilson (1998, 2000). The following discussion is based on Simar and Wilson (2008).

Simulating by means of bootstrapping provides approximations of the sampling distributions of $\hat{\theta}(x, y) - \theta(x, y)$, the difference of the estimated score $\hat{\theta}(x, y)$, and the true value $\theta(x, y)$. The true values are expected to be lower, also because the data set can only be a sample of observations, and thus misses some of the best performers. The logic is then as follows: DGP generates the original data $X_n$ and is completely characterized by knowledge of $\psi$, the production possibility set, and the probability density function $f(x, y)$. Assume $\hat{P}(X_n)$ to be a consistent estimator of the DGP. The true $P$, $\psi$, and $\theta(x, y)$ are unknown (I only observe the data $X_n$, and this set must be used to construct estimates of $P$, $\psi$, and $\theta(x, y)$). Assume also that the simulated world, i.e., the bootstrap world, is analogous to the real world, but that estimates take the place of the real world. Thus in the simulated bootstrap world, a new data set $X_n^* = \{(x_i^*, y_i^*), i = 1...n\}$ can be drawn from the estimated DGP. By using the usual linear program an estimator $\hat{\theta}^*(x, y)$ based on the new sample can be computed. $\hat{\theta}^*(x, y)$ is an estimator of $\theta(x, y)$ based on the pseudo sample $X_n^* = \{(x_i^*, y_i^*), i = 1...n\}$. The sampling distribution of $\hat{\theta}^*(x, y)$ is approximated by Monte Carlo simulations (see Simar and Wilson, 1998, 2000, 2008, for an in-depth discussion). I use the bootstrap algorithm by Simar and Wilson (1998) known as the smoothed homogeneous bootstrap to conduct bias correction in each step of the different linear programming problems of merger gains decomposition.

DEA estimators are biased by construction as follows:

$$BIAS(\hat{\theta}(x, y)) = E(\hat{\theta}(x, y)) - \theta(x, y)$$ (4.6)

The same relation holds for the bootstrap bias estimate for the original estimator:

$$\overline{BIAS}_B(\hat{\theta}(x, y)) = B^{-1} \sum_{b=1}^{B} (\hat{\theta}^*_b(x, y)) - \hat{\theta}(x, y)$$ (4.7)
Following Simar and Wilson (1998) I construct a bias corrected estimator of $\theta(x, y)$ by computing:

$$\hat{\theta}(x, y) = \theta(x, y) - \text{BIAS}_B(\hat{\theta}(x, y)) = 2 \cdot \hat{\theta}(x, y) - B^{-1} \sum_{b=1}^{B} \hat{\theta}_b^*(x, y)$$

(4.8)

### 4.3 Data and Model Specification

#### 4.3.1 Data Set

The data set consisting of 43 local public transport companies in Nordrhein-Westfalen in 2006 was retrieved from the annual VDV statistics. Since the data set does not include the degree of personnel outsourcing by which the companies may have organized their operations, the number of employees (full-time equivalents) in the data set may be underestimated. The data set does include the number of chartered buses which can be used as a proxy for the degree of outsourcing, and on this basis the number of FTEs can be updated. Following Leuthardt (1986, 2005) I assume two additional FTEs per chartered bus.\(^{12}\) After the adaptation of the data set two of the 43 companies were identified as outliers due to a very low ratio of FTEs to employed vehicle capacity. For these companies the FTE numbers are apparently not correctly stated in the statistics.

Of the remaining 41 companies, 38 are under complete private ownership and three are under mixed, public and private, ownership; 12 are multi-output companies (in addition to bus services they also offer tram, metro-similar light railway, and, in Wuppertal, aerial cableway services); and 29 are purely bus operators (including trolley-buses in Solingen).

To evaluate the efficiency of mergers under a VRS technology, the data set must contain firms of at least similar size in comparison to the mergers. To study merging of larger firms, I therefore collected additional data points of local public transport firms that are larger than those in the original 43-company data set.\(^{13}\) After eliminating outliers, I arrived at a data set of 44 companies for the reference technology. The requirement of peers of similar size for mergers limited my maximum evaluated number of merged companies to five.

\(^{12}\)The analyses have also been conducted with 1.5 and 2.5 additional FTEs per chartered bus. No significant different results could be observed.

\(^{13}\)I do not want to extend the data set to all of Germany because different demographic, geographical, and political circumstances could bias the results of an analysis with physical inputs and outputs. Therefore I only included three additional companies: BVG (Berlin), HHA (Hamburg), and MVG (München).
4.3.2 Model

My model specifications were limited by data availability, e.g., the data set does not include cost and input factor prices, particularly for the smaller bus companies. Thus I examine only the companies’ technical efficiency. Under input orientation two different input-output specifications are possible and summarized in Table 4.1:

1. The first specification contains the inputs *number of seats in the bus fleet* and *number of seats in the railcar fleet* (both include standing room) and the outputs *seat-kilometers in buses* and *seat-kilometers in railcars*.

2. The second specification contains the inputs *pure number of buses* and *number of railcars* and the outputs *vehicle-kilometers for buses* and *vehicle-kilometers for railcars*.

Additionally, both input-output specifications have in common the input FTEs.

I now evaluate the possible input-output specifications. The first input-output specification with seat-kilometers is the most appropriate because the variables incorporate as much information as possible. In comparison to the second input-output specification with vehicle-kilometers, the capacity of vehicles is included. This capacity can differ substantially, e.g., between articulated buses in urban
areas and normal buses in rural areas, or between large light railways in Dort-
mund and the aerial cable cars in Wuppertal. I note that a public transport
company may have little influence over capacity utilization, since it is not di-
rectly responsible for marketing, ticketing, traffic planning, and the like. Thus
my model’s supply side focus is economically justified.

Companies may also have little control over structural variables representing
environmental conditions or those representing additional specifications of input
or output variables beyond the scope of management during a merger. Follow-
ing Coelli et al. (2005, p. 192), my analysis includes two structural variables
introduced on the output side:\[14\]

- Some companies may have lower costs because of the network’s dispersion
connected with low population in that area (see Chapter 2). These costs
are not covered because of the use of physical input data. A density index
is defined as total track length for trams and light railways and line length
for buses divided by the number of inhabitants in the operation area of a
local public transport provider. With my approach companies operating
in these areas will obtain a better efficiency score, because they obtain
additional “output”.

- The provision of metro and possibly light railway services requires greater
infrastructure investments that cannot be discussed in this chapter due to
the lack of cost data. On the other hand the average speed of tram services
is much lower and therefore output production is more difficult with given
inputs.\[15\] A tram index measures the tram capacity as the percentage of all
rail-bound capacity. Hence the model supports companies offering tram\[16\]
services in comparison to those offering light railway or metro services.

\[4.3.3\] Mergers

In general, proposed mergers should fulfill two criteria:

1. A tram or light railway network with connecting lines, operated by more
than one company at present, should be operated by only one company
after the merger in order to facilitate operations planning and to encourage
the use of shared facilities.

\[14\]Within the DEA framework there is also another approach to capture conditions which are
not under the control of management. It was first proposed by Banker and Morey (1986) who
formulated a DEA model in which one only seeks radial input reductions over some variables
of the input vector, the discretionary set.

\[15\]The data for the non-discretionary variables is obtained from Verband Deutscher

\[16\]Also aerial cableway because the average speed is similar to trams (approximately 30 km/h).
2. All other companies are assigned to mergers where it makes geographical sense, since the realization of efficiency gains from mergers in public transport relies on the geographical nearness of the cities and companies. Only under this constraint will gains in the production process, e.g., from combined operations, appear feasible (Nordrhein-Westfalen in comparison to the rest of Germany best fulfills this constraint).

Based on the results of the merger gain calculation, I selected 14 out of 80 potential mergers as shown by the patterns in Figure 4.1. For Herten, Lüdenscheid and the two companies from Münster, no adequate merger combinations could be found; thus these four remain unmerged. I achieve three mergers with trams and light railways operating on a network with connecting lines;17 four mergers of one tram and light railway operator with several pure bus operators; and seven pure bus mergers.

4.4 Results and Interpretation

I first calculate average efficiency estimates for the unmerged companies and analyze the impact of structural variables on company performance. Second, I present merger gains under variable and constant returns to scale. Third, I compare technical efficiency and real merger gains with/without a structural variable and calculate alternative decompositions of the real merger gains into synergy and size effects. The robustness of the results is checked and guaranteed by means of bias correction.

4.4.1 Average Efficiencies for the Unmerged Firms

Table 4.2 shows the average efficiencies for the unmerged firms with seat-kilometer as output for different model variations. In addition, I compare standard DEA results with bias-corrected results based on bootstrapping.18 In general the bootstrapping results show the expected lower average efficiencies (e.g., 0.792 bias-corrected in comparison to 0.851 standard DEA of overall efficiency under VRS without structural variables) because I assume the true frontier to be on a higher efficiency level than the estimated frontier with standard DEA. The

---

17 These three networks are comprised of the companies from Köln and Bonn, Düsseldorf and Krefeld as well as Essen and Mülheim. Duisburg with its connecting lines to Düsseldorf and Krefeld is assigned to Essen and Mülheim because of an ongoing actual merger process. Apart from these mergers, there is only one additional tram network in Germany with connecting lines between different cities. Interestingly, the joint-venture Rhein-Neckar-Verkehrsgesellschaft (the public transport companies of Mannheim, Heidelberg, and Ludwigshafen in the Rhein-Neckar area) has already been set up on this network.

18 Bootstrapping was conducted with 2000 replications.
Figure 4.1: Geography of local public transport mergers in Nordrhein-Westfalen

![Map of local public transport mergers in Nordrhein-Westfalen](image)

Legend: Tram or light railway operators in bold font
Different shadings relate to the mergers
Not merged companies

Source: Own illustration

ranking and the proportional magnitude of results between the models under standard DEA and bias-corrected DEA do not differ. Therefore, and because of the superior theoretical properties, I focus on the bias-corrected values in the following explanation.

I begin with the base model (Model 1) absent the inclusion of any structural variables. The average efficiency for the unmerged firms is 0.792 for VRS and 0.769 for CRS. The average firm therefore would be able to save 20.8% of its inputs for VRS and 23.1% of its inputs for CRS if produced on the efficiency frontier.

Models 2 and 3 introduce structural variables in order to compare the overall efficiency of Model 1. Model 4 includes both structural variables at the same time. Following Hollingsworth and Smith (2003), the use of ratios within the CRS formulation can lead to incorrect efficiency results. A peer firm can be constructed by the input and the output vector of a real firm times a scalar greater than one. Thus, when using ratios, a peer firm would be able to have
Table 4.2: Average efficiency estimates with seat-kilometers as output

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>without structural density index</td>
<td>with density index</td>
<td>with tram density index</td>
<td>with tram density index</td>
</tr>
<tr>
<td>VRS</td>
<td>0.851</td>
<td>0.877</td>
<td>0.863</td>
<td>0.889</td>
</tr>
<tr>
<td>Standard-DEA</td>
<td>0.806</td>
<td>0.830</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bias-corrected</td>
<td>0.792</td>
<td>0.816</td>
<td>0.799</td>
<td>0.824</td>
</tr>
<tr>
<td>CRS</td>
<td>0.806</td>
<td>0.830</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard-DEA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bias-corrected</td>
<td>0.769</td>
<td>0.784</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*VRS = variable returns to scale, CRS = constant returns to scale.*

Source: Own calculation

a ratio value greater than one although this may lie outside the realistic range. Therefore, I only use the VRS formulation for Models 3 and 4. The impact of the density index is slightly higher than that of the tram index. Including both leads to even higher efficiency values.

4.4.2 Merger Gains under Variable and Constant Returns to Scale

The following discussion of the merger gains omits the density index included in Models 2 and 4 to avoid over-specifying of the general DEA model regarding the relatively small data set. I hence focus on Models 1 and 3.

I calculate the overall potential merger effects for VRS and CRS absent structural variables (Model 1), based on the bias-corrected efficiency estimates. I decompose these overall effects into real merger effects (synergy and size effect together) and technical efficiency effects. Table 4.2 presents the mergers in descending order by merger size. The most important result is the existence of significant real merger gains, i.e., gains that are only possible when merging the operational processes. Under VRS and CRS the largest merger 1 with two large bus, tram and light railway operators and one bus operator shows significant real merger gains of 12%. Under VRS only, I also find mergers with negative real merger gains (the mergers result in increased inefficiency in terms of synergy and size). However, mergers 6, 7, 9, and 11 can still have a positive overall impact if the technical efficiency is brought to the frontier level. The negative real merger effects can be explained by looking at the specifics. Merger 6 is of an economic nature: Wuppertal has an aerial cableway with which synergies to bus services are not probable, at least not for maintenance, technology, and substitutability.
Mergers 7, 9, and 11 are big bus companies which do not yet exist in the German market. Therefore the negative effects could stem from the missing references. In reality, however, real merger gains appear possible.

In the following I adhere to the VRS assumption because it allows me to further decompose the real merger gains into synergy and size gains.

4.4.3 Merger Gains with/without Incorporating Differences in the Production of Tram and Light Railway Services

Figure 4.2 shows the VRS results from Table 4.3. I observe substantial real merger gains (synergy and size) for the mergers of companies operating on a common tram and light railway network (dark-shaded) and mergers of bus, tram and light railway operators (light-shaded) with the exception of merger 6. The mergers of companies operating on a common tram and light railway network are at the same time the largest in terms of output seat-kilometers (bus, tram, and light railway; indicated by the size of the bubble). The results for smaller pure bus mergers vary and must be evaluated on a case-by-case basis.

I now include the tram index as structural variable. Since the mergers consist of companies of different sizes, the tram index is input-weighted. Comparing Figures 4.2 and 4.3, I observe some heterogeneity and can thus group the mergers into four clusters: pure bus mergers 7 and 9-14 with no changes (reasonable because the tram index itself is not directly affecting the results for the bus companies); bus, tram, and light railway mergers 1, 4 and 8 with no significant changes (the level of tram services differs little in comparison to their benchmarks and hence the incorporation of the structural variable does not change the results); bus, tram, and light railway mergers 2a and 3a that are still favorable (but with few firms – Krefeld removed from merger 2 and Oberhausen and Moers removed from merger 3); and mergers 5 and 6 that are no longer beneficial (hence not included in Figure 4.3).

All of the mergers in Model 1 (except merger 6) are highly beneficial without including the tram index. However, not all the non-beneficial mergers in Model 3 are likely to be really disadvantageous. As Table 4.2 shows, the individual efficiency increases with the number of structural variables. Hence a careful interpretation and evaluation of these mergers is necessary.

4.4.4 Alternative Decompositions of Synergy and Size Gains

So far I have only looked at the real merger gains generally. I did not differentiate between a synergy effect from a better input mixture and the common provision

\footnote{The integrated transport company Deutsche Bahn with its bus subsidiary DB Stadtverkehr, which would be big enough to serve as a benchmark, is not included in my data set.}
<table>
<thead>
<tr>
<th>Merger Overall Real Technical Overall Real Technical</th>
<th>Potential merger efficiency</th>
<th>Potential merger efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>θ</td>
<td>J</td>
<td>θ</td>
</tr>
<tr>
<td>J</td>
<td>T</td>
<td>J</td>
</tr>
<tr>
<td>Synergy effect</td>
<td></td>
<td></td>
</tr>
<tr>
<td>θ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>J</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>θ</th>
<th>J</th>
<th>θ</th>
</tr>
</thead>
<tbody>
<tr>
<td>J</td>
<td>T</td>
<td>J</td>
</tr>
<tr>
<td>Synergy effect</td>
<td></td>
<td></td>
</tr>
<tr>
<td>θ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>J</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

VRS = variable returns to scale; CRS = constant returns to scale; Bold = companies with tram/light railway; *Following from $\theta^*J = 0$ and $T_J = 0$.

Source: Own calculation

Table 4.3: Decomposition of bias-corrected potential merger effects for variable and constant returns to scale (model 1).
of different outputs and a size effect resulting from the production at a larger scale. I want to calculate this decomposition with three different values for $\alpha$, the scalar determining the size of the firm evaluated with the synergy measure (see Subsection 4.2.2). First I follow Bogetoft and Wang (2005) with the default value of $1/n$ where $n$ is the number of firms merged. As the tram index has been recalculated for the mergers and is not just the sum of the original unit values, there is an additional technical rationale for this robustness check on the synergy and size allocation of gains. For inputs and outputs only, it is natural to divide the number of units being merged since this corresponds to the maximum of what can be gained by a pure reallocation. I therefore halve and double the default value of $1/n$ for a sensitivity analysis. This also gives some indication about the magnitude of the merger effects if there is a very small firm operating with this input mixture, or if the merger consists of a very big firm and additional
smaller firms.

Table 4.4 gives the result for the described decomposition. The most obvious result is the much more advantageous status of synergy gains, in particular for mergers 1 and 4 where the conclusion of superior and positive synergy gains holds for all three different values of \( \alpha \). For the scalar value of \( 2/n \), the majority of the synergy gains are greater than the size gains. However, the fact that these input mixtures in the mergers seem beneficial is not purely related to synergy. Size over a specific threshold can be conditional in order to reach this beneficial input mixture, e.g., for automated maintenance activities. Furthermore, the question remains which input mixture and output combination best determines the synergy gains. I leave this to further research.
Table 4.4: Evaluation of bias-corrected synergy and size effects for variable returns to scale

<table>
<thead>
<tr>
<th>Merger</th>
<th>Synergy gains 1/(2n)</th>
<th>Synergy gains 1/n</th>
<th>Synergy gains 2/n</th>
<th>Synergy gains 1/(2n)</th>
<th>Synergy gains 1/n</th>
<th>Synergy gains 2/n</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Köln, Bonn, Siegen</td>
<td>0.81</td>
<td>0.80</td>
<td>0.84</td>
<td>1.08</td>
<td>1.10</td>
<td>1.05</td>
</tr>
<tr>
<td>2) Düsseldorf, Krefeld, Neuss</td>
<td>1.02</td>
<td>0.96</td>
<td>0.90</td>
<td>0.86</td>
<td>0.91</td>
<td>0.96</td>
</tr>
<tr>
<td>3) Duisburg, Mülheim, Essen, Oberhausen, Moers</td>
<td>1.00</td>
<td>0.94</td>
<td>0.88</td>
<td>0.89</td>
<td>0.95</td>
<td>1.01</td>
</tr>
<tr>
<td>4) Dortmund, Hagen</td>
<td>0.92</td>
<td>0.86</td>
<td>0.84</td>
<td>0.92</td>
<td>0.98</td>
<td>1.00</td>
</tr>
<tr>
<td>5) Bochum, Herne</td>
<td>1.02</td>
<td>0.97</td>
<td>0.91</td>
<td>0.89</td>
<td>0.94</td>
<td>1.00</td>
</tr>
<tr>
<td>6) Wuppertal, Ennepetal</td>
<td>0.95</td>
<td>0.94</td>
<td>1.10</td>
<td>1.16</td>
<td>1.18</td>
<td>1.00</td>
</tr>
<tr>
<td>7) Aachen, Geilenkirchen</td>
<td>0.96</td>
<td>0.94</td>
<td>1.13</td>
<td>1.18</td>
<td>1.20</td>
<td>1.01</td>
</tr>
<tr>
<td>8) Detmold, Extertal, Bielefeld</td>
<td>1.19</td>
<td>0.98</td>
<td>0.90</td>
<td>0.74</td>
<td>0.89</td>
<td>0.97</td>
</tr>
<tr>
<td>9) Troisdorf, Euskirchen, Düren</td>
<td>1.04</td>
<td>0.98</td>
<td>0.95</td>
<td>1.12</td>
<td>1.19</td>
<td>1.23</td>
</tr>
<tr>
<td>10) Gummersbach, Remscheid, Solingen</td>
<td>1.01</td>
<td>1.00</td>
<td>0.99</td>
<td>0.96</td>
<td>0.97</td>
<td>0.98</td>
</tr>
<tr>
<td>11) Dormagen, Gladbach, Viersen</td>
<td>1.08</td>
<td>1.02</td>
<td>0.97</td>
<td>1.02</td>
<td>1.08</td>
<td>1.14</td>
</tr>
<tr>
<td>12) Hamm, Kamen</td>
<td>1.06</td>
<td>1.00</td>
<td>0.97</td>
<td>0.92</td>
<td>0.97</td>
<td>1.00</td>
</tr>
<tr>
<td>13) Monheim, Leverkusen</td>
<td>1.00</td>
<td>0.95</td>
<td>0.91</td>
<td>0.91</td>
<td>0.96</td>
<td>1.00</td>
</tr>
<tr>
<td>14) Gütersloh, Soest</td>
<td>1.05</td>
<td>0.99</td>
<td>0.95</td>
<td>0.90</td>
<td>0.96</td>
<td>1.00</td>
</tr>
</tbody>
</table>

*Bold: companies with tram/light railway*

Source: Own calculation
4.5 Conclusion

Local public transport in Germany faces increased calls for reform, primarily because the companies still operate in monopolistic, historically defined, regional market structures.

This chapter has applied recent methods of DEA to evaluate the potential efficiency gains from mergers in Germany’s local public transportation sector. I motivated the approach with prior research indicating inefficiency, the high fragmentation of public transport, and the suitable geography of the proposed mergers. I found that the incorporation of differences in rail-bound local public transport services is necessary, but must be analyzed on a case-by-case basis. Population and network density play no substantial role in this already very densely populated area. I determined that substantial merger gains can be expected for bus, tram, and light railway mergers and smaller bus mergers and that larger bus mergers deserve further research. A sensitivity analysis for decomposition of real merger gains revealed the importance of synergy gains over size gains. Nevertheless the two effects can only be addressed together.

Following my analysis, the implementation of mergers with companies operating on a common tram and light railway network should be a high priority from both political and operational perspectives. The merger process assists companies to prepare for a market environment defined by an increasing number of tenders. Companies that are active in several cities learn to diversify their risks, and are no longer dependent on contracts with one city. It is furthermore a goal of transport and competition policy to aim at a framework and measures for a new industry structure. Increasing financial pressure and changes in demography as well as settlement structures will also raise the topic again.
Part III

Competition
Chapter 5

Operator Changes through Competitive Tendering

5.1 Introduction

Local public transport in Germany has long been characterized by local operator monopolies for bus and other road-bound operations like tram and light railway services and the national monopoly for regional rail service, DB Regio, subsidiary of Deutsche Bahn AG. For regional rail services, increased competitive tendering has been introduced throughout Germany and has been scientifically analyzed (e.g., Laliv and Schmutzler, 2008). The introduction of competitive tendering for bus services lags behind. It has not yet started for other road-bound transports. However, there have been tenders for bus services in the entire federal state of Hessen, and in two of Germany’s largest transport associations, MVV and HVV, and occasionally in some other districts. Whereas the MVV in Bayern was the first public transport association that introduced competitive tendering in 1997,\textsuperscript{1} Hessen with its economic heart Frankfurt is surely the most important region for competitive tendering of bus services. Competitive tendering is also called \textit{competition for the market}, in contrast to \textit{competition in the market}, when bus lines are served by more than one operator simultaneously (competition on the road). In Hessen, competition for the market has been introduced for all kinds of bus services, in particular for urban services in Frankfurt. In Munich and Hamburg, the focus is on regional bus services in the surrounding area only. In Hessen, competitive tendering started in 2002 after an initial phase of preparation.\textsuperscript{2}

Each tender for bus services in Germany can contain several line bundles,

\textsuperscript{1}Start year according to Schenck et al. (2003).
\textsuperscript{2}The subsequent chapter is based on Augustin and Walter (2009).

93
called batches. These batches are usually operated by different companies before the tender process and batches can be assigned to different operators when tendering.

Now, that a three-digit number of batches have been tendered out, the outcome is of interest. Several research areas can be identified when evaluating the results of competitive tendering:

- Monetary savings from competitive tendering,
- Quality aspects,
- Market structure,
- Tender setup, structural conditions, and competition.

This chapter aims to analyze the last two aspects, market structure, and with an empirical focus, tender setup, structural conditions, and competition. I evaluate the impact of structural conditions like operation period, volume of the tender, point of time, etc., on an operator change and on the level of competition, measured by the number of bidders. I apply a unique data set with 196 batches using a probit analysis.

One of the hypotheses is that a new entrant will be more likely to win if the volume of the tender is high and the tendered batch hence exhibits higher revenue possibilities. Due to data constraints, I do not look at the managerial factors contributing to successful bids, and at monetary and quality effects of tendering. But I can give recommendations for the future design of competitive tendering, in order to foster competition and attain a better market outcome with decreasing operating costs and decreasing public subsidizing while maintaining or even improving the quantity and quality of services.

Although there is a wide body of international literature on competitive tendering of bus services, econometric studies are rare. Since competitive tendering was introduced relatively early in Scandinavia (Sweden in the 1980s and Norway 1994, all Hensher and Wallis, 2005), studies from these countries are among the few available.

Mathisen and Solvoll (2008) evaluate the market structure of the bus industry in Norway. They use OLS to regress the percentage share of bus-km offered for tendering in 18 counties from 1991 until 2004 on the percentage reduction in the number of bus companies. The share offered for tendering shows a significantly positive impact on the reduction in the number of companies, explaining the 45% decrease in the number of bus companies in that period. Naturally, the average company size increases, by 65%, and increased market concentration follows. The ownership structure changes, from private and local public companies to foreign private and non-local public companies. Furthermore, there are
strong ownership links in the Norwegian bus industry. This has contributed to an average number of bidders between three and five companies.

Alexandersson et al. (1998) evaluate deregulation in Sweden, which was accompanied by competitive tendering of 70% of all bus services. The authors show a positive impact on costs in tendering areas. However, no neighborhood effects could be observed, meaning that introducing competitive tendering has no positive impact on adjacent regions. The authors conduct a regression based on a data set with 24 Swedish counties pooled over 7 years to 168 observations. As dependent variable, Alexandersson et al. (1998) use changes in costs. The independent variables are represented by changes in the share of tendering in year of interest, the preceding and the following year, the accumulated share of traffic subjected to tendering, the change in bus-km, and yearly dummies. The changes in tendering shares in the current and the preceding year show a significantly negative effect on changes in costs. In fact, boosting the share of tendered services from 0 to 100% appears to have a cost-dampening effect of 13.4%. Privatization in turn appears to have no effect. Furthermore, market concentration increases from the end of the 1980s until 1994. Privately- and state-owned companies gained market shares whereas municipally-owned companies lose.

Other noteworthy studies are by Amaral et al. (2009), Hensher et al. (2007), Stoelinga and Hermans (2005), and Yvrande-Billon (2006). Whereas Hensher et al. (2007) reflect theory and empiricism on contracting regimes, asset ownership, and partnerships between government and operators applied to several countries, Amaral et al. (2009) and Yvrande-Billon (2006) focus on France (and London) in more detail. For France, they find a decreasing number of bidders, from 2.5 in 1993 to under 1.5 in 2005 and for London, to a lesser extent, from over 4 in 1996 to under 3 in 2006. Based on an evaluation of 123 bidding procedures from 1995 until 2002, no operator change is observed in 88% of the French cases. In London, this key indicator is 63.5% with 115 renewed contracts between 1999 and 2006. Whereas tenders are executed on entire networks in France, bidders apply for any number of routes or route packages in London. In France, unit costs and labor productivity do not show a positive tendency while in London the results appear ambiguous (Yvrande-Billon, 2006). The main reason for the negative development in France is however said to be low transparency, a lack of capacity, and expertise with the authorities, and the first signs for possible collusion and corruption.

Preliminary results from Italy (Boitani and Cambini, 2006) have also demonstrated some potential problems in competitive tendering such as a limited number of participants and a low percentage of operator changes leading to negligible subsidy savings. The authors conclude that the tender organization should be improved, e.g., through the assignment of independent agencies with the tender
procedure to avoid any potential conflict of interest at local authorities. Evidence from the Netherlands shows that in 26 tenders from 2001 to 2004, 66.6% lead to a renewal of the incumbent. The average number of bidders is equal to 3 (Stoelinga and Hermans, 2005).

The remainder of this chapter is structured as follows. Section 5.2 is dedicated to the theoretical and regulatory framework and the data set concerning competitive tendering. Section 5.3 provides the evaluation of market shares and the empirical analysis of conditions contributing to successful bids. Section 5.4 concludes.

5.2 Sector and Tenders

5.2.1 Theoretical and Regulatory Framework

Krishna (2002) describes the process of procurement via competitive bidding as nothing but an auction, except that bidders compete for the right to sell their products or services. Auctions and competitive tendering are indeed related. The tender is a public announcement of requirements for which the submission of bids is expected (Hadeler et al., 2000). Competitive tendering is often used for public awards of government procurement contracts (Hensher and Wallis, 2005), e.g., for the construction of roads and transport services. Hence, they are sometimes called procurement auctions (Klemperer, 1999). In these cases the objective is to achieve low prices rather than high prices. Thus, tenders and auctions are very similar with the difference being that the lowest bid submission wins. Hence, competitive tendering is also called a “reverse auction” in the literature. According to West (2007, p. 96), competitive tenderings in public transport can contain both private and common value elements. In a private value auction, each operator knows exactly the value of the transport service to itself but not the valuations of the other bidders. In common value auctions, transport services being bid have a true value which is the same to all operators, but none knows it.

The effects of competitive tendering in Hessen and around München and Hamburg have been intensively discussed. Based on an anonymous sample of 81 batches, Beck and Wanner (2007, 2008) find that the price per bus-km in the first tender round is considerably lower than before, up to 40%. The costs of tendering appear to be only 5% of the realized savings. Wanner and Zietz (2008) emphasize that at the same time quality has increased. The average vehicle age in the RMV (Rhein-Main-Verkehrsverbund)\footnote{One of the largest German public transport associations, located in Hessen around Frankfurt.} is 4.4 years on tendered lines and
7.8 on non-tendered lines. Further indicators of improvements are the vehicle emission and noise standards, the use of low-floor buses, and the percentage of vehicles with air conditioning. The authors also note the need for further evaluation of residual costs\(^4\), the effects of second and third tender rounds in particular on the market structure, and the consequences for employees.

### 5.2.2 Data

Each tender for bus services can contain several batches. These batches are usually operated by different companies before the tender process and batches can be assigned to different operators when tendering. In turn, each batch can be composed of several lines, but all lines of a batch will be operated by the same company afterwards.\(^5\) The analysis is hence based on batches because they represent the smallest unit of interest when looking at operator changes and the number of bidders. Figure 5.1 gives an example for a possible tender structure. I classify lines as either urban or regional. If a batch contains both, it is a mixed transportation batch.

Table 5.1 shows the descriptive statistics for the data set. The sample includes 196 line bundles tendered by German public transportation associations and

\(^4\)Costs occurring when a franchise or a license is assigned to a new operator, e.g., the incumbent must still pay its staff.

\(^5\)Except that lines or parts of lines can be sub-contracted.
authorities. To discover which conditions encourage an operator change I define three types of variables regarding competition, contract, and geography. I note that the influence of managerial experience cannot be included in the analysis because it is difficult to measure and the information is not contained in the data set. Since I want to predict the probability of an operator change, the variable to be explained is dichotomous, taking “1” if bus services are awarded to a new operator and “0” if the incumbent stays in place. The mean operator change is 58.2%. The variables in the competition category contain the number of bidders, and, as a second tender round has regularly only started in Bayern, tender round 1 in Bayern and tender round 2 in Bayern.

The number of bidders and the probability of an operator change have decreased remarkably over time, as shown in Figure 5.2. The development shown is based on six time categories, 1997-2004, 2005, 2006, 2007, 2008, and 2009 with an approximately equal number of batches in each period. The high number of bidders in the beginning may be explained by trial and error strategies by small private operators without tendering experience and with strategies that aim at rapidly gaining market shares. The preliminary figures for 2009 (9 observations so far) show that a further decrease is indicated. I note that the low number of bidders may also be related to the global financial crisis which makes vehicle financing more difficult.

For variables tender round 1 in Bayern and tender round 2 in Bayern, a “1” represents a yes and a “0” represents a no. Outside Bayern, there have only been three round 2 tenders.

Then, the collected data considers contract conditions such as the operation period in years. The mean operation period is about six years, and varies between one and ten years in the sample. To reflect the batch size the data contains the number of vehicles, with a mean of 11 vehicles. The variable has a strong influence on assets, bus depots, and maintenance and repair activities provided or at least organized by the company itself. It gives bidders information about the attractiveness of the transport in terms of revenue possibilities. The number of lines, an indicator for the size and the complexity of the batch, varies between 1 and 26. The number of vehicles and the number of lines exhibit a high standard deviation compared to other variables, shown by the coefficient of variation. As already indicated, the operation start is classified in six time-dummies.

There are three types of contract: gross-cost, net-cost, and sub-contracts. Sub-contracts resemble gross-cost contracts with fewer requirements and lower risk for the operator. Sub-contractor services are included in this study only if they are published in the TED – Tenders Electronic Daily: Supplement to the Official Journal of the European Union6. Descriptive analyses reveal that their structure

Table 5.1: Descriptive statistics for 196 tendered batches

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Mean</th>
<th>Std. dev.</th>
<th>Coef. of var.</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operator change</td>
<td>0.58</td>
<td>0.49</td>
<td>0.79</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Competition variables</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of bidders</td>
<td>5.14</td>
<td>2.53</td>
<td>0.49</td>
<td>1</td>
<td>14</td>
</tr>
<tr>
<td>Tender round 1 in BY</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tender round 2 in BY</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Contract variables</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation period in years</td>
<td>6.47</td>
<td>2.12</td>
<td>0.33</td>
<td>0.99</td>
<td>10.01</td>
</tr>
<tr>
<td>No. of vehicles</td>
<td>11.35</td>
<td>9.89</td>
<td>0.87</td>
<td>0</td>
<td>58</td>
</tr>
<tr>
<td>No. of lines</td>
<td>4.47</td>
<td>4.22</td>
<td>0.94</td>
<td>1</td>
<td>26</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Operation start</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1997-2004</td>
<td>35 observations</td>
<td>.</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>35 observations</td>
<td>.</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>37 observations</td>
<td>.</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td>33 observations</td>
<td>.</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>47 observations</td>
<td>.</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td>9 observations</td>
<td>.</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of contract</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>gross-cost: 161; net-cost: 19; sub: 16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Geography variables</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of transport</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>regional: 80; mixed: 83; urban: 33</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Federal state</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HE: 119; BY: 58; SH: 11; others: 8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Own calculation

is similar to the tenders on the primary level. It is noteworthy that in Germany net-cost contracts play a minor role, with only 19 observations.

Next, I consider geographical aspects. The spatial type of transport, either regional, urban, or both (mixed), can also reflect complexity. Handicapped or school transports are excluded because they are a specialized market segment. From the variable federal state, it is obvious that most tenders occur in Hessen (119 observations) and Bayern (58 observations). Schleswig-Holstein is far behind with 11, representing the services in the Hamburg area. Other states included are Baden-Württemberg with 4 observations, Rheinland-Pfalz (Rhineland-Palatinate) with 3 observations and Nordrhein-Westfalen with 1 observation.
5.3 Empirical Analysis

5.3.1 Change in Concession Ownership

Urban public transport is dominated by domestic municipal companies. In nearly all of the large cities, there is a municipally-owned company. The major player in regional services is DB Stadtverkehr GmbH, a subsidiary of Deutsche Bahn AG, organized in 22 major subsidiaries. Market concentration and the presence of multinational companies has not developed as much as in the UK, for example, although some companies like Arriva and Veolia have entered the market through acquisitions of local operators.

Usually neither larger municipal companies nor international ones hold capacities for the entire network for which they are responsible. Therefore, subcontracts are negotiated with small-scale private bus companies. These 4992 companies also operate independently and are building more bidding associations.\(^7\)

\(^7\)For more information, see Deutsche Bahn AG (2009a).

\(^8\)See Bundesverband Deutscher Omnibusunternehmer (2009).
Table 5.2: Batch migration matrix

<table>
<thead>
<tr>
<th>after tender</th>
<th>before tender</th>
<th>Winner is*</th>
</tr>
</thead>
<tbody>
<tr>
<td>abs. rel.</td>
<td>(1) (2) (3)</td>
<td></td>
</tr>
<tr>
<td>196</td>
<td>58 15 123</td>
<td></td>
</tr>
<tr>
<td>rel. %</td>
<td>29.6% 7.7% 62.8%</td>
<td></td>
</tr>
<tr>
<td>Incumbent is subsidiary of DB</td>
<td>92 46.9%</td>
<td>44.6% 1.1% 54.3%</td>
</tr>
<tr>
<td>Municipal incumbent</td>
<td>22 11.2%</td>
<td>13.6% 40.9% 45.5%</td>
</tr>
<tr>
<td>Private incumbent</td>
<td>82 41.8%</td>
<td>17.1% 6.1% 76.8%</td>
</tr>
</tbody>
</table>

*Winner is (1) subsidiary of DB, (2) municipal company, (3) private company; Abs. = absolute, rel. = relative

Source: Own calculation

Table 5.2 shows the development for concession ownerships between the three groups of operators: 1) DB Stadtverkehr, 2) municipal companies, 3) private operators, both SMEs and multinational companies. From 196 tendered batches, DB Stadtverkehr originally held 92 (46.9%), but is now responsible for only 58 (29.6%). Municipal companies also lose slightly, but private companies increase their share from 82 (41.8%) to 123 (62.8%). DB Stadtverkehr has a much smaller market share but mostly their services are tendered out. A closer look at the migration matrix shows that DB Stadtverkehr regains 44.6% of their services tendered out, or 3.7% more than municipal incumbents. The corresponding figure for private incumbents, 76.8%, has to be interpreted with care, because this could be due to regains of privates or switches from privates to other privates. The average probability for operator changes of 58.2% reflects the weighted diagonal of the batch migration matrix under consideration of switches from privates to other privates.

The highest switching rate is reached by private operators, gaining 54.3% of the services formerly provided by DB Stadtverkehr companies. Small private operators may have cost advantages through lower wages and bus depots in the center of their operating areas, but economies of scale for larger companies may be a counter-argument. In the meantime, DB Stadtverkehr faces the competition with models of cooperation, integration, and joint ventures.9

A similar picture emerges for the vehicle-km migration matrix in Table 5.3, which shows the distribution of vehicle-km driven per year before and after the tendering process between the three groups of operators. In contrast to the batch migration matrix shown in Table 5.2, it becomes evident that batches with municipal incumbents exhibit higher volumes per batch, and batches with private incumbents exhibit smaller volumes per batch. Furthermore it shows the very low regain rate of DB Stadtverkehr in terms of vehicle-km, only 18.7%.

9See Deutsche Bahn AG (2009b, p. 22).
Municipal companies have a much higher rate with 56.1%.

The incumbent is not further considered in the analysis. On the one hand I apply variables that can serve as proxies for incumbents, e.g., urban batches are very likely to be operated by municipal operators before the tender. On the other hand, preferential treatments for some kind of companies are difficult to implement because the decision on the winner is mainly based on the single criteria of subsidy requirements.

### 5.3.2 Probit Estimation

In the following I conduct several econometric probit estimations to detect the influence of structural variables on the probability of an operator change in competitive tendering. The dependent variable in the models shown in Table 5.4 is therefore always operator change, taking “1” if the new operator has not been the operator before the tender and otherwise “0”. I conduct the estimations with Stata 9.1 using the Newton-Raphson algorithm for maximum likelihood optimization. The Pseudo R² reported here is defined according to McFadden (Kohler and Kreuter, 2006, p. 286).

The inclusion order of variables is driven by significant levels and the follow-

---

*(1) Subsidiary of DB, (2) municipal or (3) private company; **In m vehicle-km; Abs. = absolute, rel. = relative

Source: Own calculation

---

10 The study design was inspired by Lalive and Schmutzler (2008) who conducted a similar analysis for regional rail services in Germany.

11 If there is more than one operator before the tender, e.g., if several formerly independent lines have been bundled into a new batch, the variable operator change will take “1” if the new operator has not been providing any of the old lines, and “0” if the new operator has been providing some or all lines which have been bundled in the new batch. If the operating subsidiary in a corporate group has changed, this is not classified as operator change. Furthermore, all new batches (in the sense of no prior existing services) are excluded to avoid distortions in the dependent variable.

12 I also experimented with the software BIOGEME 1.8 (Bierlaire, 2008) using different algorithms. The results are very similar to those presented here.
Table 5.4: Probit regression results of structural variables on operator changes

<table>
<thead>
<tr>
<th>Model</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
<td>Estimate</td>
<td>Estimate</td>
<td>Estimate</td>
<td>Estimate</td>
<td>Estimate</td>
<td>Estimate</td>
</tr>
<tr>
<td>No. of bidders</td>
<td>0.26*** (0.04)</td>
<td>-0.59 (0.38)</td>
<td>-0.55 (0.39)</td>
<td>-0.63 (0.39)</td>
<td>-0.73* (0.41)</td>
<td></td>
</tr>
<tr>
<td>Start in 2005</td>
<td>-1.09*** (0.37)</td>
<td>-1.04*** (0.37)</td>
<td>-1.05*** (0.37)</td>
<td>-1.16*** (0.39)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start in 2006</td>
<td>-1.40*** (0.37)</td>
<td>-1.35*** (0.38)</td>
<td>-1.33*** (0.38)</td>
<td>-1.36*** (0.40)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start in 2007</td>
<td>-1.42*** (0.37)</td>
<td>-1.47*** (0.38)</td>
<td>-1.49*** (0.38)</td>
<td>-1.54*** (0.39)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start in 2008</td>
<td>-1.90*** (0.57)</td>
<td>-1.95*** (0.58)</td>
<td>-1.60*** (0.60)</td>
<td>-1.66*** (0.62)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed transport</td>
<td>-0.43* (0.22)</td>
<td>-0.40* (0.23)</td>
<td>-0.37 (0.23)</td>
<td>-0.43* (0.26)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban transport</td>
<td>-0.52* (0.30)</td>
<td>-0.35 (0.32)</td>
<td>-0.26 (0.32)</td>
<td>-0.39 (0.35)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of vehicles</td>
<td>0.03** (0.01)</td>
<td>0.02* (0.01)</td>
<td>0.02 (0.01)</td>
<td>0.02 (0.01)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of lines</td>
<td>-0.08** (0.03)</td>
<td>-0.07** (0.03)</td>
<td>-0.06* (0.04)</td>
<td>-0.07* (0.03)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operation period</td>
<td>0.10* (0.05)</td>
<td>0.09* (0.05)</td>
<td>0.16*** (0.05)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross-cost contract</td>
<td>-0.15 (0.49)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net-cost contract</td>
<td>0.55 (0.63)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bayern (BY)</td>
<td>0.04 (0.50)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hessen</td>
<td>0.09 (0.40)</td>
<td>0.17 (0.36)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tender round 1 in BY</td>
<td>0.62 (0.41)</td>
<td>0.60 (0.52)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tender round 2 in BY</td>
<td>-1.06*** (0.23)</td>
<td>1.51*** (0.31)</td>
<td>1.53*** (0.32)</td>
<td>0.85* (0.47)</td>
<td>1.01 (0.87)</td>
<td>-1.05** (0.51)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.15</td>
<td>0.16</td>
<td>0.19</td>
<td>0.20</td>
<td>0.21</td>
<td>0.10</td>
</tr>
<tr>
<td>Pseudo R²</td>
<td>-113.35</td>
<td>-111.93</td>
<td>-108.30</td>
<td>-106.38</td>
<td>-104.64</td>
<td>-120.35</td>
</tr>
<tr>
<td>Log-likelihood</td>
<td>39.77</td>
<td>42.60</td>
<td>49.87</td>
<td>53.70</td>
<td>57.19</td>
<td>25.76</td>
</tr>
<tr>
<td>Significance level</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

*** Significant at 1%, ** significant at 5%, * significant at 10%; Standard errors in parentheses. Log-likelihood constant-only = -122.32
Source: Own calculation
ing rationale: The first simple model uses the number of bidders as the single independent variable influencing an operator change. The number of bidders is itself determined by structural conditions of the tender and cannot be considered simultaneously in a probit estimation. In the following models, I hence replace the number of bidders by structural conditions. First, I consider structural conditions that are exogenous to the transport authorities (start year, spatial type of transport). Then I turn to variables that are changeable by the authorities (no. of vehicles, no. of lines, operation period, type of contract). The tender round variables, combined with the federal state, exhibit a special case, because tender round is related to start year. I dedicate an extra model to these variables.

The coefficient of the number of bidders is significantly positive at the 1% level. As a first result, I can state:

**Result 1: The more bidders participate in the tender the more likely is an operator change.**

The reasoning is that the number of bidders is an indicator for the attractiveness of the tender. With an increasing number of bidders, it becomes more probable that there will be one bidder with a better offering than the incumbent, leading to an operator change.

The second model introduces a time dimension, represented by time dummies for the years 2005–2009 with 1997–2004 representing the omitted reference category. The coefficients are all significantly negative (except for 2005) with the magnitude increasing from early to recent years.

**Result 2: The later the tender occurs the less likely is an operator change.**

In the late 1990s, competitive tendering was new to the German bus sector, and many entrepreneurs wanted to try it out. As decision support systems improved, and in some cases the winner’s curse appeared, participation has declined. Moreover, some batches were tendered for a second time. Increased market maturity is said to be related to decreased competition intensity, potentially because of increased market concentration, operator resignations, and so on. This development is similar to the one described for France and London (Amaral et al., 2009). In Germany, the average number of bidders is 7.6 at the beginning of competitive tendering (1997–2004), pointing to a “gold rush”

---

13 I also conducted preliminary OLS estimations with the number of bidders as dependent variable and the structural conditions as independent variables. The coefficient results are similar to those presented here.

14 See Beck (2006) for an example.
character.

The second model includes the spatial type of transport. In a simple differentiation, I use a dummy for mixed services and a dummy for urban services, whereas regional services represent the reference category. The coefficients for mixed and urban services are significantly negative at the 10% level.

**Result 3:** Tendering regional services more often leads to an operator change.

One can expect that urban services are less attractive to bidders in comparison to regional services because of the complexities of providing services in urban areas such as the locations of bus depots, network effects, congestion, etc. For mixed services, the same argument applies with the additional complexity of providing both regional and urban services. Bus design for example differs across settlement structures. Low-floor buses are preferred in urban areas whereas coach-type buses are preferred in rural areas.

The third model includes the number of vehicles required and the number of lines in the batch. The coefficient of the number of vehicles required is significantly positive at the 5% level.

**Result 4:** The more vehicles required in the tender the more likely is an operator change.

The number of vehicles required is an indicator for the size of the tender. Large tenders entail higher revenue potential. Assuming that the effort for the submission of a bid only increases slightly with larger tenders, large tenders also involve a better revenue potential to bid effort ratio. Hence, large tenders are more appealing to local public transport companies.

The number of lines however is significantly negative at the 5% level.

**Result 5:** The more lines bundled in a batch the less likely an operator change.

Since I include the number of vehicles and the number of lines simultaneously in the regression, the number of vehicles fully captures the size of the batch, yet the number of lines on the other hand picks up complexity. More lines make scheduling and network more complex. Although the true degree of complexity depends on the network structure (which is difficult to measure), lines may serve as a good proxy.

The result is emphasized by two additional regressions (Table 5.5). Model A
resembles Model 3 except that number of vehicles and lines is replaced by the combined variable number of vehicles per line. The number of vehicles per line is significantly positive at the 5% level.

I also experiment with a combination of these two variables. The variable line-category takes the number of lines per batch if the spatial type of transport is regional and twice the number of lines per batch if the spatial type of transport is mixed or urban. This complexity measure turns out to be significantly negative at the 1% level in Model B. It can hence be interpreted as follows. A single regional line is least complex whereas a high number of lines in urban or mixed areas indicate the highest network complexity.

The fourth model includes the operation period in years. Its coefficient is significantly positive at the 10% level.

**Result 6: A long operation period increases the chances for an operator change.**

The result shows that long operation periods in the sample positively trigger operator changes in comparison to shorter periods. Longer operation periods are more attractive to bidders because of planning reliability and lower invest-
ment risks for the bus fleet. The operation period averages 6.5 years in the sample and the maximum operation period amounts to 10 years. A short operation period may not encourage much investment in bids or assets. If a bus life cycle of eight to twelve years is assumed, longer operation periods in the sample may represent such life cycles and vehicles can fully amortize during the contract period. Operation periods that are too long may raise incumbent advantages, but also introduce new long-term risks for operators. This effect is however not observable in the samples since the maximum period is 10 years.

The fifth model adds two more aspects, both without any significant influence. The two dummies that characterize the type of contract are gross-cost contract and net-cost contract, and sub-contractor gross-cost contracts provides the omitted reference category. I expect the net-cost contract to have a significantly negative influence on the probability of an operator change, since the operator has to additionally bear the revenue risk. Although this provides added incentives and the chance for increased demand orientation, the additional risk should make a tender less attractive. One could argue that it will only be less attractive if this additional risk is not reflected in higher subsidies. This argument may also be valid for the complexities that arise with a high number of lines and mixed or urban operations. As the standard variation for the type of contract is high, I do not further interpret the coefficient.

The two dummies for Bayern and Hessen characterize the federal state in which the tender and service takes place, with all other federal states (with the small minority of tender) providing the omitted reference category. The different political frameworks suggest that there are differences between federal states. Here, I find no significant differences, possibly because the differences have already been accounted for in the structural variables.

Result 7: The type of contract and the federal state do not show any significant influence on the probability of an operator change.

The sixth and last model in Table 5.4 adds the federal characteristic again, in combination with the tender round. As competitive tendering is a relatively new phenomenon in German local public transport, Bayern is the only state where tender round 2 has regularly begun. It appears natural to introduce some combinatorial variables associated with these aspects. I include a dummy for first round tenders and a dummy for second round tenders in Bayern. I also include the dummy for Hessen once more, with tenders in all other federal states providing the omitted reference category. As the tender round contains a temporal aspect, I include the new variables in a modification of the fourth model. The coefficients for the tender rounds in Bayern are not significant.
Result 8: The first and second tender round in Bayern show no significant influence on an operator change.

I recognize that the coefficients for the first and second tender round in Bayern are positive, with a higher magnitude than the coefficient for Bayern in Model 5. This may also be related to the spatial type of transport which was excluded from the sixth model. The coefficients of the variables operation period, number of vehicles, and number of lines are otherwise very similar to the other models.

5.4 Conclusion

The analysis showed that the focus of competitive tendering in Germany has been on regional bus services, which led to a loss in market share for DB Stadtverkehr companies and gains for private companies, whereas municipal services have only rarely been tendered out.

I identified structural conditions that significantly influence the probability of an operator change in competitive tendering of local public transport services in Germany. Whereas a low percentage of operator changes is said to be an imperfect indicator for the competition intensity, a high percentage of operator changes appears to be a good sign of competition (Amaral et al., 2009). In the analysis, 58% of operators have changed, but this value has decreased from 91% between 1997 and 2004 to 38% in 2008, the last year fully captured.

The number of bidders is dependent on these structural variables. It can also serve as an indicator for the possible savings from competitive tendering in comparison to the previous approach of directly awarding concessions for line services, without competition. Competitive tendering will achieve its targets only if a sufficient number of bidders participate in the reverse auction. These targets are an efficient production of services, a bid that corresponds to average production costs plus an opportunity cost of capital that is normal in the market, and a quality of services that is at least as good as before (Williamson, 1976). The concrete monetary effects could not be evaluated, due to data constraints, but should be subject to further research. It is then interesting to compare the subsidies paid before the first tender, in the first tender round and in further tender rounds. It would also be useful to separate those tenders where actual savings could be realized from those tenders where the successful bidder only won at the cost of future losses. When comparing the subsidy levels, structural conditions should be accounted for again.

In detail, the analysis revealed some contractual variables that can be ad-
justed in further tenders to foster competition. The tender design should not fit a specific type of company, but encourage competition by providing equal conditions for all bidders. A long operation period and a large volume in terms of vehicle requirements positively influence operator changes. The number of lines negatively influences operator changes. Some more structural variables could be revealed as further determinants, but cannot be changed in a tender process because they are exogenous. An earlier start of operation and first round of tenders in Bayern are such positive determinants and urban and mixed transports are such negative determinants of operator changes. The type of contract did not show any significant influence, possibly because of the low number of net-cost contracts to date.

The latter issue highlights the importance of data availability. Whereas the data set contains rich information about a multitude of tenders, some tenders are missing and should be included in future analyses. The same applies to other variables not considered here due to data constraints, such as the number of batches per auction, the volume in terms of actual vehicle-km, planned timetable-km, and timetable hours, and bonus-malus-systems and securities. Were designated information about the bidders available the analyses could be extended to a multi-nominal system of alternatives.
Chapter 6

Prospects of Express Coach Services

6.1 Introduction

Express coach services in Germany historically have been heavily restricted by regulation to protect the national railway from competition. According to the Passenger Transport Act (§ 13 PBefG), which applies to all public road transport, new services are only allowed if they can demonstrate significant improvements in travel and the existing local or long-distance railway operator must first be asked if it can operate the new service suggested or improve its service. Hence, the possibilities for market entry have been negligible.\(^1\)

Recently, the framework for transport provision has changed due to the liberalization of transport markets in general, increased horizontal integration of international transport companies, more environmental awareness, and demographics. These and other changes pose the question: From the viewpoint of economics, is it worthwhile to supply extensive express coach services in Europe’s largest economy and transport market?

To relate the question to the challenges faced by Germany’s public transport companies, I review their incentives for entrance to the market. I focus on the diversification of existing transport operators and their corporate strategies, and because of the scope of this chapter, omit looking at specialized entrepreneurs. By providing a comprehensive economic analysis of the express coach market considering supply and demand, I contribute to the ongoing policy discussion. The results are relevant for the business community, policymakers, and researchers.

The remainder of this chapter is structured as follows. Section 6.2 describes

---

\(^1\) The subsequent chapter is based on Walter et al. (2009b). See also Becker et al. (2008) for the implementation of the conjoint analysis.
PROSPECTS OF EXPRESS COACH SERVICES

selected international express coach operations. I review the existing literature about express coach services and conduct a player analysis of the major firms operating express coach services with respect to business segments and their turnover figures. A profitability analysis shows the attractiveness of market entry. Section 6.3 looks at the regulatory practice in Germany as well as the major German public transport players that potentially could be interested in providing express services. Section 6.4 looks at the supply side by comparing external and internal costs of different modes of transport. Section 6.5 studies the demand side with a market share estimation derived from a conjoint analysis based on an extensive survey. Section 6.6 concludes.

6.2 Selected International Express Coach Experience

6.2.1 International Literature on Express Coach Services

The deregulation of express coach services in Britain in 1980 has been intensively analyzed in the international literature (e.g., Cross and Kilvington, 1985, and Robbins and White, 1986). More recent papers focus on efficiency analysis of coach and bus transportation (Yu and Fan, 2008, for Taiwan, Dalen and Gómez-Lobo, 2003, for Norway) and on scheduling express coach services (Yan and Tang, 2008, and Yan et al., 2007). However, recent literature on the regulation of express coach markets and on the overall perspectives of express coach services is rare. There are some governmental reports and domestic articles on the development of services, e.g., Maertens (2006) for Germany, Statens Institut för Kommunikationsanalys (2005, 2007) and Banverket (2006) for Sweden, and Schwieterman et al. (2007) and Transit Cooperative Research Program (1999, 2002) for the US.

6.2.2 Market Shares, Turnover Figures, and Profitability

To study Germany, I first look at domestic express coach activities in the UK, the US, and Sweden, because they have already experienced liberalization (UK 1980, Sweden 1998, US 1982). Their express coach markets are dominated by integrated transport companies offering mainly train, express coach, and local bus services (UK and Sweden), and to a lesser extent in the US, where the market is more diversified. Understanding the domestic express coach activities

---

2 An additional consideration of international express coach connections, apart from purely domestic services, is beyond the scope of this chapter. However, to provide some background, there is a dense network of international express coach lines connecting Germany with many destinations throughout Europe.

3 This explains why I omit express coach services in Finland, South America, etc.
Player Analysis for Great Britain

National Express is the market leader in Great Britain with a market share of 83% in British express coach services in 2007 (National Express Group, 2008). In that year National Express generated total revenues of over 3 bn EUR. Its largest branch is represented by the UK train business with 56% turnover share. Local buses in Great Britain and the North American student transport division of National Express generate 12% each of total turnover. Urban and commuter as well as long distance services in Spain contribute 11% of total turnover, followed by the British express coach division with a 9% turnover share. Figure 6.1 shows the normalized operating profit margin\(^4\) of National Express’ different business units from 2003 through 2007. Additionally the operating profit margin of the company as a whole is given. National Express shows an express coach profitability continuously above company average. Profitability of express coach services is only topped by the profitability of local bus services: 14.2% in comparison to 10.0% for 2007.

The “biggest” rival of National Express’ coach services is Stagecoach with the coach brands Oxford Tube, megabus.com and Citylink. Stagecoach is another integrated transport company active in the rail, coach, and bus sectors. While National Express acts as a franchisor and contracts with local bus companies in order to keep its express coach business running, Stagecoach manages its own bus operations. These operations are, as White (2008) points out, mainly based on pre-booking relying on a yield management system.

Player Analysis for the US

Stagecoach is also active in the US. This market has 3500 providers (Nathan Associates Inc., 2006), making it far more diversified than any European market. The market leader, Greyhound, is a subsidiary of another integrated British transport company, FirstGroup. Greyhound has a share of 37% in the total US market for express coach services of around 0.95 bn EUR in 2007 (FirstGroup, 2007 and BEA, 2008). For First Group, the adjusted operating profit margin\(^5\) of express coach operations is 3.1% in 2007. This relatively low number in comparison to Great Britain can be explained by the restructuring undertaken

---

\(^4\)Profit before tax, goodwill impairment, intangible amortization and exceptional items divided by revenue.

\(^5\)Profit before amortization charges, non-recurring bid costs, other non-recurring items, and profit/loss on disposal of properties divided by revenue.
after the company’s acquisition, by various competing offerings in the market in general, and by the price wars among competitors particularly on the East Coast.\footnote{The operating profit margins for FirstGroup are only available for 2007, because FirstGroup acquired Greyhound in early 2007.}

**Player Analysis for Sweden**

The express coach market in Sweden is dominated by Swebus Express, a subsidiary of Concordia Bus. Concordia Bus is one of Scandinavia’s largest transportation companies with a turnover of more than 0.5 bn EUR in 2007/2008.\footnote{Exchange rate Swedish Krona to EUR (5 December 2008): 0.0945.} Horizontally integrated as well, Concordia Bus operates only with buses. Revenues from contractual bus services in Sweden amounted to a revenue proportion of 74%, followed by contract services in Finland (10%) and Norway (9%) and the express coach revenues of Swebus Express (7%) (Concordia Bus, 2008). Swebus Express operates mainly on the trunk routes between the domestic urban areas of Stockholm, Göteborg, and Malmö, but serves Oslo and København as well. The main competitor in intermodal transportation is Statens Järnvägar (SJ), the largest Swedish rail company, which has a market share of 75%, whereas Swebus Express has a 5% share (Concordia Bus, 2008) in intermodal competition. The operating profit margin\footnote{Profit including dissolution of provisions for loss contracts, restructuring expenses, and reconstruction expenses divided by revenue.} of Concordia’s express coach services is superior to its other business units.

**Summary of the International Player Analysis**

In Great Britain and Sweden, the express coach markets are dominated by integrated transport companies. In the cases of Concordia in Sweden and Stagecoach in Great Britain, local bus and express coach services are operated by the same company. National Express reverts to other local bus companies by their franchising strategy. Although First Group’s US-American Greyhound business is not directly linked to local services as well, the company still represents a model of offering all services in one company. The strategies described above could function as models for German public transport companies to adopt, because the German firms already own parking and maintenance facilities and employ driver workforces.

While it can be difficult to directly compare the profitability of companies across the three countries I have selected, because some are franchisors or franchisees, some offer local and rail services in addition to express coach, and some operate in more than one country, international experience suggests that express
Figure 6.1: Operating profit margin of express coach market leaders in the UK, Sweden, and the US

Source: Own illustration derived from annual reports

coach services are not only a reasonable possibility for diversifying transport activities, but may also improve average profitability.

6.3 German Situation

6.3.1 Regulatory Barriers to Market Entry

To understand the German express coach market, I describe the regulatory framework set by legislation, and the specific consequences that impact express
coach services. Domestic express coach services in general are scarce. The first regulatory ordinance and the first law were created in the 1920s and affirmed forty years later by the enactment of the Passenger Transport Act in 1961. This law was originally designed to protect Deutsche Bundesbahn, the national rail operator, from Germany’s rapidly expanding bus and coach companies. The PBefG limits the possibility to set up new services. Existing operators can expand their services with priority and the 1961 law explicitly prohibits competition among different operators on a single route.

In recent years, several judiciary appeals by incumbents (i.e., the enterprise serving a similar or partially parallel route) which were unhappy after a concession was granted to a competitor have produced inconsistent decisions by German courts. Market entrants and established firms and policy-makers have hence been refused a clear understanding of the law’s application. I note also that continued political support in Germany for the 1961 law goes against the intent of the European Union to encourage competitive transport markets throughout the continent.

6.3.2 Diversification Opportunities for Public Transport Companies

Before analyzing the supply and demand of domestic express coach services in Germany, I want to show the strategic business options in a deregulated express coach market. I hereby refer to Figure 1.1 in which I conduct a strategic player analysis of the German bus market. Four main types are identified: municipally owned local transport companies, state-run public transport companies, international players, and private SMEs.

For municipally owned local transport companies, there are three strategic possibilities in a deregulated German express coach market. One is direct entry, where economies of scope can be realized for sales and marketing or, most importantly, for technical divisions such as vehicle maintenance, fuel purchasing, etc. Municipal companies can also utilize their existing depots and service

---

9 Apart from some airport links, most of the few existing routes offer only one daily departure. Historically, there are various connections from and to Berlin. However, a dense schedule with hourly departures is only offered on a single route connecting Berlin and Hamburg (Berlin-LinienBus, 2008).

10 Veolia subsidiary NordWestBahn circumvented the introduction of an express coach service intended by Deutsche Bahn between Bielefeld and Paderborn because of its partially parallel train services (ÖPNV-Wettbewerb, 2007). Between Frankfurt and Dortmund, Deutsche Touring was allowed to offer coach services despite existing train connections by Deutsche Bahn (ÖPNV-Wettbewerb, 2008). This was also the first time a German court accepted the argument that significant lower prices on the bus route would count as an “improvement” of the transport service. It is possible that the court’s ruling could be a major turning point for the introduction of new express coach services in Germany.
areas as starting points for long-distance routes. To exploit these synergies at both ends of their routes, local operators can partner or cooperate with similar companies in other cities and regions. A second strategic possibility is that local public transport operators or their private subcompanies can act as subcontractors that deliver services to the enterprises holding the concession. On the operational side, the advantages are similar to those resulting from direct entry, but leave the potential risks arising from a lack of market information in long-distance traffic to the contractor. A third option is to operate as a franchisee and thus benefit from the experience and reputation of the franchisor. A natural candidate for a contractor or franchisor is DB Stadtverkehr. An alternative option for DB Stadtverkehr is direct entry without subcontracting or franchising.

A possible strategy for gaining market share in a deregulated express coach market for foreign companies is to pursue a franchise strategy. For direct market entry, most would face the need to cooperate with local partners, however, since depots and other key infrastructure may be too costly to install in other regions solely for use by express coach services. In this case more acquisitions may be expected, although most of the large enterprises’ growth in market share has been based on winning competitive tenders in the past.

The strategic options of local SMEs in a deregulated express coach market lie in subcontracts, franchised operations, or direct entry through co-operation with similar SMEs like Svenska Buss in Sweden. Their major advantage is experience with hired coach travel, a business similar to express coach services but with less regularity and less risk. 2% of these enterprises already offer (on a limited scale) long-distance scheduled transportation, mainly on less-regulated international routes (Bundesverband Deutscher Omnibusunternehmer, 2009).

6.4 Analysis of External and Internal Costs

Next, I evaluate the potential supply of and demand for express coach services in Germany. External and internal costs are significant criteria in comparing means of transport and both give important evidence about the economic and environmental effects of intercity bus usage. In 2005, overall external costs for passenger and goods transportation in Germany totaled 80.4 bn EUR (INFRAS, 2007), which includes the costs resulting from accidents, air pollution (basically particulate matter), climate (mainly for CO₂), noise, up- and downstream processes (e.g., energy generation for trains), disruption of the natural environment, and additional costs for urban areas.

To establish a consistent basis for comparison, I must calculate all costs per person and per kilometer. Therefore it is necessary to examine capacity utiliza-
tion for all transport sectors. For trains and airplanes, I use the capacity utilization of the market leaders (Deutsche Bahn AG, 2008, and Lufthansa, 2008), and for passenger cars I use data from the largest German automobile club (ADAC, 2008). Higher petrol prices have made arranged lifts (carpooling) more popular in Germany. A study by Strauß and Stegmüller (2006) has determined a capacity utilization of 3.5 people per passenger car in the case of arranged lifts which is much higher than the average capacity utilization of 1.5 people per passenger car in Germany, determined by INFRAS (2007). For hired coach transportation for tourism purposes, I assume capacity utilization between 60% to 80% (Umweltbundesamt, 2008, and Maertens, 2006), but these values can not be applied to express coach services without further study. Due to in-advance booking, hired coach travel tends to achieve high-capacity utilization. Hence, for express coach services, I assume the lower boundary of 60% capacity utilization. For a second scenario, I assume a capacity utilization of 44%, prevailing for intercity rail transportation in Germany. Figure 6.2 shows that express coach services have the same or lower external costs as all other means of transport. Regular and non-scheduled bus services feature non-internalized costs of 1.56 EUR per 100 passenger-kilometers for an operating grade of 60%. Even with a capacity utilization of 44%, express coach services achieve the same level of external costs as the other means of transport. The highest external cost fraction for express coaches is represented by accident costs.

Figure 6.3 sets the external costs in relation to internal costs. Data for intercity trains, airplanes, and passenger cars derive from Deutsche Bahn AG (2008), Lufthansa (2008), and ADAC (2008). To identify internal costs for express coach transportation I use the proposed costs by Maertens (2006) and Leuthardt (2008), cost values identified through the Transport Statistics Great Britain (Department for Transport, 2007), and the cost values of the Swedish market leader Concordia Bus (Concordia Bus, 2008). Despite these different approaches, I find nearly identical cost values and take the mean of them in the following. Nonetheless, I note that costs will depend considerably on the degree of capacity utilization for express coaches as well. Figure 6.3 shows that the express coach segment is first for both scenarios. Hence, cost advantages on

11 Arranged lifts or rides are characterized by informal private agreements to travel together. In doing so the car owner usually posts the offering on the Internet (e.g., www.mitfahrelegenheit.de, retrieved 06 March 2009). Car owners are price-takers due to the large amount of offerings.

12 Information on the capacity utilization of Deutsche Bahn ranges between 42% to 48% (Handelsblatt.com, 2008, Umweltbundesamt, 2008, and Deutsche Bahn AG, 2008.)

13 Regarding the Transport Statistics Great Britain (Department for Transport, 2007) internal costs are calculated as the ratio of overall transportation revenues and passenger-kilometers generated by express coach services. To get the costs, revenues are reduced by the 10% profit margin of National Express in 2007.
both the external and the internal costs side appear, with a possible internalization of external costs leading to increased competition of express coach services, independent of operating grades.

### 6.5 Market Share Estimation

#### 6.5.1 Methodology: Conjoint Analysis

Having evaluated the supply side of express coach services, I now turn to demand estimation, using a conjoint analysis. This method measures the share of single components to overall utility based on empirically collected total utility values (Backhaus et al., 2006, pp. 557 ff.). The generated partial utility values are aggregated to a preference-determining total utility value. Identifying partial utility values is realized via changing combinations of attribute levels (stimulus). The recall of the stimuli uses either profile or trade-off methodologies (although the full profile method is more complex with an increasing number of attributes, the trade-off method delivers less accurate results, because the customer can only choose between two attributes). A combination of both methodologies is here employed.

The attribute levels are typical for the respective products. This leads to restrictive assumptions, which are to be respected while choosing attributes. Advantageous for a conjoint analysis, the importance of single attributes is mea-
Figure 6.3: Internal and external costs in long-distance passenger traffic considering different operating grades

Source: Own illustration after Becker et al. (2008) and INFRAS (2007)

Moreover, there is a possibility to develop or design products, which in their combination of attribute levels have not existed previously, since any combination of attributes to a total utility value is possible.\(^\text{14}\)

The first-choice rule, also called the maximum utility rule, is used here to calculate market shares. The rule implies that each respondent can only choose one alternative per purchase (obviously true of decision-making about travel). Following Henrichsmeier (1998), market shares determined by first-choice rule are the more valid the more extensive the purchase decision. As a majority of the respondents\(^\text{15}\) stated that their choice for a means of transport was rethought before starting their travel, the decision process is proven to be extensive.

However, the first-choice rule is a very restrictive decision. Even when the difference between utility values is slight, only the alternative with the highest value is chosen. Therefore, the sample size must be sufficiently large to minimize the standard error. Orme (1998) recommends a respondent number of

\(^{14}\)For a more detailed description of consumer-choice modeling with a conjoint analysis, see Green and Srinivasan (1990).

\(^{15}\)68.15% of all respondents stated that they consider alternative means of transport before traveling, 31.85% stated to be determined on a certain means of transport.
approximately 200 individuals. By transforming product decision probabilities, the first-choice rule then leads to the generation of market shares.

6.5.2 Questionnaire and Sample

The questionnaire for the conjoint analysis was available on an independent Web site between 8 April and 30 September 2008 to reach a large number of respondents. Although internet-based advertising via bulletin boards, newsgroups, newsletters, and online communities was quite successful, I note that not all of the proportions in the data set were representative of Germany’s actual population. Therefore statistical loadings were applied in order to receive representative results. The resulting sets were then classified to find information on market share by social groups (e.g., home region, age, income, etc.). After eliminating implausible and incomplete sets, the final sample consisted of 1200 usable observations (respondents), which fulfilled the requirement to apply the first-choice rule.

Respondents questions were asked about socio-demographic aspects and past travel behavior for purposes of classification. Four relevant attributes were included: travel price, duration of travel, service/comfort, and reliability. The actual conjoint analysis which required respondents to state their preferences first presents different levels of only one attribute. In subsequent questions, the set of alternatives includes up to three attributes with different levels. An example is to choose between alternative 1 with travel duration of 3 hours, travel price of 20 EUR, and a medium service/comfort level on the one hand and alternative 2 with travel duration of 1:45 hours, travel price of 40 EUR, and a low service/comfort level. Travel price and duration of travel are objective attributes with a definite measuring scale. Thus an explicit level can be assigned to each choice of transport (for Germany’s long-distance traffic they are passenger car, train, bus, and aircraft). Passenger cars were differentiated by respondent-driven cars and cars driven by someone else. Service/comfort and reliability are subjective attributes, meaning that the same level of an attribute at the same time can be perceived differently by different customers. Defining a certain level of service and explaining it to all respondents would risk introducing irrelevant elements into the analysis. Hence, for the two subjective attributes each respondent was required to assign a level (high, medium, low) to the four choices of transport. Then the individual levels to the utility value calculation were applied.

\[\text{The differentiation was introduced to cover the services of agencies for arranged lifts, which are common in Germany, especially for younger people.}\]
6.5.3 Market Share Results

In order to receive appropriate market shares, the availability of the different means of transport must be considered, since not all means of transport are available for every trip. 77.0% of all Germans have access to a passenger car (Statistisches Bundesamt, 2007). The availability factors for train respectively air transport are basically calculated from the structural data of the German Bundesamt für Bauwesen und Raumordnung (2006), resulting in 10.0% for air travel and 63.6% for long-distance train travel.\textsuperscript{17} Two scenarios for the market shares of different transport modes are estimated. In the first scenario, the availability of express coaches is set equal to the long-distance railway service availability. This does not imply that coaches only stop at train stations; rather, it means that express coach stops and rail stations are accessible for the same number of people. Based on this assumption, Figure 6.4, left, shows the scenario of higher network coverage for express coach services on a representative 300 kilometer long-distance trip.\textsuperscript{18} I observe a high potential, up to 28%, for express coaches, compared to trains (19%). Passenger cars retain about 50% of market share, and air is last at 3.9%. These findings indicate that following express coach deregulation, passenger cars will likely lose the most market share.\textsuperscript{19} Additionally, in the highly elastic long-distance market an additional mode could not only divert trips from other modes, but also stimulate new or more frequent travel (e.g., making a visiting friends and relatives trip twice instead of once a year if price were reduced).

Figure 6.4 (right) evaluates a second scenario with lower network and access point density. Apparently, regarding the few currently existing express coach routes (and excepting tourist services), only cities with more than 100 000 inhabitants are served. This matches observations in the deregulated Swedish

\textsuperscript{17}The availability factors for train and aircraft are calculated on the basis of the population distribution given by Bundesamt für Bauwesen und Raumordnung (2006) as follows: At a travel distance of 300 kilometers a maximum access time to long-distance rail stations or airports of 30 minutes is set as acceptable. Ca. 26 m people live in the ambit of these 30 minutes around all German passenger airports, which in relation to today’s total population of 82.4 m people leads to an availability factor of 0.3158. Accessibility of long-distance rail stations in the same radius is calculated analogically to 0.7974. As this considers only the access, but in most cases destination airport or destination rail station are not the final destination of a trip, the calculated factors are squared to cover the availability at the destination as well. This results in a relatively low availability factor of 10% for air travel. However, through the distance restriction imposed, traveling from and to Berlin is for example not possible by aircraft within 300 kilometers.

\textsuperscript{18}The distance of 300 kilometers was chosen because it is approximately the medium travel distance in German domestic long-distance traffic (Reim and Reichel, 2005).

\textsuperscript{19}The most recent survey on modal split in German long-distance travel for different distances (Zumkeller, 2005) results in an empirically determined modal split of approximately 80% for road transport and 18% for rail transportation.
market, where most long-distance coach services concentrate on links between metropolitan areas. Here I have calculated an availability of 8.9%, which produces a 5.3% market share for express coaches. Even assuming low accessibility, express coach services are competitive.

The results also reveal interesting correlations between some socio-demographic criteria and coach affinity. As shown in Figure 6.5, older, younger, albeit to a lower extent, and low-income individuals tend to use coach services more intensely. Although the lower ticket prices for coach travel partially accounts for this finding, on the other hand older people may express an unwillingness to travel long distances by passenger car (their health may be a factor), or do not hold driving licenses.\footnote{The socio-demographic results refer to the scenario of low network coverage. The corresponding results for the high network coverage are quite similar.}

### 6.6 Conclusion

Currently, the German regulatory regime for long-distance transportation impedes competition and protects monopolistic structures, contradicting the European Union’s intentions to create freely accessible markets. In particular, express coach services are not allowed to prove their economical and environmental su-
Express coaches have the lowest internal and external costs among all long-distance transport, and with additional internalization of external costs, their economic advantages increase.

Due to recent developments, however, regulatory changes can be expected which encourage more competition in Germany’s long-distance travel sector. The results predict an express coach market share in national long-distance travel of at least 5%. I suggest that both seniors and people with lower incomes would use express coaches more often.

I find that this potential market offers interesting diversification opportunities for public transport firms. Economies of scope with local bus services can be expected in various areas, including sales and marketing, vehicle maintenance, and fuel purchasing. These agglomeration economies are critical success factors for withstanding competition and ensuring profitability. However, I note that this may only hold for the scenario of high network coverage, because a critical volume may be necessary to exploit the potential.
Appendix A

Program Code

This appendix provides the program code for the econometric and linear programming calculations. The reader will find commands provided by the program in blue letters.

A.1 LIMDEP Code for Chapter 2

/* LIMDEP CODE: COST EFFICIENCY AND SOME OF ITS DETERMINANTS */

/* reset and afterwards set range with data (out_data_v04d.mw.02092009.x(ls)) reset$ */

/* variable definition */

/* total costs */
create: cl=per_cost+mat_cost+dep_cost+oth_cost+int_cost+ass_cost$
create: y1=skm_bus$
create: y2=skm_tra$

/* labor price */
create: w1=per_cost/mak$
create: w2=(cl−per_cost)/(seat_bus+seat_tra)

/* linear time trend */
create: z1=t$
create: z1sq=t$
create: z12=td2$
create: z13=td3$
create: z14=td4$
create: z15=td5$
create: z16=td6$
create: z17=td7$
create: z18=td8$
© 2023 John Wiley & Sons, Inc. All rights reserved.

```
\[ \begin{align*}
\text{create; } & z19=td05 \\
\text{create; } & z10=td06 \\
\text{create; } & z2=len\text{.tram} \\
\text{create; } & z3=len\text{.bus} \\
\text{create; } & z5=\text{pop\_area}/(len\text{.tram}+len\text{.bus}) \\
\text{create; } & z6=\text{pur\_cost}/c18 \\
\text{create; } & z7=vkm\text{.bus}/v\text{.bus} \\
\text{create; } & z9=vkm\text{.tram}/v\text{.tram} \\
\text{create; } & z9c=xbr/z9c \\
\text{create; } & c1lh=c1xc/w1xc \\
\text{create; } & w2lh=w2xc/w1xc
\end{align*} \]
```
PROGRAM CODE

/*
 * create variables for translog function
 */

/* logarithms */
create: lnC1lh = log ( C1lh )
create: lny1 = log ( y1xc )
create: lnw2lh = log ( w2lh )

/* square terms */
create: y1sq = lny1+lny1+0.5
create: y2sq = lny2+lny2+0.5
create: w2lhoq = lnw2lh+lnw2lh+0.5

/* cross terms */
create: yly2 = lny1+lny2
create: yly2lh = lny1+lnw2lh
create: yly2w2lh = lny2

/* namelists for variable calling */
namelist: xcyw=one, lny1, lnw2, lnw2lh, y1sq, y2sq, w2lhoq, yly2, yly2lh, yly2w2lh
namelist: time=z12, z13, z14, z15, z16, z17, z18, z19, z20

/* estimation of Random Effects models */
frontier: cost: lns=lnC1lh; rhs=xcyw, time, z5xc; panel: pds=N1; eff=efcrem$
calc: rem=rem$1
create: efcrem=exp(-ucrem)$
kernel: rhs=efcrem$

/* model of publication */
frontier: cost: lns=lnC1lh; rhs=xcyw, time, z5xc; het: hfu=one, z8xc; panel: pds=n1; eff=efcrem$
calc: rem=rem$8
create: efcrem=exp(-ucrem$8$
kernel: rhs=efcrem$

/* estimation of True Random Effects models */
frontier: cost: lns=lnC1lh; rhs=xcyw, time, z5xc; par$
frontier: cost: lns=lnC1lh; rhs=xcyw, time, z5xc; hfu=one, z6xc, z8xc;
         pds=n1; rpm: fn=one(n); halton: pts=1000; eff=efcrem$8$; test b(21)=0, b(22)=0
create: efcrem=exp(-ucrem$8$
kernel: rhs=efcrem$

/* model of publication (different Wald test than in the model above) */
frontier: cost: lns=lnC1lh; rhs=xcyw, time, z5xc; par$
frontier: cost: lns=lnC1lh; rhs=xcyw, time, z5xc; hfu=one, z6xc, z8xc;
         pds=n1; rpm: fn=one(n); halton: pts=1000; eff=efcrem$8$; test b(21)=0

/* model of publication (different Wald test than in the model above) */
frontier: cost: lns=lnC1lh; rhs=xcyw, time, z5xc; hfu=one, z6xc, z8xc;
         pds=n1; rpm: fn=one(n); halton: pts=1000; eff=efcrem$8$; test b(22)=0
PROGRAM CODE

# estimation of Random Parameter models

```r
# model of publication
frontier; cost; lhs=linc1lh; rhs=xcyw, time, z5xc; par$
frontier; cost; lhs=linc1lh; rhs=xcyw, time, z5xc; hfn=one, x6xc, x8xc;
pds=ni; rpm; fcn=one(n), lny1(n), lny2(n); halton; pts=1000; eff=efcrpm68;
test.b(19)=0.8; test(20)=0$
calculate: ecfre68

# model of publication (different Wald test than in the model above)
frontier; cost; lhs=linc1lh; rhs=xcyw, time, z5xc; par$
frontier; cost; lhs=linc1lh; rhs=xcyw, time, z5xc; hfn=one, x6xc, x8xc;
pds=ni; rpm; fcn=one(n), lny1(n), lny2(n); halton; pts=1000; eff=efcrpm68;
test.b(19)=0$
```

# Likelihood-Ratio tests for Random Effects

```r
# calculating the test statistic
```

```r
calc.list; lrtest = 2 * (remz6z8 - rem)$
calculate: pvalue=1-
```

```r
# calculating the critical test statistic
```

```r
calc.list; femlr=one, z6xc, z8xc; ctb=summarized
```

```r
# with tablevlu, commands summarized
```

```r
calc.list; lrtest = 2 * (rem6z8 - rem); pvalue=1-chi(lrstest, 1); tablevlu=ctb(.95, 1)$
```
\texttt{calc: list; rkc(rankre68, rankre8) $
}\texttt{calc: list; rkc(rankre8, ranktr68) $
}\texttt{calc: list; rkc(rankre8, rankrp68) $
}\texttt{calc: list; rkc(ranktr68, rankrp68) $
}\texttt{efficiency correlation for all observations}\n\texttt{calc: list; cor(efcrem68, efcctrem8) $
}\texttt{calc: list; cor(efcrem68, efcrpm68) $
}\texttt{calc: list; cor(efcrem8, efcctrem68) $
}\texttt{calc: list; cor(efcrem8, efcrpm68) $
}\texttt{Spearman rank for group means}\n\texttt{calc: list; rkc(range68, rangre8) $
}\texttt{calc: list; rkc(range8, rangtr68) $
}\texttt{calc: list; rkc(range8, range68) $
}\texttt{calc: list; rkc(range68, range68) $
}\texttt{Spearman rank for group means}\n\texttt{calc: list; cor(egcrem68, egcctrem8) $
}\texttt{calc: list; cor(egcrem8, egcctrem68) $
}\texttt{calc: list; cor(egcrem8, egcrpm68) $
}\texttt{calc: list; cor(egctrem8, egcrpm68) $
}\texttt{calculate Kruskal–Wallis tests in STATA}\n\texttt{end}
A.2 LIMDEP Code for Chapter 3

# LIMDEP CODE: ECONOMIES OF SCALE AND SCOPE

reset

## Variable Definitions

reset $end$

## Total Costs

create: cl=per_cost+mat_cost+dep_cost+oth_cost+int_cost+ass_cost

creat: sm=km_bus

creat: y1=skm_bus

creat: y2=skm_tram

creat: w1=per_cost/mak

## Capital Price

create: w2=(cl-per_cost)/(seat_bus+seat_tram)

## Linear Trend

create: z1=t

## Quadratic Trend

create: z1sq =0.5∗t∗t

## Time Dummy 1997

create: z11=td1

## Time Dummy 1998

create: z12=td2

## Time Dummy 1999

create: z13=td3

## Time Dummy 2000

create: z14=td4

## Time Dummy 2001

create: z15=td5

## Time Dummy 2002

create: z16=td6

## Time Dummy 2003

create: z17=td7

## Time Dummy 2004

create: z18=td8

## Time Dummy 2005

create: z19=td9

## Time Dummy 2006

create: z20=td10

## Network Length Rail-Bound

create: z2=len_tram

## Network Length Bus

create: z3=len_bus

## Population in the Operation Area

create: z4=pop_area

## Density Index

create: z5=pop_area/(len_tram+len_bus)

## Sum Network Length Rail-Bound and Time Length Bus

create: z6=len_tram+len_bus

# Create by Mean Divided Variables

matrix: xbry1=[0]

matrix: xbry2=[0]

matrix: xbrw1=[0]

matrix: xbrw2=[0]

matrix: xbrw3=[0]

matrix: xbrw4=[0]

## Mean Calculation

calc: xbr1=xbr(y1)

calc: xbr2=xbr(y2)

calc: xbrw1=xbr(w1)

calc: xbrw2=xbr(w2)
calc; xbrz2=xbr(z2)$
calc; xbrz5=xbr(z5)$
calc; xbrz6=xbr(z6)$

† mean divided variable creation
create; y1xcy1=xbr(y1)$
create; y2xcy2=xbr(y2)$
create; w1xcw1=xbr(w1)$
create; w2xcw2=xbr(w2)$
create; z2xcz2=xbr(z2)$
create; z5xcz5=xbr(z5)$
create; z6xcz6=xbr(z6)$

‡ establish linear homogeneity in factor prices
create; c1lh=c1/w1xc$
create; w2lh=w2xc/w1xc$

‡ square terms
create; y1sq = y1xc*y1xc*0.5$
create; y2sq = y2xc*y2xc*0.5$
create; w2lhsq = w2lh*w2lh*0.5$

‡ cross terms
create; y1y2 = y1xc*y2xc$
create; y1w2lh = y1xc*w2lh$
create; y2w2lh = y2xc*w2lh$

‡ create variables for time trend à la Saul et al. (2007)
create; y1z1 = y1xc*z1$
create; y2z1 = y2xc*z1$
create; w2z1 = w2lh*z1$

§ name lists for variable calling
namelist; xcywone, y1xc, y2xc, w2lh, y1sq, y2sq, w2lhsq, yly2, y1w2lh, y2w2lh$
namelist; time2006=x11, x12, x13, x14, x15, x16, x17, x18, x19, x108$
namelist; publ=xcyw, time, z2xc$
namelist; publ2006=xcyw, time2006, x2xc$
namelist; publine=publ, publ2006, x2xc$
calc; l=col(publine)-1$
calc; l=col(publine)$

† estimation of pooled models (consistency check)
‡ model of publication
frontier; cost; lhs=c1lh; rhs=publine; eff=ucpoo$
calc; list; a=a*b(8)$

‡ additional model with time dummies
frontier; cost; lhs=c1lh; rhs=xcyw, time, z2xc; eff=ucpoo$
**PROGRAM CODE**

```plaintext
\[ bh = b(1:k), v0 = \text{varb} \]
```

**estimation of Fixed Effects models**

```plaintext
\[ bh = \text{bline}; \text{ apply } \text{fixed}; \text{ apply } \text{ucfem} ;\]
```

**model of publication**

```plaintext
\[ y2 \text{ insignificant} \]
```

```plaintext
\[ \text{regress: } \text{cost}; \text{lsb} = \text{c1lh}; \text{rhs} = \text{publine}; \text{panel}; \text{pds} = \text{ni}; \text{fixed}; \text{ apply } \text{ucfem} ;\]
```

```plaintext
\[ \text{matrix: } bh = b(1:k), v0 = \text{varb} ;\]
```

**additional model with time dummies, y2 insignificant**

```plaintext
\[ \text{regress: } \text{cost}; \text{lsb} = \text{c1lh}; \text{rhs} = \text{publine}; \text{panel}; \text{pds} = \text{ni}; \text{fixed}; \text{ apply } \text{ucfem} ;\]
```

```plaintext
\[ \text{matrix: } bh = b(1:k), v0 = \text{varb} ;\]
```

**estimation of Random Effects models**

```plaintext
\[ \text{model of publication, exit status 0, linear time trend, reasonable frontier; } \text{cost}; \text{lsb} = \text{c1lh}; \text{rhs} = \text{publine}; \text{panel}; \text{pds} = \text{ni}; \text{ fixed; apply } \text{ucfem} ;\]
```

**additional model with time trend à la Saal et al. (2007)**

```plaintext
\[ \text{reasonable but mostly not significant frontier; } \text{cost}; \text{lsb} = \text{c1lh}; \text{rhs} = \text{cxyw, x1, x2sq, y1z1, y2z1, w2z1, z2xc}; \text{panel}; \text{pds} = \text{ni}; \text{ fixed; apply } \text{ucfem} ;\]
```

**additional model with quadratic time trend**

```plaintext
\[ \text{frontier; } \text{cost}; \text{lsb} = \text{c1lh}; \text{rhs} = \text{cxyw, x1, z2xc}; \text{panel}; \text{pds} = \text{ni}; \text{ fixed; apply } \text{ucfem} ;\]
```

**additional model with time dummies and rail-bound network length**

```plaintext
\[ \text{frontier; } \text{cost}; \text{lsb} = \text{c1lh}; \text{rhs} = \text{cxyw, x1, x2z}; \text{panel}; \text{pds} = \text{ni}; \text{ fixed; apply } \text{ucfem} ;\]
```

**additional model with time dummies**

```plaintext
\[ \text{frontier; } \text{cost}; \text{lsb} = \text{c1lh}; \text{rhs} = \text{cxyw, x1, x2z}; \text{panel}; \text{pds} = \text{ni}; \text{ fixed; apply } \text{ucfem} ;\]
```

**additional model with time dummies and density index**

```plaintext
\[ \text{frontier; } \text{cost}; \text{lsb} = \text{c1lh}; \text{rhs} = \text{cxyw, x1, x2z}; \text{panel}; \text{pds} = \text{ni}; \text{ fixed; apply } \text{ucfem} ;\]
```

**Hausman test (cp. Greene, 2007b, p. R17/30 f)**

```plaintext
\[ \text{matrix: } bh = b(2:1), vl = \text{part}(\text{varb}, 2, 1, 2, 1), d0 = b0 - bh, d1 = \text{v0 - v1}; \text{ list}\$
```

```plaintext
\[ \text{hausman = sinv(vd) * d; list; bh}$
```

**estimation of True Random Effects models**

```plaintext
\[ \text{model of publication}$
```

```plaintext
\[ \text{frontier; } \text{cost}; \text{lsb} = \text{c1lh}; \text{rhs} = \text{publine}; \text{par}$
```

```plaintext
\[ \text{frontier; } \text{cost}; \text{lsb} = \text{c1lh}; \text{rhs} = \text{publine}; \text{panel}; \text{pds} = \text{ni}; \text{rpm; fen = one(n); halton; pts = 1000}; \text{parameters; matrix; eff = uctre}$
```

**additional model with time dummies and density index**

```plaintext
\[ \text{frontier; } \text{cost}; \text{lsb} = \text{c1lh}; \text{rhs} = \text{cxyw, x1, x2z}; \text{panel}; \text{pds} = \text{ni}; \text{rpm; fen = one(n); halton; pts = 10}; \text{eff = uctre}$
```

**additional model with time dummy and rail-bound network length**

```plaintext
\[ \text{frontier; } \text{cost}; \text{lsb} = \text{c1lh}; \text{rhs} = \text{cxyw, x1, x2z}; \text{par}$
```

**additional model with time trend à la Saal et al. (2007)**

```plaintext
\[ \text{frontier; } \text{cost}; \text{lsb} = \text{c1lh}; \text{rhs} = \text{cxyw, x1, x2sq, y1z1, y2z1, w2z1, z2xc}; \text{par}$
```

**frontier; cost; lsb = c1lh; rhs = cxyw, x1, x2sq, y1z1, y2z1, w2z1, z2xc; par$**

```
```
addional model with time dummies and rail-bound network length, use of "par"

frontier; cost: lhs=c1lh; rhs=xcyw, time, z2xc; par$
frontier; cost: lhs=c1lh; rhs=xcyw, time, z2xc;
    pds=ni; rpm; fcn=one(n); halton; pts=10; eff=uctre$

addional model with time trend à la Saal et al. (2007) except for factor price

time trend reasonable but mostly not significant

frontier; cost: lhs=c1lh; rhs=xcyw, z1, zlsq, y1z1, y2z1, z2xc; par$
frontier; cost: lhs=c1lh; rhs=xcyw, z1, zlsq, y1z1, y2z1, z2xc;
    pds=ni; rpm; fcn=one(n); halton; pts=10; eff=uctre$

calculate economies of scale and scope in EXCEL

d
A.3  R Code for Chapter 4

# R CODE: POTENTIAL GAINS FROM MERGERS
# specify commands and data
#
# load DEA commands
library(PEAR)
# clear memory
rm(list=ls())
ls()
# choose number of bootstrapping replications
arg1=2000
# choose returns to scale: 1 for vrs OR 3 for crs
arg2=3
# choose orientation: 1 for input OR 2 for output
arg3=1
# choose scalar for synergy and size determination: 0.5 OR 1 OR 2
alpha=1
# load data
mref = read.table("090823_data_ref_techr69.txt", header=T)
# count number of observations in the reference technology
n=nrow(mref)
xref=matrix(c(mref$,x1,mref$,x2,mref$,x3),nrow=n,ncol=3)
yref=matrix(c(mref$,y1,mref$,y2),nrow=n,ncol=2)
yref2=matrix(c(mref$,y1,mref$,y2,mref$s1),nrow=n,ncol=3)
yref3=matrix(c(mref$,y1,mref$,y2,mref$s2),nrow=n,ncol=4)
zref=matrix(c(mref$,z1,mref$,z2),nrow=n,ncol=2)
xobs = xref[, -1:3]
yobs1 = yref[, -1:3]
yobs2 = yref2[, -1:3]
yobs3 = yref3[, -1:3]
yobs4 = yref4[, -1:3]
zobs = zref[, -1:3]
1) Köln (25), Bonn (7), Siegen (38)
2) Düsseldorf (13), Krefeld (26), Neuss (35)
3) Duisburg (11), Mülheim (32), Essen (15), Oberhausen (36), Moers (29)
4) Dortmund (10), Hagen (21)
5) Bochum (6), Herne (25)
6) Wupperthal (49), Ennepetal (14)
7) Aachen (4), Gelsenkirchen (18)
8) Detmold (8), Ettelbruck (17), Bielefeld (5)
9) Troisdorf (41), Euskirchen (16), Düren (12)
10) Gummersbach (19), Remscheid (37), Solingen (40)
11) Dormagen (9), Gladbach (30), Viersen (42)
12) Hamm (22), Kamen (34)
13) Monheim (31), Leverkusen (27)
14) Gütelsloh (20), Soest (39)
15) Duisburg (11), Düsseldorf (13)
16) Duisburg (11), Krefeld (26)
17) Düsseldorf (13), Krefeld (26)
18) Essen (15), Mülheim (30)
19) Mülheim (32), Oberhausen (36)
20) Mülheim (32), Essen (15), Oberhausen (36)
21) Essen (15), Bochum (6)
22) Düren (12), Euskirchen (16)
23) Aachen (4), Düren (12), Euskirchen (16)
24) Euskirchen (16), Troisdorf (41)
25) Köln (25), Bonn (7), Euskirchen (16)
26) Köln (25), Bonn (7), Euskirchen (16), Troisdorf (41)
27) Viersen (42), Gladbach (30)
28) Wupperthal (49), Solingen (40), Remscheid (37)
29) Wupperthal (49), Ennepetal (14), Remscheid (37)
30) Dortmund (10), Herne (25), Herten (44)
31) Dortmund (10), Hagen (21), Kamen (24)
32) Ettelbruck (17), Bielefeld (5)
33) Ettelbruck (17), Bielefeld (5), Gütelsloh (20)
34) Viersen (42), Gladbach (30), Neuss (35)
35) Duisburg (11), Krefeld (26), Neuss (35)
36) Mönchengladbach (27), Leverkusen (27), Köln (25)
37) Mönchengladbach (31), Leverkusen (27), Solingen (40)
38) Duisburg (11), Düsseldorf (13), Krefeld (26)
39) Düren (12), Euskirchen (16), Troisdorf (41), Gelsenkirchen (18)
40) Remscheid (37), Gelsenkirchen (18)
41) Gladbach (30), Neuss (35)
42) Hamm (22), Kamen (24)
43) Wupperthal (49), Solingen (40)
44) Hamm (22), Soest (39), Gütelsloh (20)
45) Düren (12), Euskirchen (16), Troisdorf (41), Gelsenkirchen (18)
46) Hamm (22), Oberhausen (36), Moers (29)
47) Hamm (22), Oberhausen (36), Moers (29)
48) Gümmerbach (19), Remscheid (37)
49) Düren (12), Troisdorf (41)
50) Hamm (22), Soest (39), Gütelsloh (20)
51) Dortmund (10), Kamen (24)
52) Düsseldorf (11), Düsseldorf (13), Krefeld (26), Moers (29)
53) Düsseldorf (11), Düsseldorf (13), Krefeld (26), Oberhausen (36)
54) Bochum (6), Herne (25), Herten (44)
55) Wupperthal (49), Ennepetal (14), Hagen (21)
56) Ennepetal (14), Hagen (21)
57) Ennepetal (14), Hagen (21), Lüdenscheid (28)
58) Ennepetal (14), Lüdenscheid (28)
59) Köln (25), Bonn (7), Siegen (38), Troisdorf (41)
60) Köln (25), Bonn (7), Siegen (38), Troisdorf (41), Euskirchen (16)
61) Siegen (38), Lüdenscheid (28)
62) Siegen (38), Gummersbach (19)
63) Siegen (38), Gummersbach (19), Remscheid (37)
64) Dormagen (9), Mönchengladbach (27)
65) Dormagen (9), Mönchengladbach (27)
66) Dormagen (9), Gladbach (30)
67) Dormagen (9), Neuss (35)
68) Dormagen (9), Mönchengladbach (27)
69) Detmold (8), Ettelbruck (17)
70) Mönchengladbach (31), Münster (SW, 34)
71) Mülheim (32), Essen (15), Oberhausen (36), Bochum (6)
72) Mülheim (32), Essen (15), Oberhausen (36), Bochum (6), Moers (29)
73) Mülheim (32), Essen (15), Oberhausen (36), Duisburg (11)
merger1 = matrix(c(25, 7, 38, 0, 0)), mergers[1,] = merger1; n1=3
merger2 = matrix(c(13, 26, 35, 0, 0)), mergers[2,] = merger2; n2=3
merger3 = matrix(c(11, 32, 15, 36, 20)), mergers[3,] = merger3; n3=6
merger4 = matrix(c(10, 21, 0, 0, 0)), mergers[4,] = merger4; n4=4
merger5 = matrix(c(6, 23, 0, 0, 0)), mergers[5,] = merger5; n5=2
merger6 = matrix(c(43, 14, 0, 0, 0)), mergers[6,] = merger6; n6=2
merger7 = matrix(c(41, 18, 0, 0, 0)), mergers[7,] = merger7; n7=2
merger8 = matrix(c(8, 17, 9, 0, 0)), mergers[8,] = merger8; n8=3
merger9 = matrix(c(41, 16, 12, 0, 0)), mergers[9,] = merger9; n9=3
merger10 = matrix(c(19, 37, 40, 0, 0)), mergers[10,] = merger10; n10=3
merger11 = matrix(c(9, 30, 42, 0, 0)), mergers[11,] = merger11; n11=3
merger12 = matrix(c(22, 24, 0, 0, 0)), mergers[12,] = merger12; n12=2
merger13 = matrix(c(31, 27, 0, 0, 0)), mergers[13,] = merger13; n13=3
merger14 = matrix(c(20, 39, 0, 0, 0)), mergers[14,] = merger14; n14=2
merger15 = matrix(c(11, 13, 0, 0, 0)), mergers[15,] = merger15; n15=2
merger16 = matrix(c(11, 26, 0, 0, 0)), mergers[16,] = merger16; n16=2
merger17 = matrix(c(11, 26, 0, 0, 0)), mergers[17,] = merger17; n17=2
merger18 = matrix(c(15, 32, 0, 0, 0)), mergers[18,] = merger18; n18=2
merger19 = matrix(c(32, 36, 0, 0, 0)), mergers[19,] = merger19; n19=2
merger20 = matrix(c(32, 15, 36, 0, 0)), mergers[20,] = merger20; n20=3
merger21 = matrix(c(15, 6, 0, 0, 0)), mergers[21,] = merger21; n21=2
merger22 = matrix(c(12, 16, 0, 0, 0)), mergers[22,] = merger22; n22=2
merger23 = matrix(c(4, 12, 16, 0, 0)), mergers[23,] = merger23; n23=3
merger24 = matrix(c(16, 41, 0, 0, 0)), mergers[24,] = merger24; n24=2
merger25 = matrix(c(25, 7, 16, 0, 0)), mergers[25,] = merger25; n25=3
merger26 = matrix(c(25, 7, 16, 41, 0)), mergers[26,] = merger26; n26=4
merger27 = matrix(c(42, 30, 0, 0, 0)), mergers[27,] = merger27; n27=2
merger28 = matrix(c(43, 40, 37, 0, 0)), mergers[28,] = merger28; n28=3
merger29 = matrix(c(43, 14, 37, 0, 0)), mergers[29,] = merger29; n29=3
merger30 = matrix(c(10, 23, 44, 0, 0)), mergers[30,] = merger30; n30=3
merger31 = matrix(c(10, 21, 44, 0, 0)), mergers[31,] = merger31; n31=3
merger32 = matrix(c(17, 5, 20, 0, 0)), mergers[32,] = merger32; n32=2
merger33 = matrix(c(17, 5, 20, 0, 0)), mergers[33,] = merger33; n33=3
merger34 = matrix(c(42, 30, 35, 0, 0)), mergers[34,] = merger34; n34=3
merger35 = matrix(c(11, 26, 35, 0, 0)), mergers[35,] = merger35; n35=3
merger36 = matrix(c(31, 27, 25, 0, 0)), mergers[36,] = merger36; n36=3
merger37 = matrix(c(31, 27, 40, 0, 0)), mergers[37,] = merger37; n37=3
merger38 = matrix(c(11, 13, 26, 0, 0)), mergers[38,] = merger38; n38=3
merger39 = matrix(c(28, 19, 37, 0, 0)), mergers[39,] = merger39; n39=3
merger40 = matrix(c(28, 19, 0, 0, 0)), mergers[40,] = merger40; n40=2
merger41 = matrix(c(22, 24, 39, 0, 0)), mergers[41,] = merger41; n41=3
merger42 = matrix(c(43, 40, 0, 0, 0)), mergers[42,] = merger42; n42=1
merger43 = matrix(c(43, 37, 0, 0, 0)), mergers[43,] = merger43; n43=2
merger44 = matrix(c(32, 15, 6, 0, 0)), mergers[44,] = merger44; n44=3
merger45 = matrix(c(36, 20, 0, 0, 0)), mergers[45,] = merger45; n45=2
merger46 = matrix(c(12, 16, 41, 18, 0)), mergers[46,] = merger46; n46=4
merger47 = matrix(c(30, 35, 0, 0, 0)), mergers[47,] = merger47; n47=2
merger48 = matrix(c(19, 37, 0, 0, 0)), mergers[48,] = merger48; n48=2
merger49 = matrix(c(12, 41, 0, 0, 0)), mergers[49,] = merger49; n49=2
merger50 = matrix(c(22, 39, 20, 0, 0)), mergers[50,] = merger50; n50=3
merger51 = matrix(c(10, 24, 0, 0, 0)), mergers[51,] = merger51; n51=2
merger52 = matrix(c(11, 13, 26, 29, 0)), mergers[52,] = merger52; n52=4
merger53 = matrix(c(11, 13, 26, 36, 0)), mergers[53,] = merger53; n53=4
merger54 = matrix(c(6, 23, 44, 0, 0)), mergers[54,] = merger54; n54=3
merger55 = matrix(c(43, 14, 21, 0, 0)), mergers[55,] = merger55; n55=3
merger56 = matrix(c(14, 21, 0, 0, 0)), mergers[56,] = merger56; n56=2
merger57 = matrix(c(14, 21, 28, 0, 0)), mergers[57,] = merger57; n57=3
merger58 = matrix(c(14, 28, 0, 0, 0)), mergers[58,] = merger58; n58=2
merger59 = matrix(c(25, 7, 38, 41, 0)), mergers[59,] = merger59; n59=4
merger60 = matrix(c(25, 7, 38, 41, 16)), mergers[60,] = merger60; n60=5
merger61 = matrix(c(38, 28, 0, 0, 0)), mergers[61,] = merger61; n61=2
merger62 = matrix(c(38, 19, 0, 0, 0)), mergers[62,] = merger62; n62=2
merger63 = matrix(c(38, 19, 37, 0, 0)), mergers[63,] = merger63; n63=3
merger64 = matrix(c(9, 41, 27, 0, 0)), mergers[64,] = merger64; n64=3
merger65 = matrix(c(9, 31, 0, 0, 0)), mergers[65,] = merger65; n65=2
merger66 = matrix(c(9, 30, 0, 0, 0)), mergers[66,] = merger66; n66=2
merger67 = (matrix(c(9,35,0,0,0))); mergers[67] = merger67; n67 = 2
merger68 = (matrix(c(9,31,35,0,0))); mergers[68] = merger68; n68 = 3
merger69 = (matrix(c(8,17,0,0,0))); mergers[69] = merger69; n69 = 2
merger70 = (matrix(c(33,34,0,0,0)))); mergers[70] = merger70; n70 = 2
merger71 = (matrix(c(32,15,36,6,0)))); mergers[71] = merger71; n71 = 4
merger72 = (matrix(c(32,15,36,6,0,29)))); mergers[72] = merger72; n72 = 5
merger73 = (matrix(c(32,15,36,11,0)))); mergers[73] = merger73; n73 = 4
merger74 = (matrix(c(32,15,11,0,0)))); mergers[74] = merger74; n74 = 3
merger75 = (matrix(c(13,26,35,29,0)))); mergers[75] = merger75; n75 = 4
merger76 = (matrix(c(13,26,29,0,0)))); mergers[76] = merger76; n76 = 3
merger77 = (matrix(c(13,35,0,0,0)))); mergers[77] = merger77; n77 = 2
merger78 = (matrix(c(13,26,35,0,0)))); mergers[78] = merger78; n78 = 3
merger79 = (matrix(c(32,15,36,29,0)))); mergers[79] = merger79; n79 = 4
merger80 = (matrix(c(25,7,0,0,0)))); mergers[80] = merger80; n80 = 2

# save the number of merged companies per merger in vector nx
nx1 = (n1, n2, n3, n4, n5, n6, n7, n8, n9, n10, n11, n12, n13, n14, n15, n16, n17, n18, n19, n20, n21)
nx2 = (n22, n23, n24, n25, n26, n27, n28, n29, n30, n31, n32, n33, n34, n35, n36, n37, n38, n39, n40)
nx3 = (n41, n42, n43, n44, n45, n46, n47, n48, n49, n50, n51, n52, n53, n54, n55, n56, n57, n58, n59, n60)
nx4 = (n61, n62, n63, n64, n65, n66, n67, n68, n69, n70, n71, n72, n73, n74, n75, n76, n77, n78, n79, n80)

nx = (nx1, nx2, nx3, nx4)

# display vector nx (consistency check)

# count number of evaluated mergers
nrow(mergers)

# display number of evaluated mergers (consistency check)
n

# set input and output vectors to 0
merger1 <- 0
merger2 <- 0
merger3 <- 0
merger4 <- 0

# recalculate in trans (auxiliary variable)
merger1 <- 0
merger2 <- 0

# recalculate in trains, light railways, and metros (auxiliary variable)
merger2 <- 0

# for recalculating s2 (tram index)
merger3 <- 0
merger1 <- matrix(mergerx1, 1, n)
merger2 <- matrix(mergery2, 1, n)
merger3 <- matrix(mergerx3, 1, n)
merger4 <- matrix(mergery3, 1, n)

for ( i in 1:n ) {
mergeRx1[i, i] = 0
mergeRx2[i, i] = 0
mergeRx3[i, i] = 0
mergeRy1[i, i] = 0
mergeRy2[i, i] = 0
mergeRz1[i, i] = 0
mergeRz2[i, i] = 0
for ( j in 1:n ) {
# for the i-th merger, inputs and outputs are summed for all j firms
mergerx1[i, j] = mergerx1[i, j] + xref[j, mergers[i, j]]
mergerx2[i, j] = mergerx2[i, j] + xref[j, mergers[i, j]]
mergerx3[i, j] = mergerx3[i, j] + xref[j, mergers[i, j]]
mergery1[i, j] = mergery1[i, j] + yref[j, mergers[i, j]]
mergery2[i, j] = mergery2[i, j] + yref[j, mergers[i, j]]
mergerz1[i, j] = mergerz1[i, j] + zref[j, mergers[i, j]]
mergerz2[i, j] = mergerz2[i, j] + zref[j, mergers[i, j]]
}
}

# recalculate tram index
if (mergeRx1[i, i] > 0) mergerz3[i, i] = mergerx1[i, i] / mergerz2[i, i]
else mergerz3[i, i] = 0
Program Code

# calculate individual and mean technical efficiencies for 41 companies from NW

# Model 1 standard DEA
indm1she <- dea(XOBS=xobs, YOBS=yobs, RTS=arg2, ORIENTATION=arg3, XREF=xref, YREF=yref)
# transform Shepard into Farrell efficiency estimates
indm1far <- 1/indm1she
# calculate mean of individual efficiency scores
meanindm1=mean(indm1far)

# Model 2 standard DEA
indm2she <- dea(XOBS=xobs, YOBS=yobs1, RTS=arg2, ORIENTATION=arg3, XREF=xref, YREF=yref1)
indm2far <- 1/indm2she
meanindm2=mean(indm2far)

# Model 3 standard DEA
indm3she <- dea(XOBS=xobs, YOBS=yobs2, RTS=arg2, ORIENTATION=arg3, XREF=xref, YREF=yref2)
indm3far <- 1/indm3she
meanindm3=mean(indm3far)

# Model 4 standard DEA
indm4she <- dea(XOBS=xobs, YOBS=yobs1s2, RTS=arg2, ORIENTATION=arg3, XREF=xref, YREF=yref1s2)
indm4far <- 1/indm4she
meanindm4=mean(indm4far)

# Model 1 bias-corrected DEA
indm1she <- boot 쉐프(XOBS=xobs, YOBS=yobs1, RTS=arg1, ORIENTATION=arg3, alpha=0.05, CI_TYPE=2, XREF=xref, YREF=yref)
indm1far <- 1/indm1she
meanindm1boot=mean(indm1far)
# display bias-corrected mean efficiency (consistency check)
meanindm1boot

# Model 2 bias-corrected DEA
indm2she <- boot 쉐프(XOBS=xobs, YOBS=yobs1, RTS=arg1, ORIENTATION=arg3, alpha=0.05, CI_TYPE=2, XREF=xref, YREF=yref1)
indm2far <- 1/indm2she
meanindm2boot=mean(indm2far)

# Model 3 bias-corrected DEA
indm3sheboot <- boot 쉐프(XOBS=xobs, YOBS=yobs2, RTS=arg1, ORIENTATION=arg3, alpha=0.05, CI_TYPE=2, XREF=xref, YREF=yref2)
indm3farboot <- 1/indm3sheboot
meanindm3boot=mean(indm3farboot)

# Model 4 bias-corrected DEA
indm4she <- boot 쉐프(XOBS=xobs, YOBS=yobs1s2, RTS=arg1, ORIENTATION=arg3, alpha=0.05, CI_TYPE=2, XREF=xref, YREF=yref1s2)
indm4farboot <- 1/indm4she
meanindm4boot=mean(indm4farboot)

# calculate partial productivity measures (additional analyses)

# calculate un normed labor productivity
labor_prodt=(yobs[1,]+yobs[2,])/xobs[1,]

# calculate un normed capital productivity
capital_prodt=(yobs[1,]+yobs[2,]+yobs[3,])/(xobs[2,]+xobs[3,])
PROGRAM CODE

```r
# display partial productivity measures and average efficiencies
#
# calculate inputs and outputs of merged companies
# show xobs (consistency check)
# show xvec (consistency check)
# set input and output vectors to 0
# calculate inputs and outputs of merged companies
# create matrix for 3 inputs and 41 firms, filled with 0s
# contract first input by inefficiency
# contract second input by inefficiency
# contract third input by inefficiency
# show consistency check

# create table of bias-corrected individual efficiencies and partial productivities
individual efficiencys <- cbind(individual far, labor prod norm, capital prod norm, indm2farboot, indm3farboot, indm4farboot)

# choose write table for desktop or laptop use
write.table(individual efficiencys, file="C:/al/individual efficiencies.csv", sep="", quote=FALSE)

# create tables of rounded mean efficiencies
average efficiencies <- cbind(mean(indm1), mean(indm2), mean(indm3))

# calculate overall potential merger gains (bias-corrected)

# Model 1
xover <- matrix(c(merge1x1, merge1x2, merge1x3), nrow = 1)
yover <- matrix(c(merge1y1, merge1y2), nrow = 1)
overall he <- boot(sw, xover, yover, NREP = arg1, R = arg2, orientation = arg3, alpha = 0.05, CI_TYPE = 2, type = "leap", yrest = TRUE)
overall far <- 1 / overall he

# Model 2 (a referring to z-variables)
zover <- matrix(c(merge1y1, merge1y2, merge1y3), nrow = 1)
overall hez <- boot(sw, xover, yover, NREP = arg1, R = arg2, orientation = arg3, alpha = 0.05, CI_TYPE = 2, type = "leap", yrest = TRUE)
overall farz <- 1 / overall hez

# calculate technical efficiency gains (bias-corrected)

# show tables of bias-corrected individual efficiencies and partial productivities
show table of individual efficiencies, file="C:/al/individual efficiencies.csv", sep="", quote=FALSE
```

for ( i in 1:n ) {
    mertecx1[1,i] = 0
    mertecx2[1,i] = 0
    mertecx3[1,i] = 0
    mertecy1[1,i] = 0
    mertecy2[1,i] = 0
    for ( j in 1:nx[i] ) {
        # for the i-th merger, contracted inputs and outputs are summed for all j firms
        # first three items of xtec matrix are used for BVG, HHL, and WVG
        mertecx2[1,i] = mertecx1[1,i] + xtec[1,( mergers[i,j] )]
        mertecx3[1,i] = mertecx2[1,i] + xtec[2,( mergers[i,j] )]
        mertecy1[1,i] = mertecy2[1,i] + xtec[3,( mergers[i,j] )]
        mertecy2[1,i] = mertecy1[1,i] + yobs[1,( mergers[i,j] )]
    }
    mertecx1[1,i] = mertecx1[1,i] + xtep[1,( mergers[i,j] )]
    mertecx2[1,i] = mertecx2[1,i] + xtep[2,( mergers[i,j] )]
    mertecx3[1,i] = mertecx3[1,i] + xtep[3,( mergers[i,j] )]
    mertecy1[1,i] = mertecy1[1,i] + yobs[1,( mergers[i,j] )]
    mertecy2[1,i] = mertecy2[1,i] + yobs[2,( mergers[i,j] )]
}

# Model 1: calculation of real merger gains to separate from technical efficiency gains
xtecm = t(matrix(c(mertecx1, mertecx2, mertecx3), nrow=n, ncol=3))
ytecm = t(matrix(c(mertecy1, mertecy2), nrow=n, ncol=2))
realmergershe <- boot.sv98(XOBS=xtecm, YOBS=ytecm, NREP=arg1, RTS=arg2, ORIENTATION=arg3, alpha=0.05, CI.TYPE=2, XREF=xref, YREF=yref)
realmergerfar <- 1/realmergershe$sdhat.bc

# Model 3:
xtecm = t(matrix(c(mertecy1, mertecy2, mergerz3), nrow=n, ncol=3))
ytecm = t(matrix(c(mertecy1, mertecy2), nrow=n, ncol=2))
realmergershez <- boot.sv98(XOBS=xtecm, YOBS=ytecm, NREP=arg1, RTS=arg2, ORIENTATION=arg3, alpha=0.05, CI.TYPE=2, XREF=xref, YREF=yref2)
realmergerfarz <- 1/realmergershez$sdhat.bc

# calculate synergy gains (bias-corrected)

# set input and output vectors to 0
mersynx1 <- 0
mersynx2 <- 0
mersynx3 <- 0
mersyny1 <- 0
mersyny2 <- 0
mersyny3 <- 0

mersynx1 <- matrix(mersynx1, 1,n)
mersynx2 <- matrix(mersynx2, 1,n)
mersynx3 <- matrix(mersynx3, 1,n)
mersyny1 <- matrix(mersyny1, 1,n)
mersyny2 <- matrix(mersyny2, 1,n)
mersyny3 <- matrix(mersyny3, 1,n)

# potential merger of size alpha/n, technical efficiency gains already realized
for ( i in 1:n ) {
    mersynx1[1,i] = mertecx1[1,i] + (alpha/nx[i])
    mersynx2[1,i] = mertecx2[1,i] + (alpha/nx[i])
    mersynx3[1,i] = mertecx3[1,i] + (alpha/nx[i])
    mersyny1[1,i] = mertecy1[1,i] + (alpha/nx[i])
    mersyny2[1,i] = mertecy2[1,i] + (alpha/nx[i])
    mersyny3[1,i] = mergerz3[1,i] + (alpha/nx[i])
}

# Model 1: actual calculation of synergy gains
yaxyn = t(matrix(c(mersynx1, mersynx2, mersynx3), nrow=n, ncol=3))
synergyshes <- boot.sv98(XOBS=yaxyn, YOBS=yaxyn, NREP=arg1, RTS=arg2, ORIENTATION=arg3, alpha=0.05, CI.TYPE=2, XREF=xref, YREF=yref)
synergyshes <- 1/synergyshes$sdhat.bc

# Model 1: actual calculation of synergy gains
yaxyn = t(matrix(c(mersynx1, mersynx2, mersynx3), nrow=n, ncol=3))
synergyshez <- boot.sv98(XOBS=yaxyn, YOBS=yaxyn, NREP=arg1, RTS=arg2, ORIENTATION=arg3, alpha=0.05, CI.TYPE=2, XREF=xref, YREF=yref2)
synergyshez <- 1/synergyshez$sdhat.bc
Program Code

# calculate size gains (bias-corrected)

# set input and output vectors to 0
mersizx1 <- 0
mersizx2 <- 0
mersizx3 <- 0
mersizy1 <- 0
mersizy2 <- 0
mersizy3 <- 0
merrt1x1 <- merrt1x1[1,i]*synergyfar[i]
merrt1x2 <- merrt1x2[1,i]*synergyfar[i]
merrt1x3 <- merrt1x3[1,i]*synergyfar[i]
merrt2x1 <- merrt2x1[1,i]
merrt2x2 <- merrt2x2[1,i]
merrt2x3 <- merrt2x3[1,i]
merrt3x1 <- merrt3x1[1,i]
merrt3x2 <- merrt3x2[1,i]
merrt3x3 <- merrt3x3[1,i]

# potential merger of size alpha/n, technical efficiency and synergy gains realized

for (i in 1:n) {
  merrt1x1[1,i] <- merrt1x1[1,i] * synergyfar[i]
merrt1x2[1,i] <- merrt1x2[1,i] * synergyfar[i]
merrt1x3[1,i] <- merrt1x3[1,i] * synergyfar[i]
merrt2x1[1,i] <- merrt2x1[1,i]
merrt2x2[1,i] <- merrt2x2[1,i]
merrt2x3[1,i] <- merrt2x3[1,i]
merrt3x1[1,i] <- merrt3x1[1,i]
merrt3x2[1,i] <- merrt3x2[1,i]
merrt3x3[1,i] <- merrt3x3[1,i]
}

# Model 1: actual calculation of size gains
sizesh = t(matrix(c(mersizx1, mersizx2, mersizx3), nrow = n, ncol = 3))
syzsh = t(matrix(c(mersizy1, mersizy2, mersizy3), nrow = n, ncol = 2))

sizesh <- bond.sw98(XORS=sizesh, YORS=syzsh, NREP=arg1, RTS=arg2, ORIENTATION=arg3, alpha=0.05, CI.TYPE=2, XREF=xref, YREF=yref)
sizefar <- 1/sizesh$9hat

# Model 3: actual calculation of size gains
sizesh <- t(matrix(c(mersizx1, mersizx2, mersizx3), nrow = n, ncol = 3))
sizefar <- 1/sizesh$9hat

# display results

# Model 1
# consistency checks
twocalfar=overallfar/realmergerfar
adjoverfar=technicalfar/sizefar
correcrealmergerfar/adjoverfar

# create table of potential merger gains
potential_merger_gains=cbind(tx,ty,round(overallfar,5),"\n",round(realmergerfar,5),"\n",round(technicalfar,5),"\n",round(synergyfar,5),"\n",round(sizefar,5),"\n",round(checkreal,5))

# write_table(potential_merger_gains, file="V:\/\potential\_merger\_gains.csv", sep = "\n")
write_table(potential_merger_gains, file="C:\/\potential\_merger\_gains.csv", sep = "\n")

# Model 3
technicalfar=overallfar/realmergerfar
adjoverfar=technicalfar+sizefar
correcrealmergerfar/adjoverfar

potential_merger_gains=cbind(tx,ty,round(overallfar,5),"\n",round(realmergerfar,5),"\n",round(technicalfar,5),"\n",round(synergyfar,5),"\n",round(sizefar,5),"\n",round(checkreal,5))

# write_table(potential_merger_gains, file="V:\/\potential\_merger\_gains.csv", sep = "\n")
write_table(potential_merger_gains, file="C:\/\potential\_merger\_gains.csv", sep = "\n")

# end
A.4 STATA Code for Chapter 5

```stata
* STATA Code: OPERATOR CHANGES THROUGH COMPETITIVE TENDERING
*
* clear stata memory
* specify path for data set and output and name of data file
* desktop path (comment path not in use out)
* cd "C:\Users\Matthias Walter\Desktop\Data\05 EE2\A5 Success Conditions"
* laptop path
* cd "R:\projects\current\ct-tr\02 Competitive Tendering"
* use sample.dta, clear
*
* create variables from raw data set
* generate variable operation period in years
* can be necessary to ensure that date specifications come in numbers from EXCEL
* gen period = ((endDate - startDate)/365)
*
* generate numeric variables from string variables for spatial category, ...
* ... federal state, and type of contract
* encode cat, generate(cat1)
* encode state, generate(state1)
* encode contract, generate(contract1)
* tabulate cat, generate(cat2)
* tabulate state, generate(state2)
* tabulate contract, generate(contract2)
*
* group operation start
* xtile startyear = startDate, nquantiles(6)
* generate of yearly dummies
* gen start_9704 = (startyear == 1)
* gen start_2005 = (startyear == 2)
* gen start_2006 = (startyear == 3)
* gen start_2007 = (startyear == 4)
* gen start_2008 = (startyear == 5)
* gen start_2009 = (startyear == 6)
*
* generate tender round
* drop if round ==
* gen round1 = (round == 2)
*
* combine tender round with state Bayern
* gen round1BY = (state22 == 1 & round == 1)
* gen round2BY = (state22 == 1 & round == 2)
*
* combine vehicle (tender size) with line (tender complexity)
* gen adjsize = (vehicle/line)
*
* generate further complexity indicator
* gen cat223 = (cat22 == 1 | cat23 == 1)
* gen linecat = line + line * cat223
*
* label variables
* label variable change "Operator change"
* label variable bidder "No. of bidders"
* label variable period "Operation period"
* label variable vehicle "No. of vehicles"
* label variable line "No. of lines"
* label variable start_date "Start date"
* label variable end_date "End date"
* label variable start_9704 "Start in 1997–2004"
* label variable start_2005 "Start in 2005"
* label variable start_2006 "Start in 2006"
* label variable start_2007 "Start in 2007"
```

label variable start_2008 "Start in 2008"
label variable start_2009 "Start in 2009"

label define cat1 lb
1 "Regional transport"
2 "Mixed transport"
3 "Urban transport"

label value cat1
1 "Regional transport"
2 "Mixed transport"
3 "Urban transport"

label define contract1
1 "Gross-cost contract"
2 "Net-cost contract"
3 "Sub-contract"

label value contract1
1 "Gross-cost contract"
2 "Net-cost contract"
3 "Sub-contract"

label define state
1 "Baden-Württemberg"
2 "Bayern"
3 "Hessen"
4 "Nordrhein-Westfalen"
5 "Rheinland-Pfalz"
6 "Schleswig-Holstein"

label value state
1 "Baden-Württemberg"
2 "Bayern (BY)"
3 "Hessen"
4 "Nordrhein-Westfalen"
5 "Rheinland-Pfalz"
6 "Schleswig-Holstein"

label variable round1_BY "Tender round 1 in BY"
label variable round2_BY "Tender round 2 in BY"

label variable adjsize "No. of vehicles per line"
label variable linecat "Line-category"

*** drop observations with missing values
***
drop if bidder ==.
drop if round ==.
drop if period ==.
drop if state1 ==.
drop if contract1 ==.
drop if cat1 ==.
drop if line ==.
drop if vehicle ==.
drop if change ==.

*** calculate descriptive and visual statistics
***
tabulate change startyear, column

mean bidder if startyear == 1
mean bidder if startyear == 2
mean bidder if startyear == 3
mean bidder if startyear == 4
mean bidder if startyear == 5
mean bidder if startyear == 6

*** calculate triangle of probit estimations
***
*** 09 September 2009, triangle
probit change bidder change start_2005-start_2009 cat22 cat23
probit change start_2005-start_2009 cat22 cat23 vehicle line period
probit change start_2005-start_2009 cat22 cat23 vehicle line period //mixed significant
probit change start_2005-start_2009 cat22 cat23 vehicle line period //contract21 contract22 state22 state23
probit change period vehicle line state23 round1_BY-round2_BY
10 September 2009 - additional models with combined variables

progib change start2005-start2009 cat22 cat23 adjust
progib change start2005-start2009 vehicle line cat

*** model 1-2 output for LaTeX
eststo: quietly probit change bidder
eststo: quietly probit change start2005-start2009 cat22 cat23
eststo: probit line start2005-start2009 cat22 cat23 vehicle line
eststo: quietly probit change period start2005-start2009 cat22 cat23 vehicle line period
eststo: quietly probit change period vehicle line state23 round1_BY-round2_BY
esttab using tendertab, probit tex, b(%−12.2f) pr2(%−12.2f) scalars (1 chi2 p) ///
noobs label star(* 0.10 ** 0.05 *** 0.01) se wide oncell nolines compress ///
alignment(1) title(Probit regression results of structural variables on operator ///
changes \{label\{tendertab probit\}) nodepvars nonumbers ///
mtitles("1" "2" "3" "4" "5" "6") nonotes

*** necessary manual adjustments:
*** replace "table" twice by "sidewaysstable"
*** include \begin\{small\} * \end\{small\}
*** add \before \end\{tabular\}:
*** \multicolumn\{3\}\{c\} $\{\textbf\{estimate\}\}$ \multicolumn\{3\}\{c\} $\{\textbf\{estimate\}\}$
*** \textbf\{Model\} & \multicolumn\{1\}\{c\} \{\textbf\{category\}\} & \multicolumn\{1\}\{c\} \{\textbf\{category\}\} & \multicolumn\{1\}\{c\} \{\textbf\{category\}\}
*** \textbf\{Model\} & \multicolumn\{1\}\{c\} \{\textbf\{category\}\} & \multicolumn\{1\}\{c\} \{\textbf\{category\}\} & \multicolumn\{1\}\{c\} \{\textbf\{category\}\}
*** \textbf\{Model\} & \multicolumn\{1\}\{c\} \{\textbf\{category\}\} & \multicolumn\{1\}\{c\} \{\textbf\{category\}\} & \multicolumn\{1\}\{c\} \{\textbf\{category\}\}

*** model A B output for LaTeX
eststo: quietly probit change start2005-start2009 cat22 cat23 adjust
eststo: quietly probit change start2005-start2009 vehicle line cat
esttab using tendertab,add tex, b(%−12.2f) pr2(%−12.2f) scalars (1 chi2 p) ///
noobs label star(* 0.10 ** 0.05 *** 0.01) se wide oncell nolines compress ///
alignment(1) title(Additional regression results with combined variables ///
changes \{label\{tendertab\}add\}) nodepvars nonumbers mtitles("A" "B") ///
nonotes

*** necessary manual adjustments:
*** include \begin\{small\} * \end\{small\}
*** add \before \end\{tabular\}:
*** \multicolumn\{1\}\{c\} $\{\textbf\{category\}\} $\{\textbf\{category\}\} $\{\textbf\{category\}\}$
*** \textbf\{category\}\{1\}\{c\} \{\textbf\{category\}\}\{1\}\{c\} \{\textbf\{category\}\}\{1\}\{c\} \{\textbf\{category\}\}
*** \textbf\{category\}\{1\}\{c\} \{\textbf\{category\}\}\{1\}\{c\} \{\textbf\{category\}\}\{1\}\{c\} \{\textbf\{category\}\}

*** end
Bibliography


BIBLIOGRAPHY


Lasch, R., Lemke, A., Jugelt, R., Probst, G., Wagener, N. and Winckler, J. (2005) ÖPNV-Markt der Zukunft. Delphi-study prepared by the Chair of Logistics at Dresden University of Technology and Wagener & Herbst Management Consultants GmbH on behalf of Deutsches Verkehrsforum, supported by the German Federal Ministry of Education and Research


Verband Deutscher Verkehrsunternehmen (2007b) VDV Statistik 2006. Köln


